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ABBREVIATIONS

BTC	Biotechnology Council
EDCS	Expediency Discernment Council of the System
EOR	enhanced oil recovery
EPC	engineering, procurement and construction
FDI	foreign direct investment
FDA	Food and Drug Administration
FYDP	Five-Year Development Plan
GDP	gross domestic product
GERD	gross expenditure on R&D
ICT	information and communication technology
IDRO	Industrial Development and Renovation Organization
IMIDRO	Iranian Mines and Mining Industries Development and Renovation Organization
INSO	Iranian National Standards Organization
IOC	international oil company
IOR	improved oil recovery
IPC	Iranian Petroleum Contract
IPF	Innovation and Prosperity Fund (also sometimes called the Innovation and Development Fund)
IPR	intellectual property rights
IPRC	Islamic Parliament Research Center
IRPHE	Institute of Research and Planning for Higher Education
IVCA	Iranian Venture Capital Association
JCPOA	Joint Comprehensive Plan of Action
KBE	knowledge-based economy
KBF	knowledge-based firm
MEAF	Ministry of Economic Affairs and Finance
MIMT	Ministry of Industry, Mines and Trade
MNE	multinational enterprise
MOA	Ministry of Agriculture
MOD	Ministry of Defense
MOHME	Ministry of Health and Medical Education
MOP	Ministry of Petroleum
MPO	Management and Planning Organisation (predecessor of PBO)
MSRT	Ministry of Science Research and Technology
MULC	Maximum Utilization of Local Capabilities (Law)
NDF	National Development Fund
NIGC	National Iranian Gas Company
NIGEB	National Institute of Genetic Engineering and Biotechnology
NIOC	National Iranian Oil Company
NIORDC	National Iranian Oil Refining and Distribution Company
NPC	National Petrochemical Company
NIS	national innovation system
NMPSE	National Master Plan for Science and Education (or Comprehensive Scientific Road Map)
NRCGEB	National Research Center for Genetic Engineering and Biotechnology
NTBF	new technology-based firm
NSF	National Science Foundation
O&G	oil and gas
OECD	Organisation for Economic Co-operation and Development
PBO	Planning and Budget Organization (formerly the MPO)
PTP	Pardis Technology Park
R&D	research and development
RIPI	Research Institute of the Petroleum Industry
RTD	research and technology development
S&E	science and engineering
S&T	science and technology
SCI	Statistical Centre of Iran
SCCR	Supreme Council for the Cultural Revolution
SCSRT	Supreme Council of Science Research and Technology
SEC	Supreme Economy Council
SIPIEM	Society of Iranian Petroleum Industry Equipment Manufacturers
SME	small and medium-sized enterprise
SOE	State-owned enterprise
STEM	science, technology, engineering and mathematics
STI	science, technology and innovation
TPO	Trade Promotion Organization
TRIPS	Trade-related Intellectual Property Rights
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
VCF	venture capital fund
VPST	Vice-Presidency for Science and Technology
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

EXECUTIVE SUMMARY

The Islamic Republic of Iran (hereinafter referred to as Iran) has made significant advances in research, higher education and technology since 1990. It has a vast wealth of oil and gas (O&G) reserves, estimated as the 4th and the 2nd largest in the world, respectively, as well as significant minerals and other natural resources. Despite this, it has managed to avoid the so-called “natural resource curse”. The industrial sector has grown both in scope and diversity in recent decades, making Iran the most economically diversified economy, with the lowest dependence on O&G incomes, compared with other oil-rich countries in the Middle East. During the past two decades, Iran has committed itself to the development of a dynamic national innovation system (NIS) and has been moving steadily towards a knowledge- and innovation-based economy. The period of international sanctions strengthened its resolve to achieve this goal. As a result of this commitment, the country’s human resource base is now impressive: it has a large number of well-educated, trained and energetic Iranians both at home and among the diaspora living abroad as scientists, entrepreneurs and business people. At present, Iran is seeking to reinforce its productive capacity, encourage international collaboration to exchange technology and know-how, and engage more actively in innovative activities to foster economic growth and sustainable development.

UNCTAD collaborated with Iran in the preparation of an STI Policy Review in 2005 – an opportune time of policy reform, when its policymakers showed a growing interest in science, technology and innovation. It marked the start of a transition away from a strong but narrow focus on science policy. The STIP Review examined Iran’s NIS, along with its oil, gas and petrochemical industries and biopharmaceuticals. Even at that time, it observed that the national development policy was aiming to shift the country from a natural-resource-based economy to a more knowledge-based one. Policymakers recognized the need for economic diversification away from the predominant O&G industry through a process of industrialization, using O&G revenues to fill the financing and foreign exchange gaps. The development strategy remained largely focused on self-reliance, although it was moving towards a more outward and export-oriented approach. Most of the issues and challenges raised in the 2005 Review have been dealt with through different policy measures and initiatives. The current STIP Review can be considered, to some extent, as a neutral and unbiased assessment of the effectiveness of government policies with regard to STI development and a pointer to the way ahead.

There have been a number of improvements in Iran’s NIS during the period 2005–2015, in scientific research and publishing, higher education, exports, and ICT infrastructure. Iran’s global rank in scientific publications improved from 34th in 2005 to 16th in 2015. Even though the country has not managed to massively increase research and development (R&D), research activities are emerging in new areas, including nanotechnology, biotechnology and renewable energy. In tertiary education, the number of graduate engineering students has increased, with Iran ranking second globally in terms of the number of engineering graduates per capita (according to the Global Innovation Index 2016 Report). As a result of the law for supporting knowledge-based firms (KBFs), which was ratified in 2010, 2,732 KBFs were benefiting from its financial and non-financial facilities as of October 2016. These firms accounted for a total of 70,000 employees and $6.6 billion in annual turnover. The drive for diversification through knowledge-intensive activities has led to an eightfold increase in knowledge-intensive exports. ICT infrastructure has also improved with respect to mobile phone penetration (from 12 per cent in 2005 to 93 per cent in 2015) and Internet users (from 8 per cent in 2005 to 44 per cent in 2015). Despite several policy actions, ICT infrastructure still requires higher investment to facilitate e-commerce and e-government, and to improve ICT services and make them more efficient for businesses.

Regarding structural and institutional changes in the NIS, a number of new policymaking institutions have been created over the past decade. The establishment of the Vice Presidency for S&T in 2007 and its 16 affiliated technology councils, as well as the Innovation and Prosperity Fund in 2011, are among the major institutional changes. In addition, new, supportive policies have been ratified and implemented (for example, with regard to KBFs), and other instruments and mechanisms have been created or expanded (such as incubators, S&T parks, S&T special districts, research and technology funds and venture capital funds). Since 2005, policies and initiatives have led to the emergence and reinforcement of technology- and innovation-intensive entities, such as new technology-based firms (NTBFs), start-ups and KBFs. Finally, since 2013, there have been major changes in the macroeconomic environment, including growth of the services sector, control of the inflation rate and macroeconomic stabilization efforts.

Compared to the situation during the previous STIP Review, Iran has faced severely tightened international sanctions. The sanctions had been in place since 1980, but became much more extensive in 2008, and effectively excluded Iran from the international payments system. They restricted imports of some technologies and isolated the country from global markets and international collaboration. Sanctions have had multiple macro effects besides limiting international transactions. In particular, they sparked a drive for STI development and created support for a push to adopt an indigenous development approach in the country. The challenges created by sanctions mustered a strong and widely shared commitment to build a comprehensive and dynamic innovation system and a knowledge-based economy.

This Review identifies three waves of STI policy development in Iran since the 1990s. The first wave focusing on developing higher education started in 1990. A second wave focusing on developing research and technology (including emerging technologies and their required infrastructure) started in 2000. The third wave marking a transition towards an innovation and knowledge-based economy started in 2010. Among the outcomes of the third wave, the large pool of young, educated and skilled labour and growing research capacity have emerged as the country's most important assets today. They now need to be fully harnessed for rapid industrialization and the transition to a knowledge-based economy. The main question is how to ensure that these assets make positive economic, social and environmental impacts and contribute to sustainable development.

The "Resilient Economy" Policy, which came into effect in 2014, can be seen as a pragmatic one aimed at managing international linkages and STI development under constrained circumstances in a way that strengthens national economic resilience and ensures the maximum realization of potential benefits from international trade, investment and technology linkages.

Some of the main institutions in the innovation system retain a focus on production, but do not give adequate consideration to the critical role that the development of innovation capacity must play in the ability of firms and industries to compete in the domestic market or to export abroad once Iran reintegrates into the global economy. This reintegration is in progress, with Iran considering accession to the World Trade Organization (WTO). The bodies with authority over the economy, such as the Supreme Economy Council, the Ministry of Economic Affairs and Finance, and even the Chamber of Commerce, need to give greater emphasis to enhancing STI capacity as a basis for building a competitive economy in the coming years.

Overall, despite the significant progress made, Iran faces a range of challenges in several areas, including raising productivity, improving the business environment, modernizing an ageing infrastructure (particularly in energy and transport), addressing issues related to the environment and climate change, stabilizing inflation, stimulating economic growth, creating jobs and raising gross domestic product (GDP) per capita. Considering Iran's sizeable infrastructure in ICT, transport and power, as well as the potential effects of large-scale urbanization (with around 73 per cent of the population living in urban areas) and a large domestic market, efforts should be directed at increasing productivity through STI and leveraging the highly skilled workforce more effectively.

A new approach based on Iran's reintegration into the global economy will be confronted with a complex mix of opportunities and challenges. Iran needs to rapidly improve productivity, modernize industry and strengthen innovation capacity so that the reintegration process does not undermine domestic industry and is as beneficial as possible for the country. Iran has good potential to develop strong STI capacity and leverage it to support sustainable development. To realize this potential, policy reforms are needed. This Review proposes some major recommendations to enhance the country's STI policy efforts. These recommendations include measures to strengthen the governance of the innovation system as well as address specific policy issues considered barriers to STI development.

- **Ensure greater coherence between STI policy and other key areas of national policy in order to increase the positive economic impacts of STI.** Diverse policy areas need to be better aligned to strengthen support for innovation, encompassing wider framework conditions as well as the mechanisms at the core of the NIS so that it has a greater impact on economic growth and sustainable development. There is an obvious need for industrial policy and STI policy to be closely linked. Coherence is also important between STI policy and FDI, trade, education, financial, competition and SME/entrepreneurship policies. Macroeconomic policies should crucially aim at maintaining economic stability and creating a pro-growth environment. The need for policy coherence also applies at the sub-national level.

- **Restructure the division of functions and responsibilities for STI governance.** Some overlaps have been observed among the key bodies that play a role in STI policymaking, design and implementation. It is advisable to devise a holistic plan to create a clear division of STI functions and responsibilities among different STI policy bodies, with clearly specified mandates. In addition, new measures, such as venture capital development, are important for promoting innovation and supporting entrepreneurship. There needs to be a change in mindsets so that all major players have a common understanding and appreciation of the role of STI and STI policy. Efforts should be made to accelerate the gradual change, already underway, from the traditionally dominant linear, science-push approach to innovation to a more innovation systems approach.
- **Establish a short- to medium-term target for an attainable level of R&D spending with a focus on promoting and providing incentives for the business sector.** In countries that invest extensively in R&D, most of it is generally undertaken by the private sector. Hardly any government in the world invests more than 1 per cent of GDP in R&D, and part of that is used as fiscal incentives to encourage private companies to invest in R&D. It is therefore recommended that Iran adjust its existing target of public spending on R&D to 1 per cent of GDP, along with a target of 1.5 per cent of GDP to be spent by the private sector. The resulting aggregate target of 2.5 per cent of GDP for R&D spending is a realistic level that could be attainable through serious effort. The focus on achieving the R&D targets should be accompanied by policy attention to promoting continued investments in further strengthening design and engineering capacity.
- **Make funding of universities, research and technology organizations performance-related by introducing R&D "project" or "mission" funding schemes targeting prioritized areas.** Iran should revise the current structure of research budgets of universities and public research organizations that is on a non-competitive basis and not conditional on performance. A centralized budget allocation system implemented through a national fund, such as the Iranian National Science Foundation, should use performance criteria in determining the extent of support to universities and public research organizations, giving priority to areas of high social and economic interest. Eligibility for funding should also be based on criteria that promote stronger linkages within the innovation system.
- **Modify the approach to evaluation and policy learning with a view to strengthening policy experimentation.** Evaluating innovation should give less weight to measuring delivery versus planned objectives. Instead, it should focus more on economic, social and environmental outcomes and impacts, evaluating the unexpected, taking direct as well as indirect impacts into account and helping to design a more effective innovation system as a whole.
- **Adopt a comprehensive strategy for attracting and benefiting from FDI as well as other external sources of funding, implementing policies and creating conditions that promote linkages, technology flows and technological learning.** Realizing the potential benefits from foreign direct investment is not automatic; it requires appropriate policies and measures, and creating the right conditions, including improving the absorptive capacity of local firms. Policymakers will need to move swiftly to take advantage of post-sanctions foreign investors interest, targeting foreign investors in industries and activities of high national priority, and promoting FDI that can help create local linkages and contribute to developing/upgrading local skills, knowledge and technological learning. Formulating an appropriate policy framework for foreign investment is therefore important. Policies on technology transfer and local content, such as the Technology Annex and the Policy on Maximum Utilization of Local Capabilities, should be implemented in a pragmatic and adequately flexible manner to realize the benefits from FDI. At the same time, it is important to ensure that investments in high priority areas are not deterred by imposing unrealistic requirements and targets that will be difficult to meet in the near term.
- **Improve the credibility and usefulness of the IPR system through its comprehensive, gradual improvement, encompassing the entire IPR life cycle, for the purpose of maximizing its relevance to the innovation system.** The Iranian Parliament is currently considering reform of the IPR law. In moving forward, Iran's IPR legislation needs to be revised to ensure maximum relevance for innovation. This requires institutional

backing from Parliament and key decision-makers to ensure that the full cycle, spanning all stages of the IPR process – from patent application to dispute resolution and rights enforcement, as well as awareness-raising, training and professional support – operates effectively and all elements of the cycle are properly aligned. The issue of copyright protection will also need to be addressed as the IPR system is improved. Starting planning for this transition may become critical if Iran is to accede to the WTO.

- **Promote the goal of a knowledge-based economy across traditional industrial sectors, while maintaining policy support for start-ups and new growth areas, including through professional business services and an upgraded innovation and entrepreneurship ecosystem.** Iran's large traditional and mature industries are impeded by an ageing and underperforming infrastructure, which needs major upgrading and expansion over the next decade. Mature firms in established industries need incentives to invest more in innovation. Simultaneously, policymakers should continue to foster the rise of new KBFs, new activities and new industries. The existing support programme for KBFs contains a well-designed package of instruments to identify and nurture a vibrant community of young firms with high-growth potential. In addition, the Government needs to facilitate the establishment of professional business service providers capable of assisting start-ups and young growth-oriented companies in areas such as strategy, registration, funding, marketing, IPRs, healthy information exchange and negotiations. It should also encourage active engagement by venture capital firms.

Iran's biotechnology innovation system: Main conclusions and recommendations

Biotechnology in Iran dates back to the 1920s when the Pasteur and Razi Institutes started to produce vaccines. It entered the modern biotechnology era two decades ago with a focus on supply-side policies such as the establishment of new research centres, the development of many related disciplines in universities, and the introduction of new supporting laws, which led to the growth of 307 biotech KBFs. Despite significant progress in biotechnology in recent years, there are a number of challenges that need to be tackled through appropriate policy initiatives. These challenges include inadequate demand-side policies, inefficiency of IPR enforcement, inadequate access to financial resources and FDI, and inadequate commercialization processes. The following recommendations seek to help overcome these challenges:

- **Improve financing for biotechnology.** Iran should develop additional effective financing mechanisms for funding biotech development, including measures to develop a domestic venture capital market and to attract international venture capital.
- **Enhance collaboration between biotech KBFs and mature firms.** Efforts should be made to intensify competition and provide incentives to induce mature firms to become more involved in R&D activities and new product development, which will increase opportunities for collaboration with KBFs through the creation of supply chain linkages, joint R&D projects and participation in acquisitions.
- **Strengthen international collaboration on biotechnology and local biotech firms' access to international markets.** Improving access of local firms to international markets will require improved marketing, branding, skills in international negotiation and the creation of distribution networks by providing local firms with appropriate education and training, empowerment and consultancy services.
- **Improve the biotech accreditation system by enhancing laboratory and testing equipment and facilities.** Biotech accreditation bodies, biotech testing and certification systems need to be established or improved to ensure that the biotech products produced in Iran meet the quality requirements and other standards necessary for entering the local market and/or export markets.
- **Enhance local content policies as well as public procurement in favour of biotech innovations.** Public procurement could be better leveraged to encourage innovation by local firms, particularly in bio-agriculture and health.
- **Strengthen balanced applications of biotechnology in its four main subsectors: health, industry, agriculture and the environment.** Policies and actions are needed aimed at unlocking the full potential

of biotechnology application in a balanced manner to help address health, industrial agricultural and environmental challenges in Iran.

Iran's oil and gas innovation system: Main conclusions and recommendations

Iran's oil and gas (O&G) industries date back to the early twentieth century, making them the oldest in the Middle East. In 2015, the O&G sector accounted for around 20 per cent of GDP. Based on both achievements and challenges in the sector, the following actions and initiatives are proposed:

- **Promote collaborative learning in the O&G innovation system combined with strategies for building local capabilities.** Policymakers, executive officers and firms' managers should give due importance to engaging actively with technology and promoting technological learning for technological catch-up, as discussed in the Review. Innovation requires not only R&D, but also engineering and design capabilities, in particular. There is a need for collaboration both among domestic actors and between them and foreign firms. For policymaking, interactive learning is a key process that must be enabled through the design of appropriate mechanisms.
- **Promote supplier development, including through MNE-local firm linkages.** Supplier development and local linkages can be supported through suitable local content requirements and a technology strategy designed specifically for the O&G sector.
- **Develop public procurement instruments and shape the financial institutions and tools needed to support both supply and demand.** There should be a supportive financial system which provides three kinds of financial services: venture capital and angel investors, special organizations for funding projects, and mechanisms to cover risks and uncertainties (such as insurance).
- **Restructure the institutional set-up of the O&G sector, and foster the development of knowledge linkages and flows between S&T organizations and companies:** It would be advisable to improve horizontal coordination among the key O&G policymaking bodies, and to change the mind-set of some policymakers to adopt an *innovation systems* approach to innovation policy. In addition, there should be an increase in the participation of the productive sector in high-level decision-making for both strategic priority-setting and programme design.

To sum up, it is important to devise a policy mix for the O&G innovation system that responds to the differing demands for knowledge-oriented linkages of various types of firms. SOEs and large engineering, procurement and construction firms should participate actively in technology development. The Ministry of Petroleum and its affiliated companies should feel as responsible for technology development in the O&G sector as they are for production in that sector. It should be noted that such efforts are in motion in a limited number of divisions in that Ministry, but they need to be adopted more broadly. Furthermore, suitable local content policies should be designed and implemented in the sector in order to enhance technological collaboration between local firms and international companies, and foster the development of technological capabilities in local firms.

An overall conclusion of this Review is that Iran possesses significant assets in terms of a strong human resources base and research and technology capabilities. These assets are key prerequisites for the country's transition to a knowledge- and innovation-based economy. It is a time of great opportunity and critical decisions for national policymakers in Iran. Decisive policy initiatives and actions are needed to fully utilize these assets to boost economic growth and sustainable development. These efforts will require action by both the public and private sectors.

Decisions made in the near future may determine what path the country will pursue for many years to come. As Iran's international trade and investment relations move towards normalization, policymakers should consider mobilizing the revenues from oil, gas and minerals for investment in industrial upgrading and modernization of the infrastructure. They should also focus on fostering efforts aimed at achieving greater technological and innovation capabilities needed to drive truly sustainable growth and development in the country over the long term. This means redoubling current efforts to shift from a natural-resource-based economy towards a more knowledge- and innovation-based one. It also requires mainstreaming innovation into the development policy mix and including it in the agenda of key public and private sector institutions.

Science, Technology and Innovation in Iran at a glance

Enrolment in and graduation from tertiary education in Iran

	2005-2006	2012-2013
Students	2,389,867	4,367,901
Graduates	340,246	718,801
PhD Students	19,237	58,683

Knowledge-based firms

52 (2014) → 2732 (2016)

Number of supported KBFs has increased from 52 in March 2014 to 2732 as of October 2016. They account for around 70,000 jobs and $6.6 billion in revenue.

Scientific publications

	2005	2011	2015
Iran's share in scientific publications in Middle East	14.8 %	32.4 %	28.6 %
Rank in Middle East	3	1	1
Iran's share in scientific publications in the world	0.4 %	1.5 %	1.5 %
Rank in the world	34	17	16

Number of S&T parks in Iran

1 (2002) → 39 (2016)

Number of Incubators in Iran

136 (2013) → 170 (2016)

Companies located in S&T parks and incubators

- 2012 → 2518
- 2013 → 3000
- 2014 → 3400
- 2015 → 3650

Gender balance in higher education

47% 53%

2013-2014
High level of gender equality in both secondary and tertiary education compared to other countries in Middle East

Innovation and Prosperity Fund

Approved projects	Total support
1380	$280 million

Number of universities in Iran

Public universities	154
Public medical universities	58
Islamic Azad University	567
Private universities	354

Technology-based exports ($ billions)

High- and medium high- tech exports

2004	2009	2014
1.5	7	12.1

Knowledge-based products exported by S&T parks and incubators ($ millions)

- 2012 → 0.7
- 2013 → 14.1
- 2014 → 49.6
- 2015 → 50.6

I

Introduction

It is a time of huge opportunities and critical decisions for national policymakers in the Islamic Republic of Iran (hereinafter referred to as Iran). Their decisions in the near future are likely to determine the path that the country will pursue for many years to come. As Iran's international trade and investment relations move towards normalization, policymakers can use the revenues from oil, gas and minerals for investment in industrial upgrading and modernization of infrastructure, and focus not only on stimulating production capacity, but also on building the deeper technological and innovation capacity needed to drive truly sustainable growth and development in the country over the long term. This means continuing with the current efforts to shift from a natural-resource-based economy towards a more knowledge- and innovation-based one. It also implies the need to ensure that the achievements of recent years in terms of vastly increased domestic production and innovation capacity, which were developed in an environment, effectively, of protection from foreign competition, are not undermined by the opening up of the economy to international competition. Indeed, a sustained focus on building science technology and innovation (STI) capabilities, strengthening innovation systems and promoting investment in technological upgrading and innovative activity by the public and private sectors in Iran is crucial to the development policy mix needed to ensure that reintegration into the global economy is beneficial for Iran.

UNCTAD collaborated with Iran in the preparation of a STIP Review in 2005. That Review came at an opportune time of policy reform, when policymakers showed a growing interest in STI policy. It was also the start of a transition from a heavy focus on science policy (evident in the first of the national five-year development plans (FYDP)) towards greater attention to technology policy (evident in the second FYDP). The third FYDP (covering the period 2001–2005) marked a gradual shift towards a more balanced focus on technology and innovation. The focus on innovation increased further in the fourth FYDP (covering the period 2006–2010). That Review examined Iran's national innovation system (NIS) along with the oil, gas and petrochemicals and biopharmaceuticals industries. It noted that the national development policy was already aiming to shift the country from a natural-resource-based economy to a more knowledge-based one. Policymakers recognized the need for economic diversification from the predominance of the oil and gas (O&G) industry through a process of industrialization, using O&G revenues to fill the financing and foreign exchange gaps. Although the development strategy remained largely based on self-reliance, it showed a move towards a more outward and export-oriented approach. The strongly centralized planning approach was slowly evolving with limited liberalization and privatization of firms and a gradual move towards a more market-based economy. A strongly export-oriented, outward development strategy was not possible at the time, given the international economic sanctions in place and tense relations with the most technologically advanced countries in North America and Western Europe. This context also limited the scope for international investment, collaboration, technology transfers and knowledge exchange.

The National Policy for a Resilient Economy of 2014 can be seen as a pragmatic policy approach to managing international linkages and STI development under such constrained circumstances in a way that will strengthen national economic resilience and enable the realization of the potential benefits from international trade and investment linkages. Most of the issues and challenges raised in the 2005 Review have been dealt with through different policy measures and initiatives. The current review can be considered, to some extent, as an assessment of the effectiveness of government policy efforts in this regard and as a pointer to the way forward.

From the 2005 STIP Review to the present: A systematic attempt to diversify and shift to a knowledge-based economy

At the time of the 2005 STIP Review, Iran had a relatively strong science and technology (S&T) infrastructure, education system and human resources compared to many other developing countries. That Review stressed the importance of building an innovation system and economy capable of generating new industries, such as those engaged in biotechnologies, petrochemicals and the use of new materials. At the time, Iran's 4th FYDP articulated a strategy to improve its higher education system and scientific publications, and develop its technological infrastructure. Since then, two more FYDPs have been implemented. This chapter attempts to assess the major macroeconomic, structural, institutional and performance changes to Iran's NIS.

The 2005 Review found that Iran had a broad industrial base, as well as relatively well-developed

S&T infrastructure and skilled manpower. However, progress in diversification and industrialization, and a shift towards greater knowledge-based production and a more innovation-based economy needed to accelerate. It argued that Iran's NIS was performing below its potential and that the country was not successfully exploiting its strong human capital and science, technology, engineering and mathematics (STEM) assets to boost technological capabilities and innovation performance. It attributed this mainly to deficiencies in the country's innovation system and the "framework conditions". Since the economy was predominantly State-owned competitive pressure was low. The private sector's share of value added in gross domestic product (GDP) was estimated at only 15 per cent (UNCTAD, 2005). Most research institutes and the higher education system were also heavily State-owned. Thus there were few incentives for technological upgrading and innovation by firms. The Review argued that firms needed a competitive stimulus and an effective innovation system to encourage them to invest in technological learning and innovation.

With little participation of foreign firms in the economy, apart from the O&G sector, international linkages and spillovers of knowledge and technology to local firms were weak or non-existent. Nevertheless, there were close production linkages in the NIS between firms, research institutes and universities and the Government (the traditional "triple helix"), as they were all State-owned. The incentive structure, however, did not promote technological learning and commercial innovation by industry, and linkages were deficient in terms of learning and collaboration for innovation to meet demand. User-producer linkages were also weak, and consumer demand (for new or improved products) was not inducing producers to innovate in products, processes, organizational or managerial approaches. The innovation system was not functioning properly to push firms to access new technologies and invest in learning and capability-building in order to improve their products or introduce new ones.

The Review found that the policy framework was not effective in providing the support and incentives needed to encourage the key actors in the system to innovate. National Policy was too focused on production, and not on using innovation as a means to promoting economic growth and development. This was, and still is, very common among many developing countries, even today. The 2005 STIP Review suggested that policy should focus more on promoting the building of technological and innovative capacity and fostering research through joint ventures and licensing. It also recommended strengthening competition (by increasing private sector participation in the economy and opening up the economy to competition), improving data on STI, improving policy monitoring and evaluation, designing and implementing national and sectoral innovation strategies, strengthening user-producer linkages in order to better articulate demand, giving priority to the development of small and medium-sized enterprises (SMEs) and building local supplier networks for large SOEs.

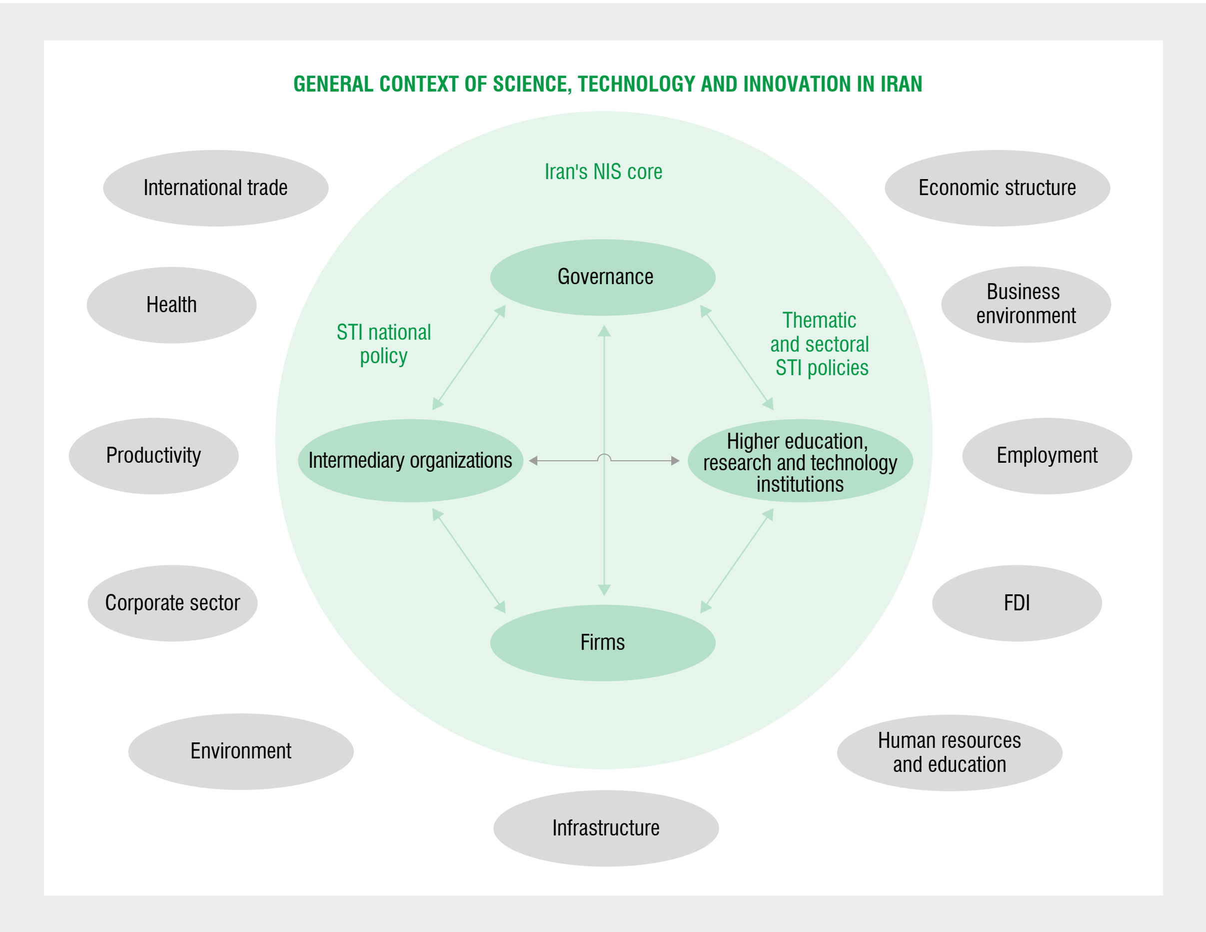
The NIS has undergone a number of changes during the period 2005–2015, with an improved STI performance in terms of increases in scientific research and publishing, higher education and exports, as well as improvements in the information and communication technology (ICT) infrastructure. With respect to scientific research and publishing, Iran's global rank in scientific publications improved from 34th in 2005 to 16th in 2015.[1] Even though the country has not managed to massively increase its research and development (R&D),[2] research activities are emerging in new areas, such as nanotechnology, biotechnology and renewable energies. Concerning the university system, Iran has increased the number of graduate engineering students, ranking second globally in terms of engineering graduates per capita (Global Innovation Index 2015 report). However, many educated people remain unemployed due to a mismatch between the education system, professional training and industry requirements.[3] Under the law for supporting knowledge-based firms (KBFs), which was ratified in 2010, 2,732 KBFs were benefiting from its financial and non-financial facilities by October 2016. These firms accounted for a total of 70,000 employees and $6.6 billion in annual turnover. This program is promising, although it is relatively small in relation to the size of the economy, with turnover of $6.6 billion amounting to 1.7% of Iran's GDP in 2015. With respect to the export profile, the value of high-tech and medium-high-tech exports grew from $1.5 billion in 2005 to $12 billion in 2014. Attempts at diversification via knowledge-intensive activities have led to an eightfold increase in knowledge-intensive exports. ICT infrastructure has also improved as evidenced by the rise in mobile phone penetration (from 12 per cent in 2005 to 98 per cent in 2015) and Internet users (from 11 per cent in 2005 to 28 per cent in 2015). Despite several policies and efforts, ICT infrastructure still requires more investment to foster e-commerce and e-government, and promote better quality ICT services and increased efficiency for businesses.

Regarding structural and institutional changes in the NIS, the last decade has seen the creation of new STI policymaking and implementation bodies.[4] New, supportive policies have been ratified and implemented (e.g. relating to KBFs), and other instruments and mechanisms have been created or expanded (i.e. incubators, S&T parks, S&T special districts; research and technology funds; and venture capital funds (VCFs)).

Finally, major changes in the macroeconomic environment have occurred as the economy has transitioned from considerable government dependence on O&G and macroeconomic instability to improved macroeconomic stabilization in recent years. This is evidenced in the declining share of O&G in GDP and in the Government's annual budgets.[5] Sanctions have had multiple macro effects, including serving as a driver of domestic STI development and inducing a push towards an indigenous development approach in the country in recent years, but also blocking financial exchanges through the international payments system and imports of equipment. Fluctuations in economic growth, stagnation and relatively high unemployment – despite positive and strong growth rates in some years – have impeded STI improvement in a number of ways. Finally, the years since 2013 have witnessed growth of the services sector, control of the inflation rate and macroeconomic stabilization efforts.

Figure 1.1 presents a conceptualization of the core structure of Iran's NIS, including its key elements, which are examined in this Review.

Figure 1.1. Organization of the NIS in the context of the key elements of the overall economy



A summary of the major trends and changes in the NIS and other elements displayed in figure 1.1 is presented in tables 1.1 and 1.2.

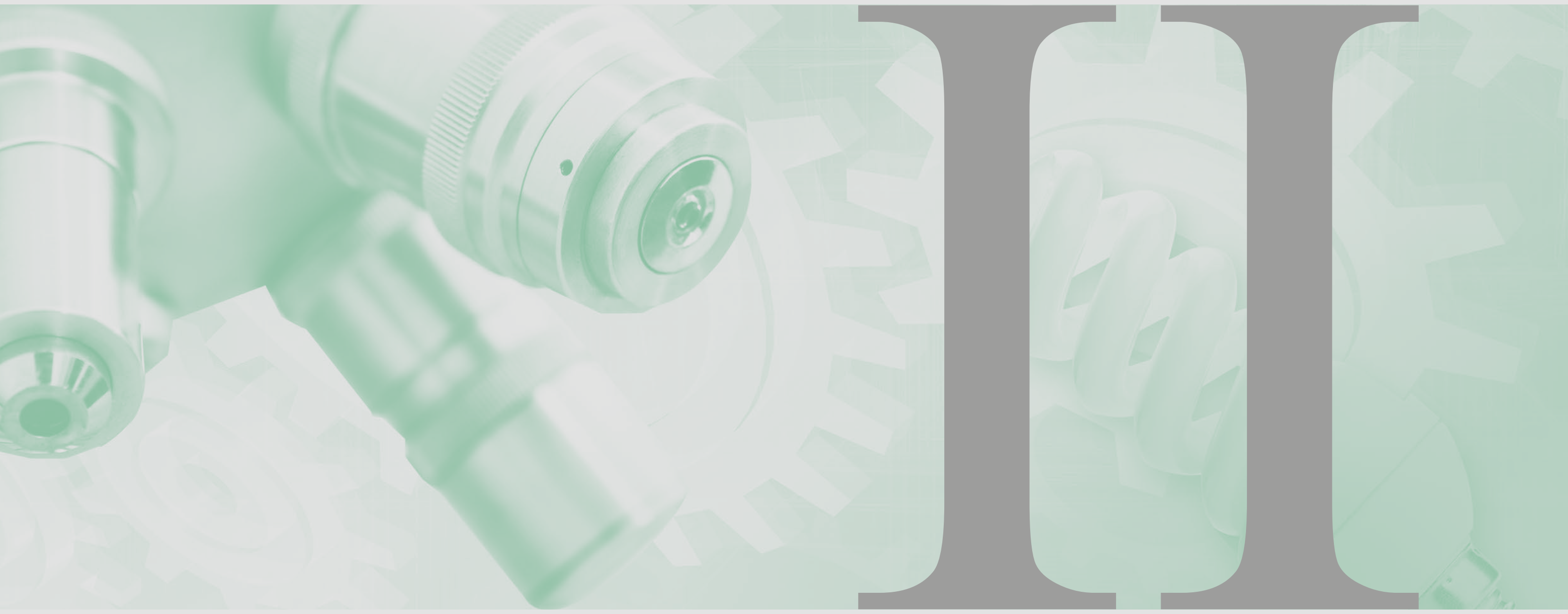
Table 1.1. Main trends and changes in Iran's NIS core and its general context, 2005–2015

Factor	Main trends and changes from 2005 to 2015/2016
	General context of STI
Economic structure	• Continuous decline in share of O&G earnings in GDP and in the government budget to 20 per cent and 35 per cent respectively in 2016. • Diversification of the economy, with a considerable share of industry (i.e. a variety of industries from iron and steel to automotives and machinery) and agriculture, and a dominant services sector, but relatively inward-looking.
International trade	• Gradual increase in the share of medium-high-tech and hi-tech exports in total non-O&G exports to 54.2 per cent in 2013. • Declining trade deficit shifted to a positive balance in 2016. • Natural-resource exports (e.g. O&G and minerals) maintain a considerable share in total exports.
Business environment	• Continuous improvement in the business environment in international rankings during recent years, especially since 2013. • Despite a high degree of government commitment to improving the business environment, it remains among the main barriers to economic growth.
Health	• Increase in average life expectancy. • Greater coverage and quality of health care. • Vast health-care infrastructure and high endogenous capabilities in the manufacture of medicines and medical equipment.
Productivity	• Gradual increase in productivity, but still lagging behind productivity goals. • With negative growth rates in all sectors except agriculture, there is a need to raise total factor productivity (TFP) through technology and innovation.
Employment	• Overall unemployment rate declined to around 11 per cent in 2015. • With the unemployment rate of educated people at twice the overall rate, there is a pool of skilled labour available for deployment in knowledge-based production.
Infrastructure (ICT)	• Considerable increase in Internet bandwidth and mobile-broadband subscriptions; however, ICT and its infrastructure should be substantially improved to boost the corporate sector. • Compared to other countries at similar levels of development, Iran lags in fixed and cellular broadband subscription and bandwidth.
Infrastructure (transportation)	• Huge investments are needed for modernizing and increasing capacity in road, aviation and maritime transportation infrastructure.
Infrastructure (environment)	• Lack of water resources and inefficiency of consumption, soil erosion and high greenhouse gas (GHG) emissions are the main environmental challenges.
Infrastructure (power & electricity)	• High production capacity and distribution, with good coverage and quality. • Need to improve efficiency of electricity production, distribution and energy intensity. • Gradual shift to renewable energies has started and is progressing.
Corporate sector	• The corporate sector has a dominant proportion of SMEs, at 96 per cent, providing more than 56 per cent of that sector's employment. • Lack of access to adequate financing, and limited networking between SMEs and large firms remain issues.
Foreign direct investment	• Low FDI inflows and absorption in the past decade. • A law for promotion of FDI was enacted in 2002, followed by scattered incentives. The Government is paying greater attention to the need for absorbing FDI. • Lack of a relationship between FDI inflows and STI capability-building.
Human resources development	• There is a large proportion of young and educated people in the population. • There is an increase in the mean years of schooling, but the government needs to reduce the adult illiteracy rate of 12.9 per cent.

Table 1.2. Main trends and changes in Iran's general context of NIS from 2005 to 2015

Factor	Main trends and changes from 2005 to 2015
	Iran's NIS core
Scientific production	• Increase in global ranking in terms of scientific publications, from 34 in 2005 to 16 in 2015, with Iran's rank in biotechnologies and nanotechnologies at 15th and 6th respectively.[a]
Higher education	• Equality of men and women in tertiary education; girls dominate in medical sciences and in studies at the bachelor degree level. • Sizeable increase in the number of students in tertiary education, rising from 2.1 million in 2005 students to 4.4 million in 2013. Iran is among the leading countries in terms of the share of science and engineering (S&E) graduates in total graduates, ranking 1st in the world in 2015 (Cornell et. al., 2015).
Governance	• Emergence of new organizations for policy formulation, most importantly the establishment of the Vice-Presidency for Science and Technology (VPST) in 2007 and its 16 affiliated technology councils.
Policy formulation	• Ratification of the National Master Plan for Science and Education (NMPSE) in 2011. • Ratification of National Policy for S&T in 2014. • Ratification of National Policy for a Resilient Economy in 2014. • Passage of the Act of Patents, Industrial Designs and Commercial Signs in 2006.
Intermediary organizations	• Establishment and reinforcement of a range of intermediary organizations, such as VCFs, research and technology funds, consultancy firms, and accreditation bodies brokering and attempting to create synergies in STI.
Knowledge-based entrepreneurship	• Approval of the Law for Supporting KBFs in 2010 and support to 2,732 KBFs by October 2016 with a total turnover of $6.6 billion. • Establishment of the IPF, with an initial capital by its mandate of $1 billion, in 2012. By October 2016 the IPF had approved and financed 1,380 projects and provided funding to KBFs totalling $280 million.

Note: [a] *http://biotechmeter.ir/ and http://statnano.com/.*



II

Science, technology and innovation indicators in Iran

2.1. Introduction

STI indicators are important for providing data to support evidence-based policymaking and effective monitoring and evaluation. They should therefore capture the whole of the NIS, including all the linkages between the actors, and they should also reflect the various stages of the policy cycle. As such, STI indicators that measure inputs (such as human capital and financial resources) and outputs as well as impacts of innovation on social and economic development are essential for effective policy formulation, implementation, monitoring and assessment (UNCTAD, 2011).

A recent panel on developing science, technology and innovation indicators for the future stated that the availability of relevant, accurate, timely and objective information on STI is critical in addressing vital policy questions for a country (Litan et. al., 2014), including:

- How are the contributions of STI to productivity, employment and growth in the broader economy changing in a world of economic globalization?
- What are the drivers of innovation that benefit the economy and society?
- Does the country have the STI-related knowledge base needed to move the nation forward, address its social challenges and maintain competitiveness with other countries?
- What effect does expenditure on R&D and education in S&E have on innovation, the economy and social welfare, and over what time frame?
- What characteristics of industries and geographic areas facilitate productive innovation?

Translating these questions into indicators leads to a long and very diverse list of potential statistics and data sources. For example, the OECD's biennial Science, Technology and Industry Scoreboard brings together over 200 statistics to help examine emerging policy issues in S&T, such as international mobility of researchers and scientists, growth of the information economy, innovation by regions and industries, innovation strategies by companies, internationalization of research, the changing role of multinational enterprises (MNEs), and new patterns in trade competitiveness and productivity (OECD, 2015a).

Such information is needed to capture not only the inputs and outputs of the innovation system, but also the linkages and interactions between the various actors. Some of the data that can be used to study the innovation system of a country are available in administrative and commercial databases, while other data require surveys, such as R&D and innovation surveys. A lack of useful and reliable indicators presents serious difficulties for all aspects of STI policymaking. Ultimately, policymakers need information on the impact of their policies. This is hard to measure directly, but can be done with empirical analyses of the data series mentioned above. Empirical methods are particularly useful if policymakers have access to enterprise-level data.

2.2. Assessment of STI indicators in Iran

Like many other countries, Iran is seeking to transform its economy into a knowledge-based economy, as reflected in the Government's Vision 2025 which was adopted in 2005. Later, in 2010, a law was passed to provide an appropriate funding mechanism, the IPF, which became effective in 2012. In order to fulfil the long-term vision through shorter term implementation strategies, the Government of Iran prepares FYDPs. The fifth FYDP for the period 2010–2015 included the following strategies devised to achieve S&T goals:

- Establish a comprehensive system for monitoring, evaluating and ranking institutions of higher education and research institutes. The Ministry of Science, Research and Technology (MSRT) and the Ministry of Health and Medical Education have been entrusted with this task. Researchers will be evaluated based on criteria such as their scientific productivity, their involvement in applied R&D or the problem-solving nature of their work.
- The ratio of gross expenditure on R&D (GERD) to GDP is to be increased by 0.5 per cent each year to reach 3 per cent by 2015.
- Establish an integrated monitoring and evaluation system for S&T.
- Incorporate major indicators of S&T in government planning, including the volume of revenues generated by exports of medium- and high-tech goods, the share of GDP per capita derived from S&T, the number of patents, the share of FDI in scientific and technological activities, the cost of R&D and the number of KBFs.

In line with the arguments discussed above, Iran needs to develop a set of indicators to assess the country's STI performance covering the whole of its NIS. This chapter outlines a set of indicators that could meet this requirement (see table 2.1). They are divided into two groups: STI inputs and STI outputs.

2.2.1. STI inputs

STI-related human resources

Human resources are key to building STI capacity in a country. In recent decades, therefore, Iran has devoted considerable efforts to boosting education, especially in STEM subjects and related fields. As a result, Iran has succeeded in developing a strong human capital base, with a high level of gender equality in both lower and higher education compared to other countries in the Middle East.

Higher education statistics

The past decade has witnessed a gradual expansion of the higher education system in Iran (figure 2.1). Enrolments grew from 2.1 million in the 2004-2005 academic year to 4.4 million in the 2012-2013 academic year, while the number of graduates increased from 178,000 to 719,000, corresponding to growth rates of enrolments and graduates of about 110 per cent and more than 300 per cent, respectively, over the period.

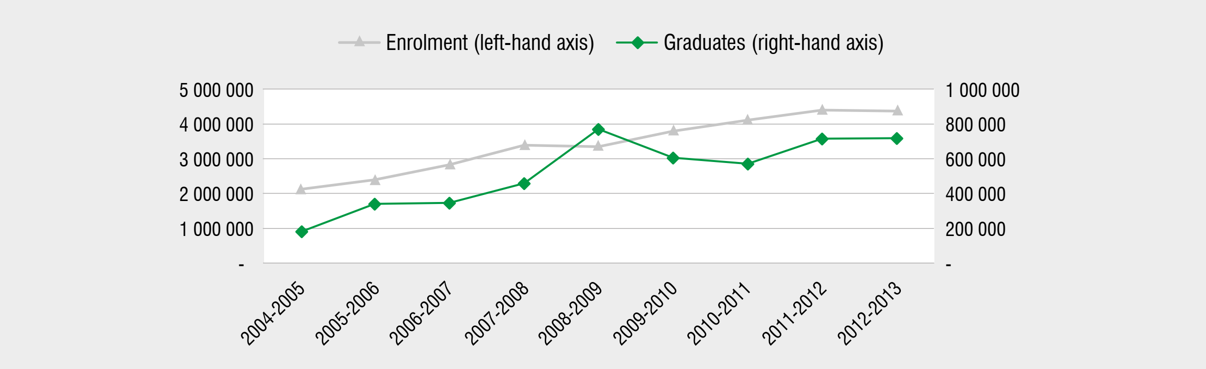
Percentage of students by educational level

During the 2013-2014 academic year, 62.3 per cent of students were pursuing bachelor degrees, 22.3 per cent associate degrees and 12.4 per cent master's degrees, and approximately 3 per cent were pursuing medical doctorates or were doctoral students. Over the past decade, the combined share of master's and PhD students in the total has increased considerably, from 6.5 per cent to 15.4 per cent. The increase in the number of university graduates improves the skills base available for firms, universities and research centres and government. In particular, post-graduates are necessary to increase the research capacity of a country. In Iran, the number of PhD students has increased rapidly, from 19,273 in 2005-2006 to 73,437 in 2013-2014 (figure 2.2).

Table 2.1. STI indicators in Iran

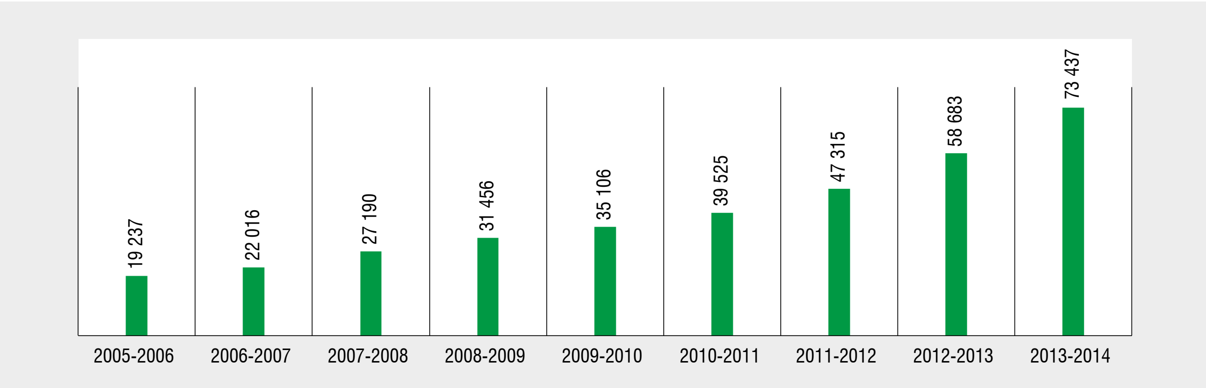
Categories	Indicators	Sub-indicators
STI inputs	STI human resources	Enrolment in and graduation from tertiary education
		Percentage of students at each educational level
		University and college students by discipline
		Science and engineering graduates
		University students by gender
	STI infrastructure	S&T parks
		Incubators
		Universities
		Laboratories
	R&D and financial support	GERD/GDP ratio
		Distribution of GERD by activity and performing sector
		Financial sources for funding STI
STI outputs	Scientific publications	Share of Iran in regional and global scientific publications
	Patents	Patents filed and registered in Iran
		Patents filed and granted to Iranian inventors at international intellectual property (IP) offices
	Knowledge- based outputs	Knowledge-based firms
		Companies located at S&T parks and incubators
		Employees in firms located at S&T parks and incubators
		Exports of knowledge-based product, by value
		High-technology exports
	Business innovations (from innovation surveys)	

Figure 2.1. Tertiary education in Iran: Enrolments and graduates, 2004–2005 to 2013–2014



Source: Institute of Research and Planning in Higher Education (IRPHE) database (available at http://www.irphe.ac.ir).

Figure 2.2. Number of PhD students in Iran, 2005-2006 to 2013-2014



Source: Same as for figure 2.1.

Number of university and college students by discipline: Enormous human resources in science and engineering

The number of students in humanities and technical and engineering fields increased during the period 2005–2014, from 1.1 to 2.1 million in humanities and from 680,000 to 1.5 million in engineering (figure 2.3). However, there was slower growth in other disciplines. The strength of Iran's human resources in S&E is reflected in its international ranking. According to the *Global Innovation Index Report 2016*, S&E graduates accounted for about half of all university graduates in Iran in 2014, which is significantly higher than in countries such as Brazil, Malaysia and Turkey (table 2.2). Indeed, Iran ranks number two in the world in the share of S&E graduates.

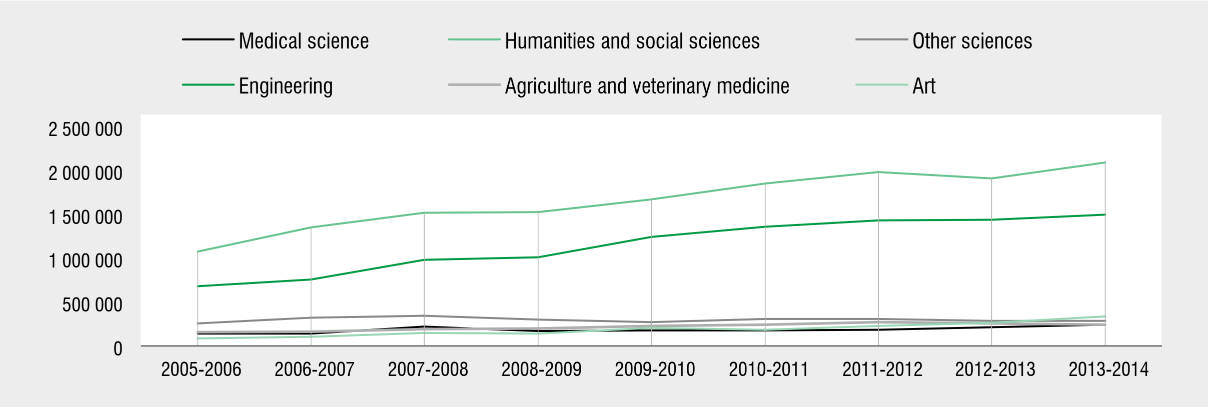
Students in higher education by gender: Equal proportion of men and women

According to IRPHE statistics, 47 per cent of students in higher education during the 2013-2014 academic year were women, showing a more balanced distribution of students by gender in Iran than in other comparable countries in the Middle East. This balance has been a feature throughout recent years, though the share of women was even higher in 2007-2008.

2.2.2. STI infrastructure

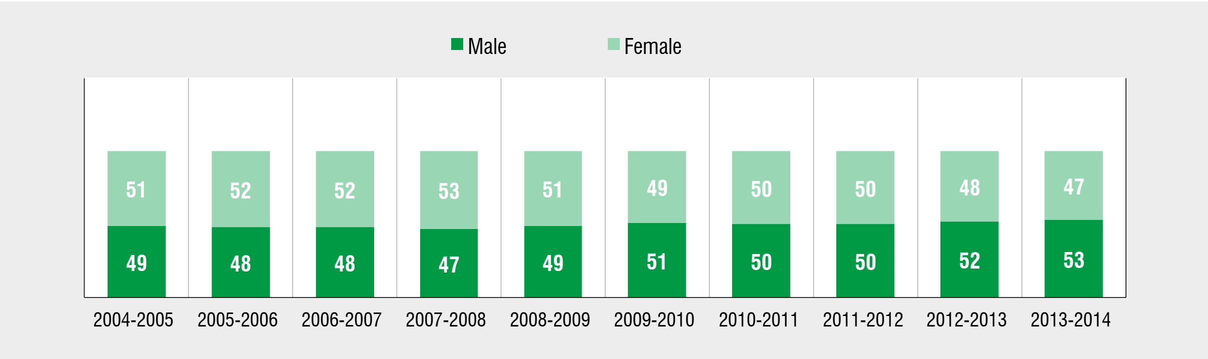
Since the 1960s, and particularly since the third FYDP (2000) that marked the start of the "second wave" of STI development (see 3.2), Iran has made sustained efforts to build its infrastructure for STI, including schools and universities, laboratories, S&T parks and incubators.

Figure 2.3. Number of university and college students by discipline, 2005-2006 to 2013-2014



Source: Same as for figure 2.1.

Figure 2.4. Students in higher education by gender, 2004-2005 to 2013-2014 (per cent)



Source: IRPHE database (at: http://www.irphe.ac.ir).

Table 2.2. Share of S&E graduates in tertiary education in selected countries and country ranking, 2014

Rank	Country	Share in all graduates	Rank	Country	Share in all grauduates
2	Iran	46.6	49	Turkey[2]	20.9
6	Malaysia[1]	33.3	63	South Africa[1]	19.0
17	Mexico[2]	26.9	96	Brazil[2]	12.0
18	Saudi Arabia	26.9	97	Egypt[1]	11.8
46	Indonesia[3]	21.7	n.a	China	n.a

Source: Cornell University et. al. (2016).
Notes: [1] Data are for 2013; [2] data are for 2012; [3] data are for 2009.

Universities

The Government sought to expand the higher education system, including universities, as the main policy tool for improving its stock of human capital.

There are various categories of universities in the country (table 2.3). Five types of public universities are affiliated with the Ministry of Science, Research and Technology (MSRT): (i) 150 public universities;

(ii) universities of applied science and technology (specializing in vocational training and administered by MSRT), of which there are 1,101 branches; (iii) technical and vocational universities (certified by MSRT, which runs all such institutions throughout the country) of which there are 160 branches; (iv) Payame Noor University which has 531 branches, and also provides distance learning programmes; and (v) Farhangiyan University, which has 103 branches and provides teacher education and human resources development for the Ministry of Education.

S&T parks

S&T parks were developed in Iran in order to promote wealth creation through the development of a knowledge-based economy. Such parks seek to facilitate commercialization of research results and linkages between research, production and services sectors of the economy, while also increasing the competitiveness of KBFs. They also support the creation of new technology-based firms (NTBFs) and the development of technology-based SMEs, innovative firms and research institutes. By the end of October 2016, there were 39 active S&T parks in Iran, up from just one in 2002 (figure 2.5).

In addition to S&T parks and incubators, innovation centres and innovation accelerators are other important components of the infrastructure for STI that have been growing rapidly in recent years.

Incubators

Incubators enable countries to support entrepreneurship, creativity and innovation by young researchers. They boost local economic growth based on technology development, and provide a physical space for firms such as KBFs and SMEs, helping them to grow and develop and to produce marketable technology-based products and processes. They also facilitate the commercialization of research outputs. By September 2016 there were 170 active incubators in Iran, up from 136 in 2013 (figure 2.6).

Laboratories

Laboratories, which play a key role in research and technology development (RTD), have grown dramatically in number over the past few years, from 3,500 in 2013 to 12,594 as of September 2016 (figure 2.7).

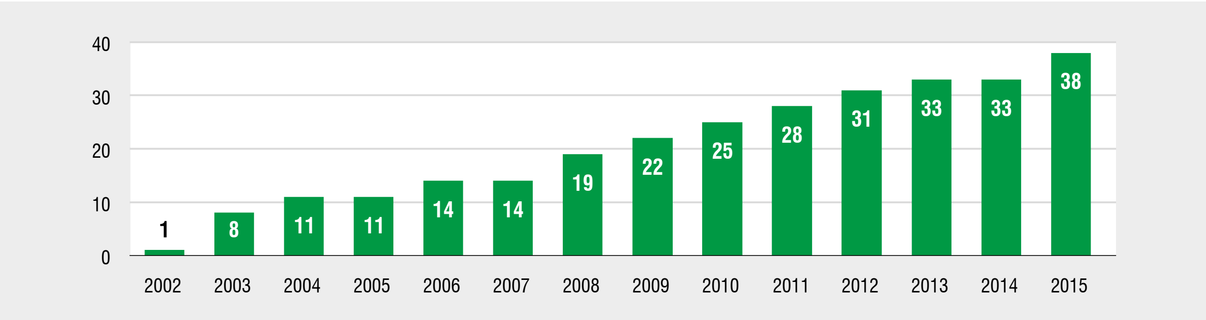
Another component of STI infrastructure is research institutes. In Iran, there are 233 private research institutes, 356 research institutes affiliated with universities, 76 research institutes affiliated with government organizations and 21 non-governmental research institutes.

Table 2.3. Number of Iranian universities, 2015

Type of university	Total number of universities
Public universities affiliated with the Ministry of Science, Research and Technology (MSRT)	154
Islamic Azad University	567
Public universities affiliated with the Ministry of Health and Medical Education	58
Non-profit private universities	354

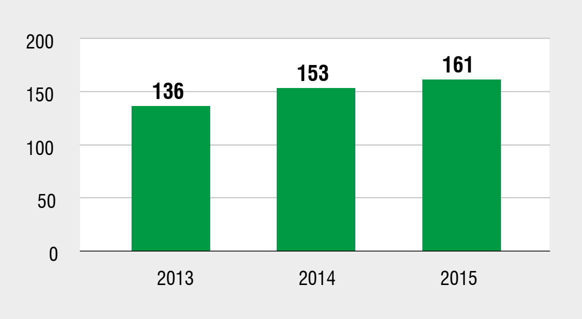
Source: IRPHE (2015).

Figure 2.5. Number of S&T parks in Iran, 2002–2015



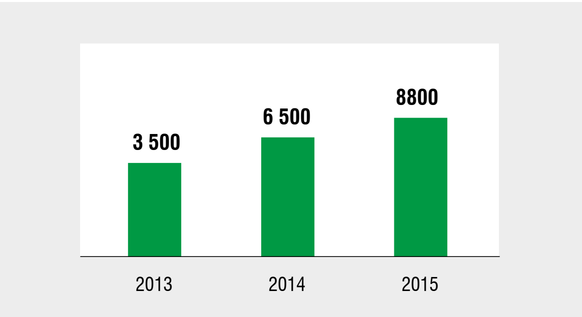
Source: MSRT database (at www.msrt.ir/fa/techno/Files/).

Figure 2.6. Number of incubators in Iran, 2013–2016



Source: MSRT database (at: www.msrt.ir/fa/techno/Files/).

Figure 2.7. Number of laboratories affiliated with MSRT, 2013–2015



Source: MSRT (2016).

2.2.3. R&D and financial support

The Research and Development Fund and other financial incentives play an important role in financing R&D in Iran. This section describes the trends and current status of these financial resources.

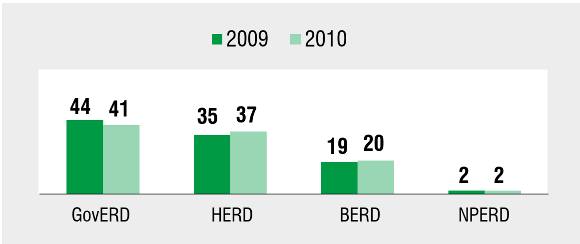
New rule to increase gross expenditure on R&D

Gross expenditure on R&D (GERD) as a percentage of GDP (or R&D intensity) has been below target. It increased from 0.52 per cent in 2011 to 0.55 per cent in 2012, then dropped to 0.42 per cent in 2014 before increasing again to 0.47 per cent in 2015 (IPRC, 2016). The Government plans to increase this figure through implementation of a recent rule that requires allocation of 1 per cent of public agencies' total spending on R&D. Also, according to table 14 of the Budget Act for 2016-2017 there will be an additional budgetary allocation to R&D funding, amounting to approximately 0.37 per cent of GDP upon its full allocation. Therefore, after full execution of this rule, the GERD is expected to increase to 0.86 per cent in 2016.[6] These percentages translate to GERD of $1.08 billion in 2011, $1.32 billion in 2012, $1.52 billion in 2013, $1.55 billion in 2014, $2.27 billion in 2015 and an estimated $4.74 billion in 2016 (IPRC, 2016).

R&D expenditure by source of financing

A fact sometimes overlooked is that in all countries with a high R&D intensity, the business sector performs the bulk of the R&D. Since most of business R&D is self-financed, the business sector accounts for a significant share of R&D funding and activities. However, in Iran, the business sector finances a very small share of R&D. According to the latest available data, in 2010 while the Government and higher education system financed 41 per cent and 37 per cent of total R&D respectively, the business sector financed only 20 per cent (figure 2.8). However, more recent, reliable figures are needed before any firm conclusions can be drawn. In any case, the business sector should be encouraged to allocate more financial resources for R&D activities in Iran in order to increase the overall GERD level in the country. The Government could act as a pioneer investor in R&D, while also seeking to encourage greater private sector participation in R&D through incentives and support measures, as well as encouraging greater competition. Meanwhile, under the current circumstances, it might be desirable for the Government to contribute a large proportion of GERD – about 50 per cent – as a pioneer. It would also need to provide an enabling environment for the private sector by developing shared infrastructure for R&D, and an efficient incentive and support system for R&D by the private sector.

Figure 2.8. Sources of R&D expenditure in Iran, 2009–2010 (per cent)



Source: Ghazinoori et. al. (2012).
Note: GovERD: Government expenditure on R&D; HERD: Higher education expenditure on R&D; BERD: Business expenditure on R&D; and NPERD: Private and non-profit sector expenditure on R&D.

Other sources of STI funding

In addition to the public and private sectors, institutions of a semi-public nature also provide funding for STI in Iran. They can be classified into five categories: private investors (VCFs and technology accelerators); funding institutions that were established by law (i.e. specialized and State development funds, and the IPF); non-governmental investment institutions (e.g. research and technology funds); public institutions (i.e. ministries, S&T parks, incubators and universities); and stock exchanges and banks.

According to the Iran Venture Capital Association (IVCA), as at end September 2015, its institutional members had funded 260 projects, granted 6,900 facilities and provided 2,300 financial services (e.g. bonds) in Iran. During the last decade, their VCFs' financial support amounted to $340 million, which is small in relation to the size of the Iranian economy.

Iran has 18 non-governmental research and technology investment institutions, which are public-private bodies that were established under Article100 of Iran's third FYDP. The number of these institutions has grown rapidly during the last four years.

One of the most important of these is the IPF which was established in 2012 to support KBFs following approval of the knowledge-based law of 2010 and the effort to support the development of a knowledge-based economy. This fund has played a significant role in supporting KBFs by financing over 1,380 approved projects and investing around $280 million (table 2.4).

Financing for knowledge-based companies and start-ups by VCFs, and research and technology funds (e.g. grants and bonds) have targeted a wide array of sectors (figure 2.9). The largest shares went to biotechnology (15 per cent), advanced medicine and biomedical engineering (14 per cent) and nanotechnology (13 per cent), followed by interdisciplinary activities (10 per cent) and advanced manufacturing and laboratory equipment (9 per cent).

2.2.4. STI output

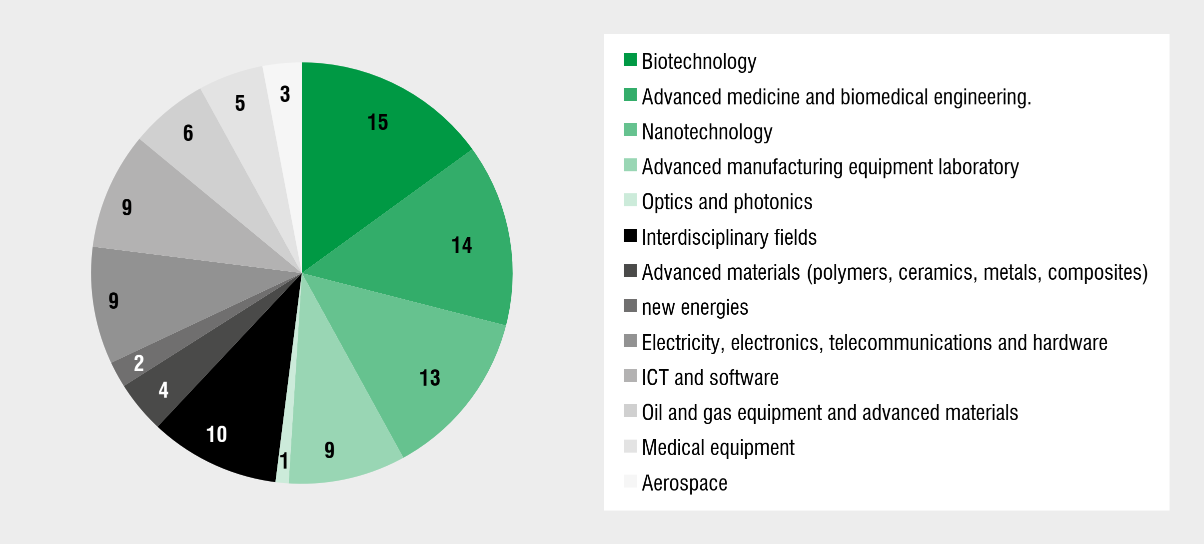
Iran has increased its efforts to promote STI, as evidenced by the sustained growth of the different indicators for STI inputs. In terms of outputs, scientific publications have increased dramatically. However, progress in creating new patents has been slower. The economic impact in terms of production and exports of medium- and high-tech products has likewise been more modest, reflecting the ongoing challenge in harnessing the greatly improved human resources base and research and technology development (RTD) system to create export-oriented innovative products.

Table 2.4. Number of IPF-approved KBF projects and its financial support, by activity, 2012–October 2016 (period total)

Industrial and technological field	Number of approved projects	Share of IPF funding for each activity in total IPF funding (per cent)
Biotechnology	203	22.2
Electronics	222	12.7
ICT and computer software	201	12.5
Advanced equipment manufacturing, production and laboratory	186	10.0
Advanced medicine and medical engineering	96	8.6
Advanced materials	77	4.0
Aerospace	52	2.1
Nanotechnology	43	1.9
Optics and photonics	30	1.0
Renewable energy	28	0.9
Commercialization services	23	0.1
High-tech products in other fields	218	23.2
Total	**1 379**	**100**

Source: IPF database.

Figure 2.9. Share of funding by non-governmental investment institutions in STI fields, March 2014–August 2015 (period total) (per cent)



Source: Iranian Venture Capital Association, Annual Report 2016 (in Persian).

Iran's contributions to regional and global scientific publications

The share of Iran in scientific publications worldwide has been growing over the past two decades, from 0.07 per cent in 1996 to 1.5 per cent in 2015 (figure 2.10). Likewise, its share in total regional scientific publications increased from 3.5 per cent in 1996 to 28.6 per cent in 2015. Around 19.8 per cent were joint publications by Iranian authors and foreign authors. A major reason for these improvements is the increasing importance given to scientific publications in assessments of performance, and for grants and promotion of university professors, and, in the case of graduate students, for obtaining grants and admission to graduate studies.

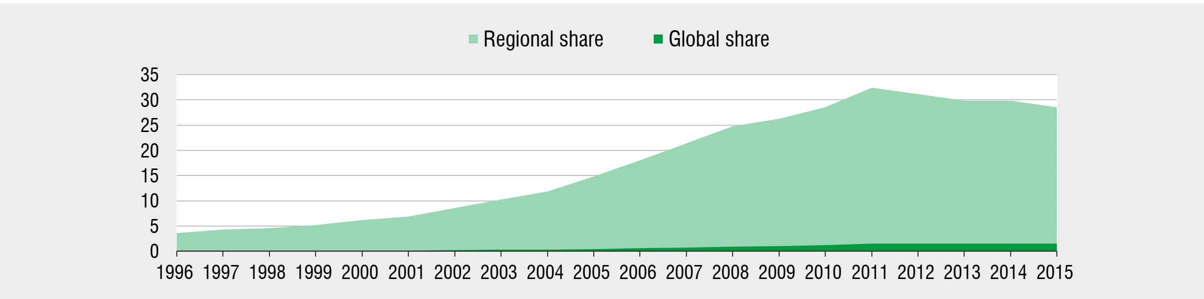
Iran is particularly strong in specific fields of research, such as nanotechnologies and biotechnologies, in which it ranked 7th in the world in 2015 and 15th in 2016.[7]

Patents

Patent applications and grants

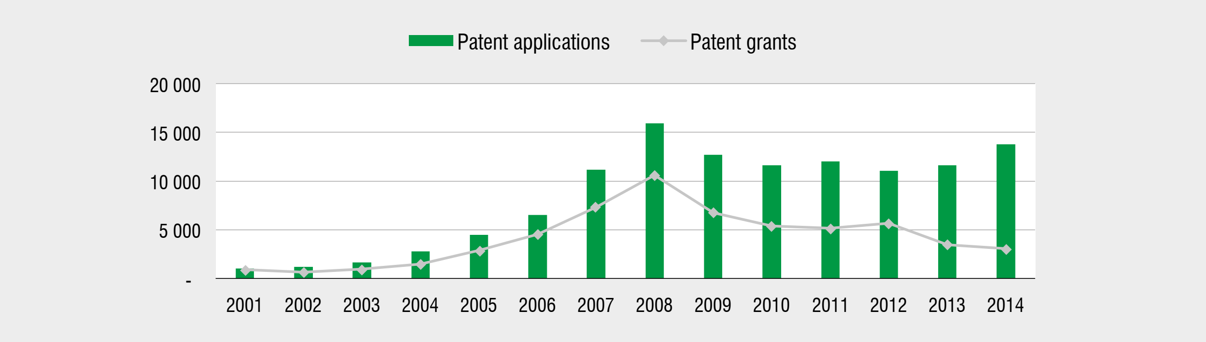
There was rapid growth in the number of patent applications and grants between 2001 and 2008, when both peaked at 5,000 and 10,000 respectively (figure 2.11). After 2008, however, while the number of applications remained fairly high, the number of patents granted declined significantly, reaching about 3,000 in 2014.

Figure 2.10. Proportion of Iran's scientific publications in total regional and global publications, 1996–2015 (per cent)



Source: Scimago database (accessed in September 2016) (at http://www.scimagojr.com/).

Figure 2.11. Number of patents applied for and granted in Iran, 2001 – 2014



Source: WIPO statistics database (last updated in December 2015).

However, these data showing a declining trend should be interpreted with caution, as this does not signify a decline in the extent and scope of innovative activities in Iran. From its inception in 1924 until 2007, Iran's patent system was declaration based, and thus applications were registered without substantive examination. In 2008, a new patent law came into force that required the patent office to examine applications with respect to their compliance with patentability requirements. It is this new, stricter examination-based process for granting patents that largely explains the decrease. The new law also led to a significant increase in the cost of patenting, though this is reportedly not a major cause of the decline in registered patents. The number of patents filed at international patent offices has increased in recent years (table 2.5). Utility patents granted in the United States have been rising since 2011, and patent filings in Europe also rose significantly in 2014 and 2015, although patents granted have not yet increased.

2.2.5. Knowledge-based output

Knowledge-based firms[8]

After approval of the law on supporting KBFs in 2010 and its implementation in 2013, various supportive mechanisms were developed for KBFs. Subsequent years saw a rapid growth of KBFs, from 52 in March 2014 to 2,732 in October 2016 (figure 2.12). They created more than 70,000 jobs and $6.6 billion in revenues.

Companies located in S&T parks and incubators

The number of companies located in S&T parks and incubators increased from 2,518 in 2012 to 3,650 in 2015 – a growth rate of 45 per cent (figure 2.13).

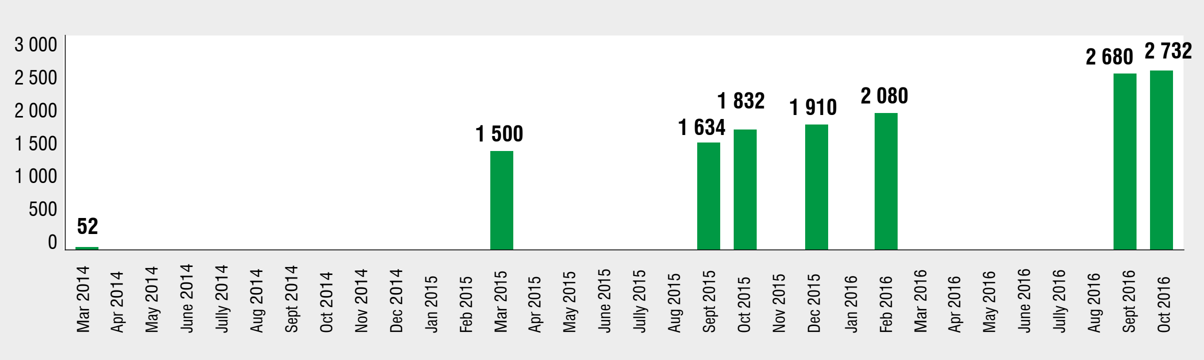
Similarly, the number of employees in companies located in S&T parks and incubators grew from 19,000 to 29,606 during the same period (figure 2.14).

Table 2.5. Number of Iranian patents at international patent offices, 2006 – 2015

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
USPTO utility patents granted	2	3	2	6	7	16	25	35	28	27
European patent filings	8	16	7	12	11	3	3	4	38	64
European patents granted	1	2	0	1	4	2	1	0	2	0

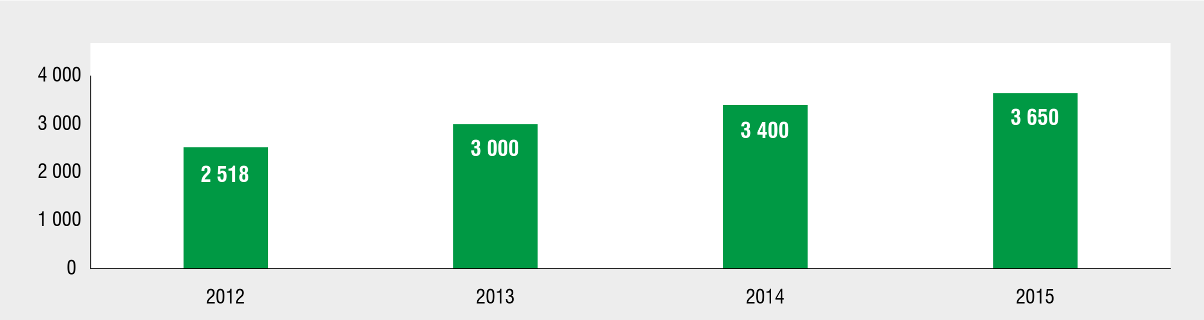
Sources: United States Patent and Trademark Office (USPTO) database (at: https://www.uspto.gov/web/offices/ac/ido/oeip/taf/stctec/irxstcl_gd.htm) and European Patent Office (EPO) database (at: https://www.epo.org/about-us/annual-reports-statistics/annual-report/2015/statistics/patent-filings.html#tab3 and https://www.epo.org/about-us/annual-reports-statistics/annual-report/2014/statistics/granted-patents.html#tab2).

Figure 2.12. Number of knowledge-based firms, 2014–2016



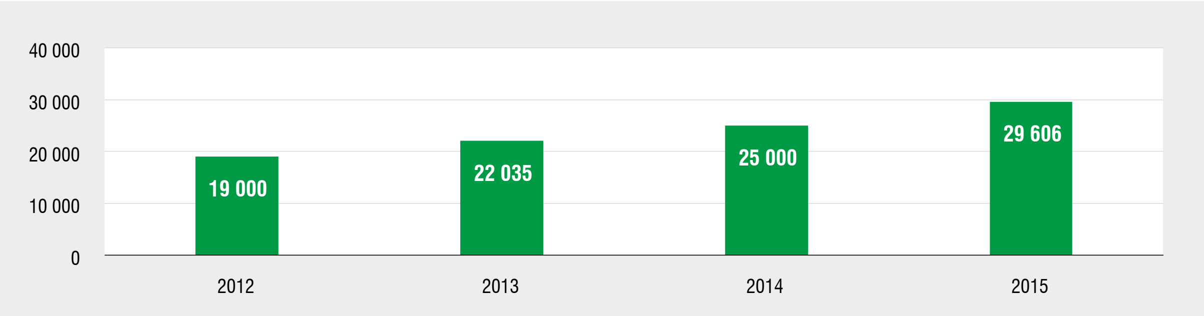
Source: VPST database (at: http://daneshbonyan.isti.ir/) (accessed in October 2016).

Figure 2.13. Number of companies located in S&T parks and incubators, 2012–2015



Source: MSRT (2016).

Figure 2.14. Number of employees in companies at S&T parks and incubators, 2012–2015



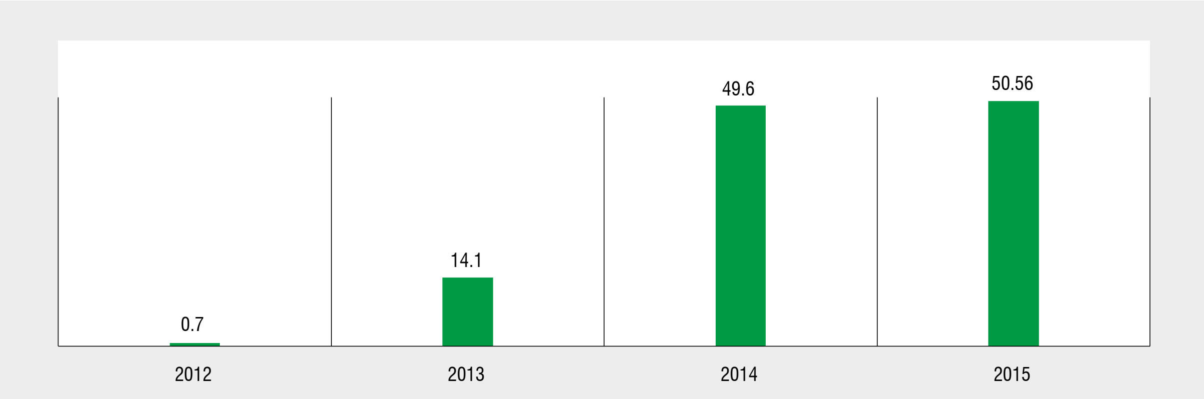
Source: MSRT (2016).

Export revenues from knowledge-based products generated by companies in S&T parks and incubators have also been increasing, from less than $1 million in 2012 to almost $51 million in 2015 (figure 2.15).

Exports of high-tech goods

High-technology exports are products with high R&D intensity, such as those related to aerospace, computers, pharmaceuticals, scientific instruments and electrical machinery. The share of Iran's high-tech products in non-fuel exports is very low – about 1 per cent of the total – while the share of medium-tech products is substantial at 30.7 per cent (table 2.6).[9] If only high-tech products are considered, Iran remains behind the other selected countries in the table. However, if medium- and high-technology exports are considered together, Iran's relative

Figure 2.15. Export revenues from knowledge-based products by firms in S&T parks and incubators, 2012–2015 ($ millions)



Source: MSRT (2016).

Table 2.6. Share of exports of high-, medium- and low-technology-intensive goods in non-fuel merchandise exports, Iran and selected economies, 2014 (per cent)

	Brazil	China	Egypt	Indonesia	Iran	Malaysia	Mexico	Saudi Arabia	South Africa	Turkey
Primary products	33.0	3.0	21.0	25.9	17.6	6.8	5.7	5.2	24.2	8.9
Resource-based manufactures	32.1	7.2	18.1	32.2	22.7	18.1	7.0	21.2	27.3	12.9
Low-technology manufactures	6.1	32.8	25.6	17.5	5.6	11.5	10.3	7.0	7.6	36.4
Medium-technology manufactures	20.6	24.3	24.6	17.2	30.7	21.4	49.6	64.1	29.9	33.6
High-technology manufactures	4.8	32.4	5.6	6.1	1.0	41.4	24.7	1.5	4.1	4.2
Unclassified	3.6	0.4	5.1	1.1	22.3	0.9	2.7	1.1	6.9	4.0

Source: UNCTAD, based on UNCTADstat (accessed 24 May 2016).
Note: The Lall classification is used to compute the figures. In computing non-fuel exports, the following were excluded: Petroleum oils, oils from bitumen, materials, crude (#333), Petroleum oils or bituminous minerals > 70 % oil (#334), residual petroleum products, n.e.s., related mater (#335) liquefied propane and butane (#342), natural gas, whether or not liquefied (#343), and petroleum gases, other gaseous hydrocarbons, n.e.s. (#344).

position improves considerably vis-à-vis the selected countries. Moreover, 22 per cent of Iran's total exports are unclassified. This is quite a substantial amount when compared with other countries, possibly biasing downwards the technology intensity estimates as technology-intensive exports may be underestimated. Overall, the data indicate that there is potential for a significant increase in Iran's high-tech manufactured exports – a proxy for STI outputs in terms of production and international trade.

2.3. Iran's National Innovation Surveys

Innovation surveys provide an insight into the innovation activities undertaken by firms to introduce new goods or services on the market, or to improve production and commercialization processes.[10] These activities include not only R&D, both intramural and outsourced, but also the acquisition of machinery and equipment, and of external knowledge such as patents, trademarks and licences, as well as staff

Box 2.1. Iran's position in the Global Innovation Index

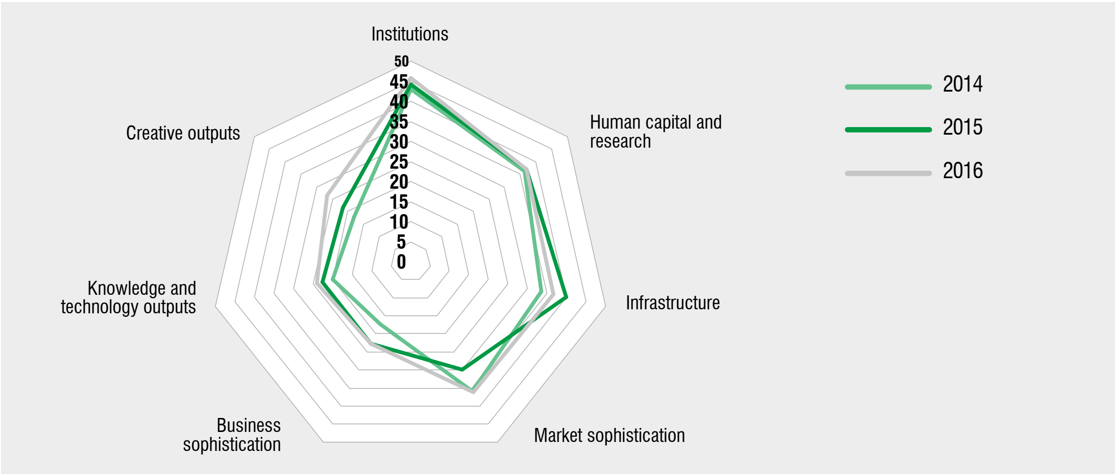
According to the Global Innovation Index (GII, 2016), Iran's ranking in terms of various STI indicators (box table 2.1.1) improved during the period 2014–2016, to 78th position in 2016, 42 steps better than its rank in 2014. This improvement was due to a better institutional framework and increased outputs (both knowledge and technology, and creative ones).

Box table 2.1.1. Iran's rank by selected indicators of innovation in GII 2016 report, 2014–2016

Indicator	2014	2015	2016
Institutions	131	126	112
Human capital and research	46	46	48
Infrastructure	81	68	91
Market sophistication	139	139	102
Business sophistication	136	130	111
Knowledge and technology outputs	113	90	65
Creative outputs	128	116	75

Source: Cornell University et. al. (2016).

Box figure 2.1.1. Iran's score by selected GII indicators, 2014–2016



Source: Cornell University et. al. (2016).

training. Innovation surveys also provide information on linkages within the innovation system, and on the objectives, obstacles and outcomes of innovation processes. In Iran, the VPST conducted a pilot innovation survey in 2014. The survey was based on the 2010 Community Innovation Survey, and covered about 110 enterprises, mainly knowledge-based firms and firms in the ICT sector. The VPST conducted a second innovation survey in 2016, which covered about 2,000 firms in 13 sectors (biotechnology, nanotechnology, automotive and propulsion industries, defence industries, ICT, cement industry, steel industry, O&G, petrochemicals, insurance, leasing and banking services, pharmaceuticals and herbal medicines, laboratory equipment and the food industry).

2.3.1. Overview of the 2016 survey results

The results of the second survey provide some insights into the innovation activities of firms in Iran, which can help in the analysis of STI and the NIS in the country, and improve the ability of policymakers to design evidence-based policies.

Investments in R&D

R&D investments in firms may be divided into four categories: internal R&D; collaborative R&D; acquisition of external knowledge from other firms and organizations; and purchase of machinery, tools, equipment and software from other firms. Purchase of machinery and equipment accounts for about 64 per cent of firms' total R&D investments (figure 2.16), whereas collaborative R&D accounts for the lowest share.

Average R&D investment rates in selected industries

During the period 2012–2014, ICT firms showed the highest ratio of R&D investments to sales, whereas the ratio was lowest in cement and agricultural firms (table 2.7).

Human resources

More than half of the employees in the surveyed firms had high school education at most, and very few (1.97 per cent) had a PhD (figure 2.17). However, in their R&D departments, most staff members (87 per cent) had at least a bachelor's degree.

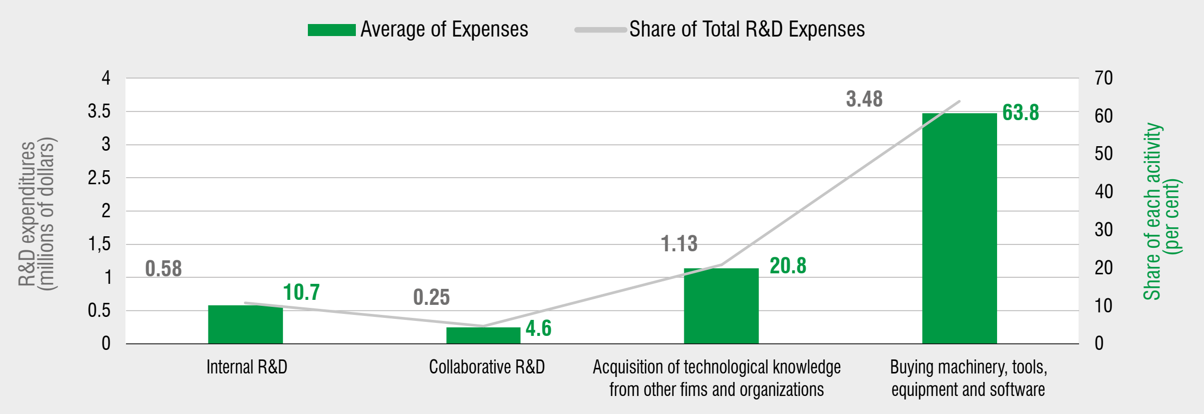
Innovation activities

Among the firms in the survey sample, internal R&D and training in innovation are the most common forms of innovation activities (figure 2.18). Over 70 per cent of the firms are engaged in internal R&D and almost 70 per cent of them undertake training activities. The share of firms that introduced an innovation to the market was 46 per cent. However, external activities such as external R&D and acquisition of external knowledge appear to be less common.

2.4. Conclusions and recommendations

This chapter has provided an overview of the most pertinent STI indicators that are used to assess STI performance in Iran. Based on the findings, this STIP Review makes the following recommendations, classified into recommendations related to the NIS, and STI statistical and information system recommendations.

Figure 2.16. Shares of different types of R&D activities in total R&D expenditure, 2016



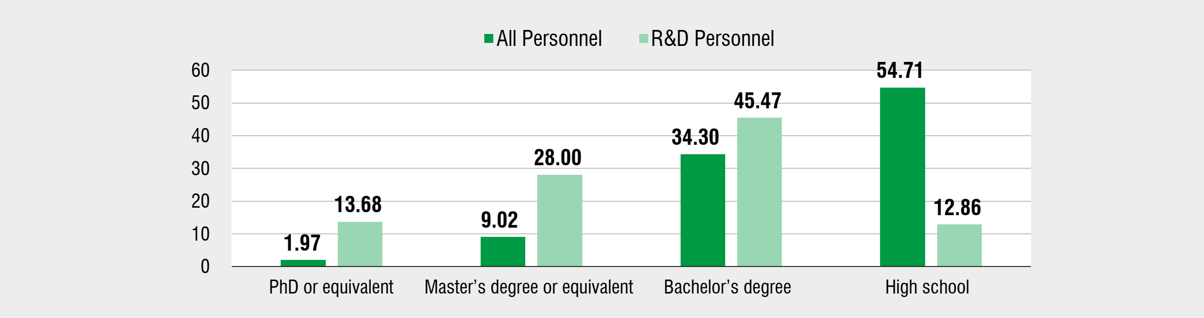
Source: VPST National Innovation Survey, 2016.

Table 2.7. Average ratios of R&D investments to sales of selected firms, by industry, 2012–2014 (per cent)

Sector/industry	Ratio of R&D investment to sales (per cent)
Automotive and propulsion industries	2.7
ICT	7.5
Cement	0.7
Steel	1.3
Oil & gas	0.3
Petrochemicals	3.0
Food industry	0.3
Agriculture	0.2

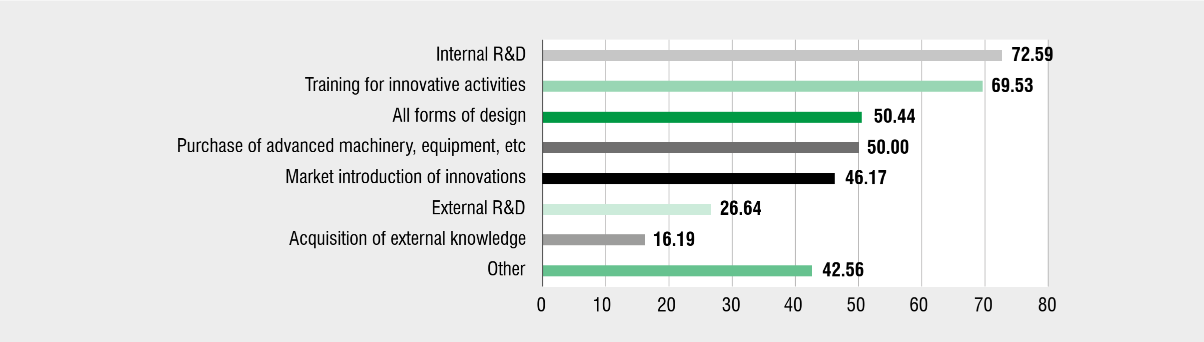
Source: VPST National Innovation Survey, 2016.

Figure 2.17. Distribution of firms' employees by level of education (per cent)



Source: VPST National Innovation Survey, 2016.

Figure 2.18. Share of different innovation activities (per cent)



Source: VPST National Innovation Survey, 2016.

2.4.1 Transitioning from human resource and infrastructure development to shaping an innovative and knowledge-based economy

Table 2.8. presents a summary of the strengths/opportunities and weaknesses/challenges relating to STI in Iran.

According to input and output indicators, it seems that there is still a gap between the relatively well-developed human resources, research (academic) and infrastructural capacities in Iran and their insufficient contributions to the creation of an innovation and knowledge-based economy. Indeed, STI indicators for Iran show that the country has done well in terms of establishing a strong higher education system and scientific production capabilities (the first wave of STI policy identified in chapter 3), as well as providing the necessary infrastructure for the development of technology and KBFs in recent decades. However, Iran still faces problems at the transition to the third wave of STI policy, i.e. in developing the necessary capabilities for innovation, and reaping large economic and development impacts from its strong human capital and research base. It appears that the main policy focus should now be directed towards strengthening the private sector, creating a dynamic ecosystem for innovation in the business sector, creating stronger demand for innovative skills and knowledge-intensive activities in mature industries that are currently using mainly mid-level technologies, and increasing private sector investment in design and engineering, R&D and innovation.

2.4.2. Need for a coordinating mechanism among the main actors for producing STI-related data and stronger support for STI data collection

The basic elements are in place for the production of STI indicators, but there is room for improvement. In particular, coordination between various actors in the system needs to be strengthened. The Statistical Centre of Iran (SCI) is mandated to collect statistics

Table 2.8. Strengths/opportunities and weaknesses/challenges relating to STI in Iran

		Main strengths /opportunities	Main weaknesses/challenges
STI inputs	Human resources	• Number of university graduates increased from 178,000 in 2004–2005 to 719,000 in 2012–2013 • Based on percentage of science and engineering human resources Iran ranks second in GII 2016 rankings) • Gender balance in higher education (women: 47 per cent, men: 53 per cent in 2013)	• Need to improve education and training policies, including technical and vocational education and training (TVET), to better match industry needs and thereby reduce the high unemployment rate of educated people
	Infrastructure	• Relatively well-developed infrastructure, with increases in numbers of S&T parks, from 1 in 2001 to 39 in September 2016, in incubators from 136 in 2013 to 170 in September 2016, in laboratories (i.e. laboratories affiliated with MSRT rose from 3,500 in 2013 to 12,594 in September 2016) and in universities	• Weak linkages between firms located in S&T parks and industry • The need to further increase the number of firms in S&T parks and incubators, and enhance support to them
	R&D & financial support	• Increased financial support for KBFs through the IPF (over $280 million)	• Low national rate of R&D • Low share of investment in R&D by private sector (20 per cent of GERD in 2010) • Small number of venture capital and business angels in STI financing
STI outputs	Scientific publications	• Large share of scientific publications, in global (1.5 per cent) and in regional (28.6 per cent) publications	• Need to further increase international scientific cooperation in scientific publications towards developed country levels (currently about 19.8 per cent)
	Patents	• Relatively large number of applications and registrations of domestic patents (around 3,100 patents granted and more than 13,800 patent applications in 2014)	• Low rates of international applications and registrations in patenting • Large share of individuals and low share of legal persons in applications and registrations at international and domestic patent offices
	Knowledge-based output	• Growing rate of development of KBFs and technological entrepreneurship: from 52 KBFs in March 2014 to 2,732 in October 2016; and number of companies located in S&T parks and incubators, from 2,518 in 2012 to 3,650 in 2015)	• Low proportion of high- tech products and exports (1 per cent of Iran's exports are high-tech and 30.7 per cent are medium-tech manufactures) • Low rate of knowledge-based employment in the national economy

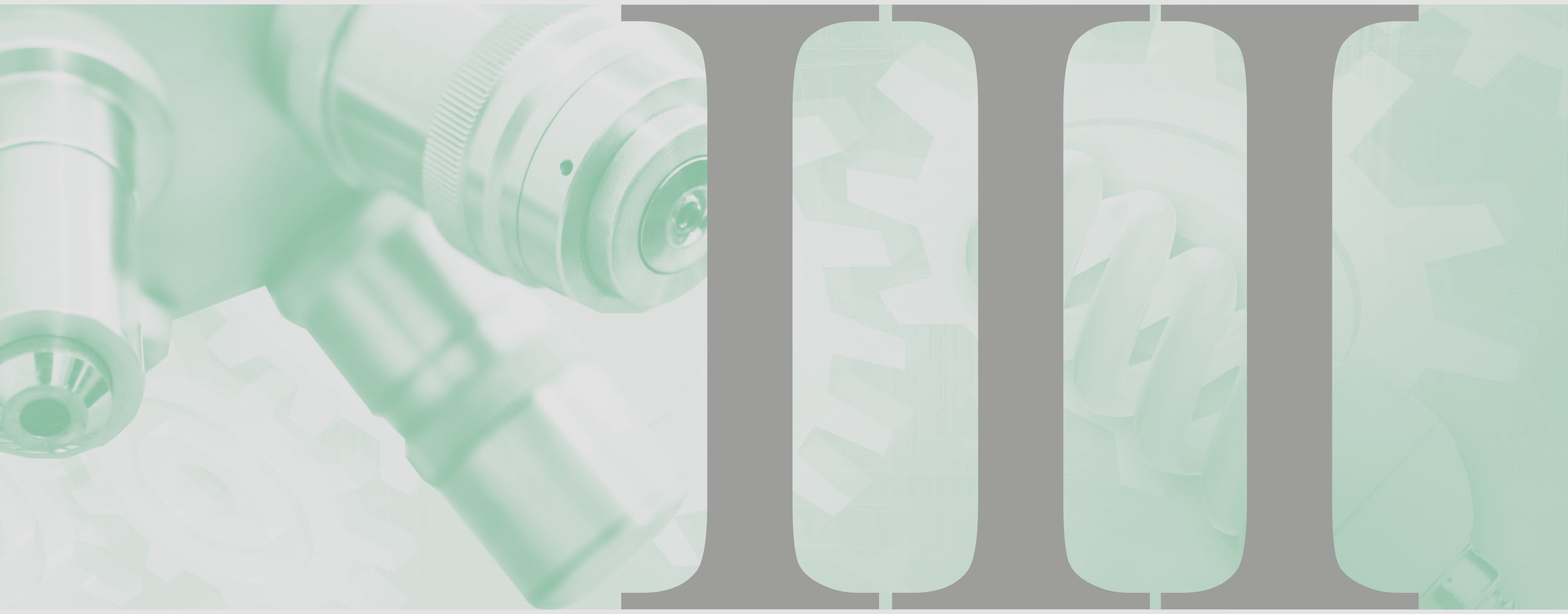
Source: UNCTAD.

relating to S&T (e.g. on R&D) and innovation, but so far it has not given sufficiently high priority to this important activity. It needs to raise its level of engagement in this respect. Efforts to produce reliable and timely R&D and innovation indicators should be supported, with adequate funding provided to enable the timely collection of reliable STI indicators and their rapid processing and distribution for use by policymakers.

The SCI needs to work together with the Supreme Council for Science Research and Technology (SCSRT), VPST and MSRT for collecting R&D data from various sectors of the economy. For example, in the higher education system, coverage should be extended to include private universities. Moreover, in the government sector, the survey sample should be broadened to cover all research organizations.

The survey aims to cover all known or potential R&D performers in Iran, from all large firms to a sample of SMEs. A number of sources can be used to create a list of potential R&D performers. They include the list of firms claiming tax deductions for R&D, firms applying for KBF status, and firms registered with the IPF. The national database for research, SEMAT, should be built up further as a source of information for the R&D survey. The survey itself should also be improved, by collecting all relevant detailed information needed by policymakers and requested by relevant international organizations. For example, R&D data should be disaggregated by sector of performance and the source of funding. Iran's existing data series in international databases should be verified and updated in order to improve the consistency of statistics between national and international sources.

It is strongly recommended that a mechanism be established for coordinating activities of these data-producing agencies. Such a mechanism would avoid duplication of efforts, share and distribute responsibilities, and resolve coverage and methodological issues. It is worth noting that an S&T monitoring system that aims to codify the relevant indicators and coordinate the efforts of the main actors has recently been approved by the SCSRT, but it has yet to be implemented.



General context of STI and Iran's national innovation system

A. GENERAL CONTEXT OF SCIENCE, TECHNOLOGY AND INNOVATION IN IRAN

3.1. A unique setting for a resource-rich economy

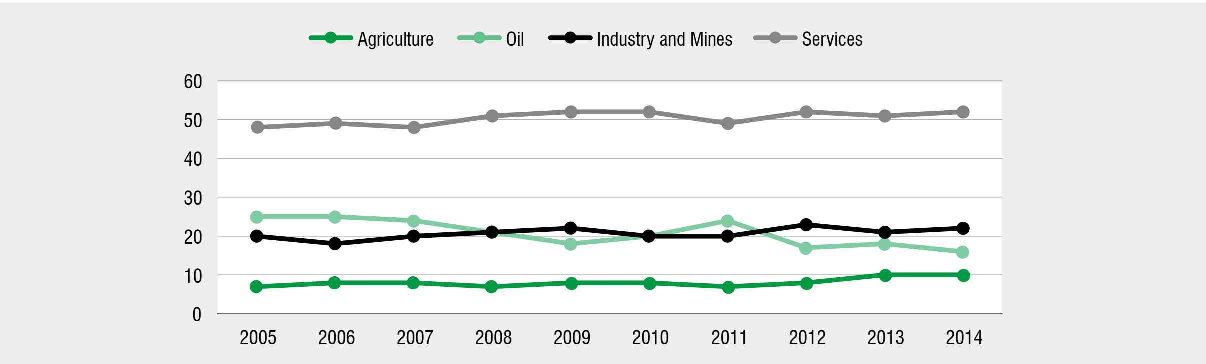
The unique features of Iran's economic context have created a national innovation system defined by a special set of characteristics. Given its vast wealth of O&G reserves, estimated as the 4th and the 2nd largest in the world respectively, Iran may be considered as being afflicted by a "natural resource curse". According to this concept, coined by Auty (1993), natural resource wealth can lead countries to fare worse, not better, in economic outcomes. In the past few years, Iran has sought to develop its industrial sector in both scope and diversity. As a result, it now stands out as the most economically diversified economy with the lowest dependence on O&G incomes compared with other oil-rich countries in the Middle East. Despite its wealth of natural resources, the country has suffered a severe squeeze on financial resources, and constraints on accessing some foreign technologies and pursuing international knowledge-based collaboration. In this situation, Iran has committed to the development of a dynamic innovation system, although it has faced difficulties in establishing mechanisms to fuel innovation and commercialization on par with its scientific and research capabilities. Its human resource base is impressive, including both the large numbers of well-educated, trained and energetic Iranians at home and the Iranian diaspora living abroad as scientists, entrepreneurs and business people.

As Iran sets out to reconnect with the global economy, in part by capitalizing on its natural resources, a number of factors will influence the way ahead. Oil prices seem set to remain modest for the immediate future. With low operating costs, Iran can benefit from recapturing world market shares of O&G, no matter how low their market price. Paradoxically, however, the complexities of the political and economic landscape pertaining to oil will discourage Iran from retreating to its earlier high degree of dependence on this volatile source of wealth. The impending relaxation and possible lifting of sanctions, along with Iran's need to modernize its infrastructure and upgrade and internationalize its industries, will likely increase foreign investment inflows. Beyond financial investment, Iran is seeking to build its productive capacity, encourage international collaboration and exchange of technology and know-how, and engage more actively in innovative activity.

3.1.1 Economic structure and international trade: Less dependence on O&G industry

The services sector accounted for close to 50 per cent of Iran's GDP, compared with almost 20 per cent for the O&G industry in 2014 (figure 3.1). The share of oil and gas is considerably less than a decade ago (MPO, 2016), and much less than for the other major oil exporters of the Middle East.[11] As national economies mature, the share of agriculture typically declines while that of manufacturing initially expands through

Figure 3.1. Trends in shares of selected sectors in GDP, 2005–2014 (per cent)



Source: MPO (2016a).

a process of diversification, after which its share also declines and gives way to a rising share of services. While this also applies to Iran, both agriculture and manufacturing have remained reasonably stable so far, with only a mild decline since 1980 (table 3.1).[12]

Iran has a variety of industries, the major ones being in chemicals and petrochemicals, cement, tiles, automotives, iron, steel, agricultural equipment, home appliances, pharmaceuticals, medical equipment, food and textiles (MIMT, 2015). This also reflects Iran's diversified economy – the most diversified among peer countries, particularly resource-rich countries in the Middle East.

Besides huge reserves of O&G, Iran has a wealth of other natural resources, including zinc (world's largest producer), copper (world's second largest producer), aluminium, iron ore and steel (1 per cent of world production). Other large commodities include decorative rocks (granite, marble, travertine, china stone, crystal) and building and facade stones. Iran's automotive industry has a large production capacity, with a total turnover of $12 billion in 2013 and 1,132,00 cars manufactured. But the industry needs to be modernized, quality improved and productivity increased. This requires more effective use of STI policy aligned with industrial policy as part of the broader policy mix.

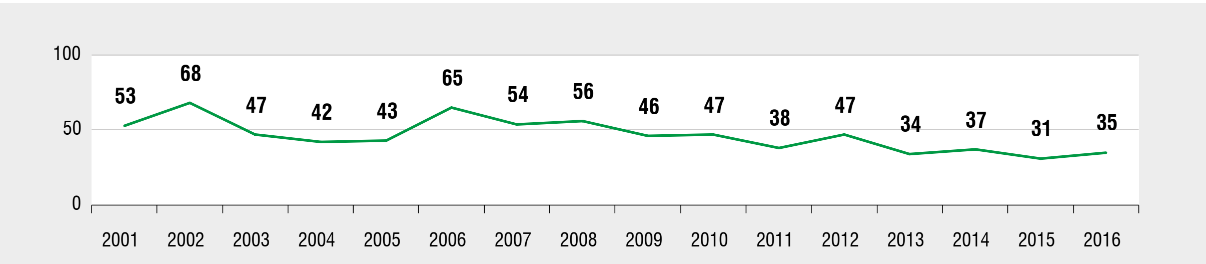
Government budget and petroleum: Falling dependence on O&G revenue

From 2002 to 2016, the share of oil revenues in the Government's annual budget fell from 68 per cent to 35 per cent (figure 3.2) signifying less government reliance on O&G, and diversification in the sources of government revenues.[13] This reflects both structural economic diversification and lower oil prices in recent years.

Trade patterns: low- and medium-tech exports are substantial

Iran's exports comprise mainly low- to medium-tech goods. In 2013, 73.6 per cent of its exports were non-O&G items, totalling $25.6 billion, with high-tech products amounting to $2.1 billion (TPO, 2015).

Figure 3.2. Share of O&G in government revenues, 2001–2016 (per cent)



Source: Annual government budget, 2001–2016.

Table 3.1. Distribution of GDP by economic activity, 1980–2014 (per cent)

	1980	1990	2000	2010	2014
Agriculture	10.9	12.7	9.0	6.7	7.4
Industry	34.7	33.3	40.0	40.3	41.6
– Mining, manufacturing and utilities	23.8	26.7	34.5	32.9	32.9
• Manufacturing	9.7	14.7	16.5	11.6	11.5
– Construction	10.9	6.6	5.4	7.4	8.7
Services	54.4	54.0	51.0	53.1	50.9
– Wholesale, retail trade, restaurants and hotels	8.4	19.4	15.6	13.2	14.2
– Transport, storage and communications	8.0	7.0	7.5	9.3	8.3
– Other activities	38.0	27.6	28.0	30.6	28.5

Source: UNCTADstat (accessed on 5 October 2016).

There has been a considerable geographical shift in Iran's trade pattern, with a large proportion of both its exports and imports shifting from Europe to Asia. In 2014, the most important destinations for its exports were China, Iraq, the United Arab Emirates (UAE), India and Afghanistan. The leading sources of its imports were the UAE, EU countries, China, Republic of Korea and Turkey.[14] As a result of the Government's efforts to boost exports, in 2015 Iran's trade balance turned positive ($42.4 billion in exports vs. $41.5 billion in imports) (IPRC, 2016).

3.1.2. Business environment

Enhancing the business environment is a highly important objective that has long been an area of focus. Iran's ranking in the World Bank's *Doing Business 2016* (World Bank, 2016a), is 118 out of 189 countries, up from 152 in 2013. The report lists the main strengths in Iran as being enforcing contracts, dealing with construction permits and starting a business. It mentions institutional factors, including cross-border trading, protecting minority investors and resolving insolvencies, as the primary challenges that require policy attention. Further improvement is needed to boost economic growth fuelled by the private sector. This is also important for creating a more innovative economy, as noted in the 2005 STIP Review. Interviews revealed that there is a need to improve business transparency with respect to accounting practices and IPRs and surmount vested interests. The recent lifting of most international sanctions is facilitating gradual improvement in the business environment. Recognition of the importance of continuously improving the business environment to foster research, technology and innovation is crucial for every country, in particular for Iran, which aims to pursue a goal of transitioning to a knowledge-based economy. Macroeconomic stabilization can play a role in improving the business environment. The Government has reduced inflation to a single digit level from 34 per cent in 2013,[15] and it will need to maintain this progress in establishing macroeconomic balance.

3.1.3. Human resources and education

The 2005 STIP Review noted a significant reduction in the poverty level and improvements in health and educational standards. The United Nations Development Programme's Human Development Index (HDI) showed that Iran had moved from the group of countries with low human development in the early 1980s to the ranks of those at a medium level in 2002. On the other hand, it also observed that employment creation had stagnated, resulting in high levels of unemployment. Iran has made consistent strides with respect to several HDIs (table 3.2), including an increase in average life expectancy and in the adult literacy rate, which rose from 77.1 per cent in 2003 to 84 per cent in 2010. Average annual growth of HDI values in Iran has been among the highest, 1.62 (1990–2000), 1.11 (2000–2010), 0.74 (2000–2014), and 1.26 (1990–2014) (UNDP, 2015). Despite these improvements, 12.93 per cent of the adult population (i.e. 15 years and older) was illiterate in 2015.[16] Thus there is need for special attention to tackling this challenge.

At the time of the 2005 STIP Review, Iran's higher educational system was of a modest size. However, the report observed that the total number of graduates in sciences had increased threefold during the 1990s, though their overall number remained low in relation to the size of the population, and that the number of post-graduates was particularly low. Despite Iran's budget constraints in the subsequent years, the country has given high priority to strengthening the university system and

Table 3.2. Human development indicators, 1980–2014

Year	1980	1990	2000	2010	2012	2014
Mean years of schooling	2.1	3.8	6	7.8	7.8	8.2
Life expectancy (years)	51.1	61.8	69.8	72.7	73.2	75.4
GNI per capita (2005 PPP$)	7,226	6,189	7,507	10,834	10,695	5,440[a]
HDI Value	0.490	0.567	0.665	0.743	0.764	0.766

Source: UNDP (2015).
Note: [a] In 2011 purchasing power parity (PPP) dollars.

tertiary education. Between 2007 and 2012, the total number of students in tertiary education increased from 2.1 to 4.3 million, and to a further 4.8 million by 2015 (IRPHE, 2016). The rate of growth in engineering was particularly remarkable, similar to that in the Republic of Korea and China.

Higher education is accorded a high status in Iran, applying equally to boys and girls. Its strong expansion contrasts sharply with the trend in most other countries. In engineering, Iran has the highest number of graduate students per capita of all countries. Iran is among the top countries in the world in terms of the number of engineering students graduating each year. While male students dominate in engineering, female students nevertheless account for 35 per cent of the total, which makes Iran one of the countries with the highest proportion of women enrolled in engineering studies. Moreover, there are more women than men in social sciences and medical sciences (UNESCO, 2015). The large base of young educated and skilled labour is an important resource for Iran, which needs to be leveraged fully in efforts towards greater industrialization and the transition to a knowledge-based economy.

3.1.4. Infrastructure

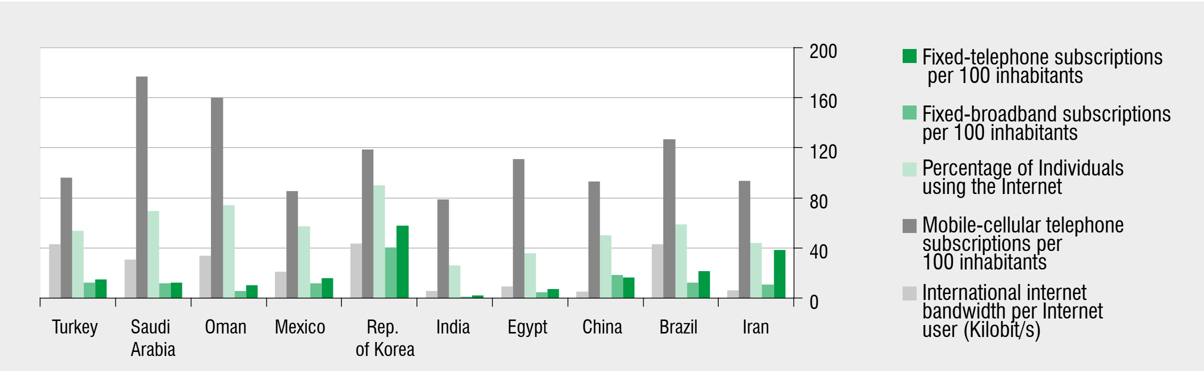
ICT

UNCTAD (2005) noted that Iran had performed strongly on telecommunications infrastructure, connecting people via telephone mainlines, but pointed out that it was lagging in terms of Internet users. Over the past decade the Ministry of ICT has undertaken a number of reforms resulting in noteworthy progress on many indicators. A high-quality optic fibre network was recently rolled out across the country, complemented by high capacity in supercomputing and cloud computing.[17] In addition, specialized IT centres possess impressive research and training capabilities (e.g. in e-health and e-security). In other respects, Iran currently ranks low internationally on indicators such as Internet use in schools, rates of broadband penetration, and overall performance in terms of Internet access and mobile networks.

The growing recognition of the role of ICT in the past few years has led to an increase in the number of mobile-cellular telephone subscriptions per 100 inhabitants, from 73.7 in 2010 to 94.22 in 2015. Active mobile-broadband subscriptions and fixed-broadband subscriptions per 100 inhabitants rose to 20.2 per cent and 11 per cent, respectively, in 2016. Use of international Internet bandwidth increased from 64.3 gigabytes/second (Gbp/s) in 2010 to 473.6 Gbp/s in 2016, which mainly occurred after 2013, reflecting tremendous – though still inadequate – efforts at improving ICT status in the past few years.[18] Iran has a larger number of fixed network subscriptions than several comparable countries (except for the Republic of Korea), and a similar number to developed countries, but it is lagging in fixed and cellular broadband subscriptions and bandwidth (figure 3.3).

The main body responsible for ICT regulations is the Communications Regulatory Authority (CRA). It was established in 2003 by Article 7 of the Law of Scope of Duties and Powers of the Ministry of Information and

Figure 3.3. Penetration of selected ICTs per 100 inhabitants, 2015



Sources: ITU Statistics database (at: http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx); Internet bandwidth from ITU Statistics database (http://www.itu.int/net4/ITU-D/idi/2015/?#idi2015rank-tab).

Communications Technology. Its aim is to stimulate a competitive market for telecommunications, and promote and optimize service quality.[19]

Transportation

Aviation, railways and maritime transportation are important for strengthening Iran's connectedness, domestically and internationally. The railway system's freight is dominated by minerals. Regarding aviation, as on February 2016 Iran had 250 aircraft of which just 148 were operational. The average age of Iran's fleet of aircraft is around 20 years, compared with a world average of about 10 years (MPO, 2016a). This is evidently due to international sanctions, including a ban on sales of aircraft and spare parts over three decades, which went against protocols and regulations of the International Civil Aviation Organization (ICAO). With the implementation of two large recent memorandums of understanding, between Iran and Boeing and Airbus, respectively, for acquiring around 218 new aircraft,[20] the next few years should see the modernization and growth of international routes by Iranian airlines. Finally, with regard to maritime transport, the container operations of Iran's ports rank 4th in the region after the UAE, Saudi Arabia and Oman (MPO, 2016a).

Power and electricity

Over the past decade, Iran has developed and expanded capabilities and innovation capacities throughout the electric power industry. Along with privatization, serious efforts are under way for improving the quality and expanding the electricity market, utilization of renewable energy sources, efficiency improvements, development of demand side management, loss reduction, value engineering, greater use of information technology, human resources development and optimization of the existing installations (Tavanir, 2015). There needs to be increased emphasis on the development of clean energies, such as renewables, which should be supported by a coherent set of policies and public procurement in favour of technology and innovation in areas of high comparative advantage (e.g. solar energy in the deserts of central Iran). However, Iran is among the most inefficient countries in terms of energy use, with the fifth highest energy intensity after the Russian Federation, Ukraine, Uzbekistan and South Africa. This clearly shows the need for policy action to address the issue of sustainability, which is central to achieving sustainable development and the new sustainable development goals (SDGs).[21]

Environment

The achievements in terms of ICT, transportation and power have been accompanied by a number of environmental challenges. There has been only marginal improvement in Iran's ecological footprint per capita from 2.68 in 2010 to 2.66 in 2012, a trend that is consistent with 1961–2010 results (MPO, 2016a).[22] Similarly, the country's GHG emissions fell by 2.4 per cent from 2010–2015, which is again a small improvement. This calls for policies to promote more eco-friendly development, including promoting the use of new technologies such as renewable energy technologies (RETs). There is tremendous need for upgrading of technologies for environmental sustainability, for example to overcome challenges from deteriorating conditions such as soil erosion, drought, water depletion, decreasing rainfall and pollution, and climate change impacts more generally. This requires more direct and systematic technological and innovation initiatives, and can offer potential market opportunities for KBFs that offer innovative solutions.

3.1.5. Health

The health sector has a very special standing in Iran. Within the educational system, medicine and health education and research were placed under the Ministry of Health (MoH) in the 1980s, and since then, they have been strongly integrated with clinical practice. Both health research and higher education programmes are relatively well funded, resulting in this sector's strong performance in many respects.

Viewed as a national priority, total expenditure for the health sector was estimated at 6.9 per cent of GDP[23] in 2014, placing it close to the top among countries in the wider region. Thanks to public support and regulations, along with the strong standing of welfare organizations, more than 90 per cent of the population is covered by health insurance.[24] Table 3.2 shows a steady increase in the average life expectancy of Iranians in recent decades. Accessible care and a high level of competence of medical and other health professionals are seen as contributing to the generally good health status of the population as a whole. Considering the population and the vast area of Iran, the quality and coverage of the health system is good. A main feature of this system is its endogeneity and competitiveness in the Middle East and in the world more generally.

3.1.6. The corporate sector

Today, the private sector is estimated to account for some 30 per cent of the overall workforce, and for about 20 per cent of GDP.[25] The sector is particularly strong in food processing, textiles and carpets, light manufactures and automotive components, though individual companies operate across a broad set of sectors. Most are micro firms with less than 5 employees (table 3.3). Firms with more than 50 employees, despite their small number, account for more than half of total employment and for about 65 per cent of total value added (MIMT, 2016). Most large enterprises are industrial firms that are either public or State-owned.

Factors reported in UNCTAD's 2005 STIP Review as being detrimental to SMEs seem to persist, namely high costs for accessing capital, foreign currency shortages and a volatile macroeconomic environment. The Government has improved two areas, namely burdensome regulations and lack of professional business services, notably for high-tech companies. A sense of general discrimination against SMEs was likewise reported in that Review. This appears to be less pronounced today, possibly reflecting the declining dominance of the oil sector and the push for diversification, but probably also as a consequence of a greater general appreciation for entrepreneurship and enterprise development.[26]

Iran needs to create conditions whereby it can benefit from international flows of investment, technology and know-how. Despite the emphasis on research in universities and the extensive presence of major national industrial technology projects that bring together multiple stakeholders, large enterprises as well as networks of SMEs, industry, and the enterprise sector more generally, should pay more attention to private sector research and innovation.[27] Given the limited scope of the private sector generally and Iran's exposure to increased international competition as trade and investment pick up following the removal of international sanctions, improved access to technology and foreign markets needs to be matched by better business skills and a greater capacity to engage in genuine innovation.

3.1.7. Productivity and employment

Productivity statistics vary to a significant degree according to the source of data used. Official national data provide a relatively detailed breakdown of productivity by sector. Based on these data, productivity growth has been relatively low over the past 5 or 10 years, with total factor productivity (TFP) of 1.9 per cent over 2005-2014 and negative labour and capital productivity over that period (table 3.4). Labour productivity performs well, with the exception of O&G, for which it is negative. Capital productivity in contrast is generally negative with the exception of industrial sector. Productivity varied widely by sector.

Manufacturing shows relatively higher productivity growth, with positive labour, capital and TFP growth. The estimated annual productivity increase over the last decade according to UNESCO's 2015 science report however is 3.9 per cent, which is respectable, although lower than that of some major developing economies which achieved more than 5 per cent over the same period (UNESCO, 2015).

The Government's current target is for productivity increases to account for 35 per cent of annual GDP growth in 2016–2020. Annual growth rates of LP, KP and TFP are targeted to reach 3.9, 2.2 and 3.7 per cent, respectively, from the present to 2020. STI can play a vital role in promoting higher productivity as a whole and TFP in particular by raising efficiency.

Table 3.3. Number of firms, their size and employment

Size of firms by number of employees	Number of firms	Direct employment (000s)	Share in employment (per cent)
Small firms (up to 49)	81 000	1 470	44
Medium firms (50 to 99)	4 000	380	12
Large firms (more than 100)	3 000	1 520	44
Total	88 000	3 370	100

Source: MIMT (2016).

Iran needs to increase both productivity and job creation. Unemployment crept up from 11 per cent at the time of the 2005 STIP Review, peaking in 2010 at 14 per cent overall and 26 per cent for youth. Since then, the demographic situation saw an annual 2.3 per cent increase in the labour supply from 2005 to 2010. The rate of increase remained virtually the same through 2015, with an average annual increase of 2.4 per cent over 2012–2015 (MPO, 2016a). At the same time, effort was put in place to expand tertiary education and vocational training. Unemployment stood at 11.5 per cent in 2015, and at 18.8 per cent for women and 24 per cent for youth (those aged 15-29 years). In urban areas, the level of unemployment was 11.6 per cent, compared with 7 per cent in the rural areas (Central Bank, 2015).

Public and social services engage a large share of the overall workforce; agriculture employs 25 per cent of the work force, operates at a low productivity level and demonstrates low growth. Automobiles and auto parts, mining, trade and transport are major employers (as they were a decade ago).

The unemployment rate of educated people is almost twice the total unemployment rate,[28] indicating the need to create jobs in high- and medium-tech industries for a large pool of young talent. This is particularly critical in order to prevent the emigration of well-educated people and/or a decline in the number of science and engineering students in the coming years.

Iran has entered a period of relatively low population growth, although somewhat later than many developed countries, with the growth rate falling from about 1.62 per cent in 1996–2006 to only 1.29 per cent in 2006–2011. The average population growth rate over the past 15 years is estimated to have been 1.4 per cent.[29] This is resulting in an ageing society and a less rapidly growing workforce. In contrast to other countries in the Middle East, there are few immigrant workers. Outward migration, on the other hand, has

Table 3.4. Labour and capital productivity trends by main sectors, 2005–2014

Sector/Indicator		2005	2010	2014	Average annual growth rate, 2011-2014 (per cent)	Average annual growth rate, 2005-2014 (per cent)
Whole economy	Labour productivity (LP)	103	127	121	-1.22	1.94
	Capital productivity (KP)	101	99	88	-2.89	-1.43
	Total factor productivity (TFP)	102	111	100	-2.44	-0.22
Agriculture	Labour productivity (LP)	109	135	159	4.04	5.1
	Capital productivity (KP)	102	70	69	-0.41	-3.59
	Total factor productivity (TFP)	106	100	126	5.85	2.1
Oil and gas	Labour productivity (LP)	102	136	92	-9.20	-1.09
	Capital productivity (KP)	92	73	49	-9.24	-5.2
	Total factor productivity (TFP)	92	73	50	-9.30	-5.1
Industry	Labour productivity (LP)	107	156	144	-1.86	3.84
	Capital productivity (KP)	102	107	105	-0.45	0.33
	Total factor productivity (TFP)	104	126	118	-1.54	1.5
Services	Labour productivity (LP)	105	121	123	0.43	1.9
	Capital productivity (KP)	105	105	96	-2.18	-0.95
	Total factor productivity (TFP)	105	112	107	-1.18	0.21

Source: National Iranian Productivity Organization Database (in Persian) (at: http://www.nipo.gov.ir/Portal/View/Page.aspx?PageId=b9836f5b-fefb-43be-98fc-ee42441428a8) (accessed September 2016).
Note: The base year used is 2004.

been an issue for several decades: estimates show a little under one million people born in Iran presently working and living in other countries (OECD, 2015b), although informal sources estimate a much higher number. Many well-trained Iranians are successful professionals and entrepreneurs working mainly in the United States, Canada, Germany and Sweden (OECD, 2015). Some of them are already returning to contribute to Iranian development, and more could follow in the years ahead, similar to recent trends in China and India.

3.1.8. Attracting foreign direct investment (FDI)

It is essential for Iran to attract long-term FDI to leverage the presence of MNEs to foster domestic knowledge and skills development and local technological learning, and secondarily to increase domestic financing. During the period of sanctions, flows of FDI to Iran stagnated and declined, but did not collapse (table 3.5). It remained relatively low at 0.5 per cent of GDP in 2014, compared to 1.5 per cent of GDP in Turkey, 3.3 per cent in Malaysia, 3.1 per cent in Brazil and 2.6 per cent for all developing economies in 2014. They have remained concentrated in the O&G sector, while they were marginal or non-existent in pharmaceuticals. The primary sources also shifted away from developed countries in Europe and North America to countries in other regions. There are no completely accurate data on FDI for Iran, which makes it difficult to draw definite conclusions. Indications are that FDI became more defensive in terms of maintaining existing businesses, rather than oriented towards developing new leading-edge firms and industries. It appears to have been mainly of the resource- and market-seeking kind - motivated primarily by securing access to resouces and the local market - rather than export-oriented or seeking collaboration with local firms in engineering, design, R&D and innovation.

The low level of FDI inflows in Iran is partly due to policymakers wishing to promote the development of endogenous capabilities and pursuing a strategy of self-reliance. However, in 2002 a law was passed with the aim of increasing FDI inflows, not only as a source of financing but also as a means of accessing knowledge and technology. To this end, and also to increase trade, the Foreign Investment Law of 2002 established the Foreign Investment Services Center as a national investment promotion agency under the Ministry of Economic Affairs and Finance (MEAF). A large increase in trade and investment flows is expected in coming years.

There is also a potential benefit in taking advantage of special assets that are unique to the local context (von Hippel, 1994; Andersson, 2013). Iran offers rich investment opportunities associated with its abundant and partly undeveloped natural resources, its need for upgrading existing infrastructure and its highly competitive workforce, creative individuals and would-be entrepreneurs. It has a host of markets that are different from the rest of the world, and a vibrant community of young companies and start-ups linked with KBF networks.

However, the business environment, including accounting practices and intellectual property rights (IPRs), is viewed as a challenge to attracting greater FDI. There is considerable need for professional

Table 3.5. FDI inflows by sector, 2004–2014 ($ millions, share)

	$ millions				share (per cent)			
	2004	2010	2014	2004-2014	2004	2010	2014	2004-2014
Primary	2,708.2	2,786.6	1,516.9	22,935.3	83.8	76.2	71.9	69.0
Petroleum	2,702.5	2,781.7	1,491.5	22,680.6	83.7	76.1	70.7	68.2
Secondary	349.1	653.0	170.4	6,381.4	10.8	17.9	8.1	19.2
Manufacture of pharmaceuticals, medicinal chemicals and botanical products	1.2	-	-	3.7	0.04	0.00	0.00	0.01
Tertiary	172.5	215.1	422.1	3,929.5	5.3	5.9	20.0	11.8
Total	3,229.8	3,654.7	2,109.5	33,246.2	100	100	100	100

Source: UNCTAD, FDI/MNE database (at www.unctad.org/fdistatistics).

business services to boost the quality of investment management, including with regard to start-ups and NTBFs. Progress in these respects is critical for establishing a sound basis for long-term partnerships between domestic and foreign firms, which would help to stimulate flows of foreign knowledge, technology and skills. Policymakers in Iran are considering arrangements for attracting the sort of FDI that could bring benefits in terms of financing, local production and deeper collaborative linkages related to engineering and design, technology and innovation.

B. IRAN'S NATIONAL INNOVATION SYSTEM

3.2. Iran's STI policy: Historical background

Iran has a remarkable history of S&T, along with philosophy and literature. However, early progress in S&T was followed by a long period of scientific and technological inertia. In the eighteenth century, Iran took steps to send envoys to various European countries and engaged in exchange of knowledge and selective adoption of new practices for local knowledge development and use. These impulses contributed to laying the basis for Iran's *first industrial expansion* during the period 1910–1930 (table 3.6). Transport, energy and other *basic heavy industrie*s *and basic infrastructure* were developed, and industrial policies were put in place. This long pre-dated STI policy in Iran, which began in an organized fashion in the 1960s and became a priority in the 2000s. A system of intellectual property rights (IPRs) was introduced in 1925 for the protection of patents and trademarks. A first wave of "modern" science institutions was established, including the Iranian French Pasteur Institute, which became a mainstay of genetic and biotechnology research that is still active today. The national system of higher education developed dramatically from the late 1940s, and a focus on packaged technology transfers from abroad grew from the 1950s.

A *second industrial expansion* phase occurred in the 1960s and early 1970s, with industrial policy focusing on *industrialization through import substitution* which led to the rise of resource-based industries. With the rise in O&G revenues from the late 1960s, the country was able to establish capital-intensive industries as well. The active role of traditional merchants, who had long been considered the country's classic entrepreneurs as the early founders of industries, particularly from the late 1950s onwards, boosted the industrialization drive considerably. The industrial structure reflected the state of natural resources and other specific endowments among regions as a basis for development across the country, and was largely cluster-based. For instance, the steel industry was established in Isfahan, the machinery industry in Tabriz, automotive and aeronautics industries in Tehran, petrochemicals in Khuzestan Province, and food in Mashhad.

Iran's *third industrial expansion* phase started in the 1980s and 1990s, after the Islamic revolution and the war with Iraq. It again centred on the development of *heavy industries and infrastructure,* which had been either destroyed during the war or had become outdated. This coincided with a period of turbulence in the post-revolutionary environment and the huge negative effects of the war with Iraq in the 1980s.

A new era was ushered in with the end of the war and a shift in policy focus towards economic growth and development, renewed industrialization and building the national STI system through a series of FYDPs starting in 1990. So far, there have been five FYDPs. These have gradually given increasing priority to the development of strong STI capabilities and an effective innovation system in order to move from a natural-resource-based economy towards a more knowledge- and innovation-based one with greater medium- and high-technology production.

Of these, the third FYDP (2001–2005) was the first to contain a chapter devoted entirely to S&T. In parallel, the Vision 2025 document devised in 2005, announced policymakers' intention to shift the country's long-term direction from a resource-based to a knowledge-based economy. At the turn of the millennium, nanotechnology advanced impressively (see further below), with the establishment of a dedicated council in 2003.[30] It brought together key stakeholders to promote nanotechnology development with great success. This model has served as the basis for 12 other councils to be set up in various key technology domains. A revised, commercial IP system was introduced in 2005.

The fourth FYDP (2006–2010) devoted a full section to S&T, under the heading, "knowledge-based economy". In 2010 a law was enacted to support KBFs in innovation and commercialization and in collaborating with universities. The importance of attracting FDI to benefit from the transfer of technology from abroad was highlighted and remains a priority. Government programmes for liberalization, diversification and privatization were also introduced. The fifth FYDP (2011–2015) also had a section on S&T, while the plan in its entirety aimed at fostering the transition towards a knowledge-based economy. Table 3.6 presents the main features of each of the phases of industrialization discussed above.

STI policy development since the 1990s may be considered as evolving in three interrelated waves (table 3.7). The first wave focused on developing higher education starting in 1990; a second wave focused on developing research and technology (including emerging technologies and their required infrastructure) starting from 2000; and a third wave marked a transition towards an innovation and knowledge-based economy starting from 2010. These three waves have led to today's innovation system. It must be noted that to some extent, STI was already under consideration from the late 1960s, with a focus on industrialization and higher education. This continued during the 1970s and 1980s, with an added focus on research and higher education.

3.3. Institutional arrangements: Actors and governance

3.3.1. The rise of today's innovation system

The 2005 *STIP Review* noted the close interactions between government ministries, on the one hand, and research institutes, universities and large firms on the other. The relevant ministries prioritized certain areas for research projects for which they provided funding. Research institutes and universities, in turn, monitored technological developments and provided feedback to the ministries to facilitate decisions relating to research priorities. The Center for Innovation and Technology Cooperation (CITC),[31] under the Presidency, had links with universities through funding of research projects for commercialization by Iranian firms. A substantive link was also observed between research institutes/ universities and large firms, many of which lacked in-house R&D and thus relied on these institutes for product development and process innovation.

The Government, by virtue of its size and its ownership of almost all the research institutes and universities, as well as the vast majority of firms, nevertheless stood out as highly dominating and directly responsible for most of the innovation and technology development activities. With the exception of a few high-tech start-

Table 3.6. Three phases of industrialization and technology development in Iran, 1900–present

Main policy emphasis in each period	Significant steps taken
1900–1959 Focus on building modern infrastructure and stimulating industrialization, leading to growth of resource and labour-intensive industries	• Oil upstream (from 1910) – natural resources • Textile, clothing and leather (from 1920) – natural resources and employment • Pharmaceuticals (from 1920) - health • Military (from 1930) – security • Railway (from 1930) – infrastructure • Cement (from 1930) – infrastructure
1960–1989 Focus on industrialization through import substitution, which gave rise to resource- and capital-intensive industries	• Agri-food (from 1960) – health, food security, resources, employment • Steel (from 1965) – capital-intensive • Machinery and equipment (from 1970) – capital-intensive • Automotive and automotive parts (1970) – capital-intensive • Petrochemical (from 1970) – capital-intensive • Electronics and telecommunications (from 1970) – capital-intensive • Aviation industry (from 1970) – capital-intensive • Nuclear technology (from 1970) – capital-intensive
1990–present Focus on advanced technologies, innovation and export development, relying mainly on knowledge-intensive industries	• Aerospace (from 1990) • ICT (from 2000) • Nanotechnology and biotechnology (from 2000)

Source: UNCTAD.

Table 3.7. Three waves of Iran's STI policy since 1990

Wave	Main institutional developments	Main functional developments
Wave 1: Developing higher education and scientific publications (from 1990)	• Expansion of graduate programmes in universities; • Increase in the number of private universities; • Support to international research and scientific publications in universities and research organizations.	• Increase in number of graduate students, particularly from 2005; • Continuous increase in women's participation in higher education to reach the current position of near equality; • Growth in number of science and engineering students; • Considerable increase in scientific publications internationally.
Wave 2: Developing research and emerging technologies (from 2000)	• Establishment of VPST and its affiliated emerging technology councils • Establishment of Supreme Council for Science, Research and Technology (SCSRT); • Ratification of NMPSE; • Expansion of S&T parks, particularly close to universities; • Growth of centres of excellence; • Establishment of institutions for commercialization of university researchers' research results (e.g. IPRs, technology transfer offices (TTOs) etc).	• Improvement of Iran's status in scientific publications, particularly in areas of emerging technologies (e.g. nano- and biotechnologies); • Increase in number of S&T parks and firms located within them; • Increase in number of research laboratories in universities; • Increase in number of locally granted patents.
Wave 3: Transition towards innovation and a knowledge-based economy (from 2010)	• Ratification and implementation of law for supporting knowledge-based firms; • Establishment of Innovation and Prosperity Fund with initial capital of $1 billion; • Ratification of law for removing barriers to competitive production, with one provision (Article 43) dedicated to a programme for developing knowledge-based products; • Ratification of a technology appendix in international contracts; • Establishment of a dedicated stock market for IPR; • Ratification of a revised IPR law; • Establishment of accelerators for innovation.	• Increase in number of knowledge-based firms, located outside S&T parks and incubators close to universities, with 2,732 firms to date; • Increase in jobs created by knowledge-based firms to 42,000; • Increase in production of and revenue from knowledge-based products; • Increase in number of S&T funds, VCFs and private innovation accelerators.

Source: UNCTAD.

ups, the contribution of the private sector to innovation and technology development appeared limited. Foreign technology flows seemed directed towards large firms, while external knowledge flows were directed to research institutes. The public and private spheres were far apart, and high-tech SMEs received little or no direct impetus from the outside world. The SME sector as a whole seemed weakly linked to the innovation system in all respects.

At the time of the 2005 Review, the MSRT stood out as the main operational actor at the core of the innovation system. Newly restructured with a broader mandate based on the 2004 Parliament Law for Establishment of MSRT, the MSRT was closely associated with academia and thus heavily focused on the educational system and research. The MIMT, by contrast, was concerned with industrial activities, but paid limited attention to research and innovation. On this basis, the Iranian innovation policy at the time seemed to be a combination of a *traditional approach* (torn between research/academic and industrial objectives, but following a "science push" linear model that views innovation as emanating largely from scientific research, with an accordingly heavy S&T focus) and an *implicit* approach (innovation activities implemented by many different, partly independent bodies, without explicit coordination).

In the years since then, a number of steps have been taken to upgrade the institutional landscape so that it is better equipped to promote technological upgrading and innovation, and support development of a more effective NIS. These steps include, notably, the following:

- The rise of two complementary councils as major coordinators of S&T policy, the Supreme Council of the Cultural Revolution (SCCR) operating at the strategic level, and the SCSRT, which has a direct stake in implementation.
- Establishment of the VPST in 2007 and16 affiliated technology councils;

- Establishment of the IPF;
- Increased emphasis on STI by various government bodies, and more broadly by society, and approval of a set of new policies and regulations;
- A campaign and associated comprehensive activities to raise awareness, interest and engagement in nanotechnology research and applications, and the creation of special councils bringing together diverse stakeholders to promote those technologies as well as other technologies;
- Reinforcement of a range of other actors (including VCFs, research and technology funds, consultancy firms and accreditation bodies) that attempt to create synergies in STI;
- A rapid increase in the number and impact of scientific publications boosting Iran's ranking to 15th place globally in terms of scientific publications in 2015;[32]
- Ratification and wide acceptance of the NMPSE, and consideration of its full implementation by the Supreme Leader and the Government;
- Significant attention to STI in both the 4th and the 5th FYDPs;
- Release of two mainstream policy documents (national policies) placing strong emphasis on innovation (while advancing the importance of the "resilient economy" and "S&T" respectively);
- A significant strengthening of institutions channelling funding, and professional services support to KBFs; and
- Introduction of the requirement for public authorities to invest 1 per cent of their budgets in R&D.

Under international sanctions, there was a process of intensive consultations at multiple levels within the country. This led to widespread awareness and acceptance of the importance of innovation and of creating a more knowledge-based economy. The Government is also making a strong push to diffuse the benefits broadly among society, and make growth and development more inclusive. There are also efforts to reduce the degree of centralization by delegating greater authority for economic planning to the provincial level (see 3.5.6). Policymakers are seeking to engage more actively in international collaboration. High priority is being given to attracting foreign investors in order to access technologies, know-how and capital. In addition, a host of new contacts are being sought, although in a tempered, careful manner, between Iranian and foreign research institutes and universities.

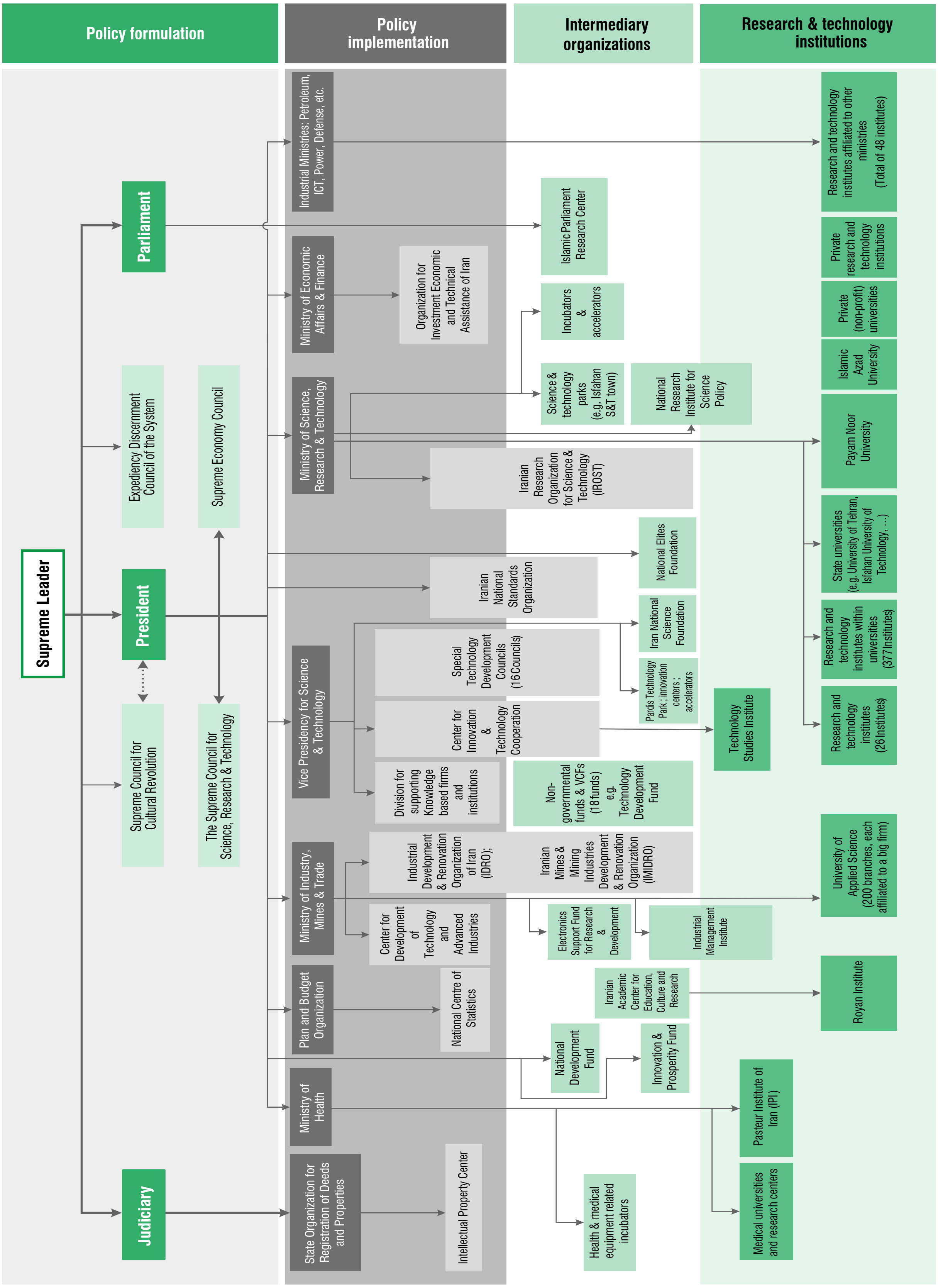
3.3.2. STI governance, policy design and implementation

Iran's innovation system is highly complex, with diverse actors operating at different levels and with varying degrees of horizontal and vertical linkages with different parts of the NIS (figure 3.4).

At the top are the high-level policymaking bodies, which decide on broad policy directions and oversee key framework conditions (figure 3.4). The Supreme Leader is at the apex, supervising the executive, legislative and judicial bodies, and pushing the whole system towards building improved STI capacity through technology development and commercialization. The President, elected directly by the public for a four-year period, leads the executive branch. Parliament, whose members are likewise elected for four years, has the main legislative role, while the head of the judiciary is appointed by the Supreme Leader.

Directly below, at the strategic policymaking level, two high-level councils translate the highest level policy direction into national goals and set priorities. First, the Supreme Council of the Cultural Revolution (SCCR), established in 1984, oversees the whole STI and higher education system at the policymaking level. Its main role with regard to STI is to approve the NMPSE and oversee its implementation. The President is its Chairman, and it includes the heads of the judiciary and parliament, the Vice-President for S&T, the Minister for Science, Research and Technology and several other ministers. The Expediency Discernment Council of the System (EDCS) is also an administrative assembly. It consults the Supreme Leader in preparing major national polices, such as Vision 2025, and national policies for S&T and the resilient economy. Secondly, the SCSRT was established by Parliament, in the new mandate for MSRT in 2004 during the second wave of STI policy. It plays a role in coordination among ministries, setting measures and regulations for the implementation of national STI policies. It is also headed by the President, and includes the MSRT and VPST along with several ministries, plus representatives of universities, scientific associations and two representatives from the business sector. Both the SCCR and SCSRT have their own secretariats. The SCCR is fairly small and independent, but brings together various strands of high-level decision-makers and expertise to coordinate top-level strategic positions. The SCSRT's secretariat is composed of specialized sub-committees that are responsible for

Figure 3.4. Institutional mapping of the NIS



implementing its decisions. These sub-committees consist of representatives from ministries, academia, industry and the main sectors, such as energy, education and agriculture. Both the SCCR and SCSRT conduct some strategic priority setting. While the former is more involved at the strategic level than the latter, there may be some overlap in their functions and responsibilities. The degree of overlap is not entirely evident, but is an issue that may need to be examined along with the limited degree of business representation in these councils.

The evolution of STI policy focus across the three waves of STI policy development since 1990 led to the establishment of different policy and executive bodies during each wave. These bodies were designed to meet the need to fulfil particular policy functions and objectives relating to the priorities established in each wave.

The MSRT has a mix of responsibilities, but its main focus is on education and research in S&T, leading to technology development, but it does not link directly with industry and production. A critical shift in thinking on STI is needed, which will make this link through a focus on innovation. There should be bodies which ensure that policies are designed and implemented to achieve this.

The VPST was established in 2007, during the third wave of STI policy, to oversee innovation policy. It thus fulfils an important horizontal mandate to engage all relevant parties in supporting innovation as part of its oversight of innovation policy. Various powerful line ministries are provided with extensive resources earmarked for research and innovation within their specific realms of responsibility. The VPST's role in the innovation system as coordinator of innovation policy is therefore of critical importance to help establish a "whole of government" (or government-wide) approach characterized by effective cross-ministry collaboration on innovation policy. As a Vice Presidency, it reports directly to the President, which should provide the influence needed to coordinate measures for greater consistency, and to ensure closer collaboration among the various actors throughout the NIS. The VPST is thus also expected to link the governance and operational levels of the innovation system. Today, it is actively engaged in implementing innovation policy programmes and in coordinating innovation activities, as well as the design of innovation policy instruments with a direct bearing on firms, business innovation and the economy.

The VPST has about 350 staff members in-house, plus consultants and experts based in other organizations but contracted by the VPST to look after various tasks. The VPST does not necessarily try to pursue all tasks in-house; rather, for many activities it relies on the organizations with which it collaborates. The main internal hierarchy of the VPST includes four Deputy Vice Presidencies responsible for: i) Resources and Development; ii) STI Policy and Evaluation; iii) Technology Development, and iv) International Affairs and Technological Exchange. In addition, it has two special operations, namely the Office of KBFs and Pardis Technology Park (PTP) located just outside the capital, Tehran. PTP, which is the only S&T Park placed under the VPST, is one of the biggest and most developed S&T parks in the country. It serves as a pioneer to support technology-based firms.

During the progression of the three waves, the dominant focus of STI policy shifted from higher education with small elements of technology and innovation (during the first wave) to a stronger focus on technology (in the second wave) and finally to an increased focus on innovation (in the third wave). The mandates of new policy bodies established in each wave were designed to address emerging areas of policy focus, but they retained minor elements of both previous and subsequent waves. In the current configuration, there exist several STI policy bodies (SCCR, SCSRT, MSRT and VPST) each of which focuses mainly on one of the three areas (higher education, technology and innovation), but still retain minor elements of the other two areas. This has led to the existence of bodies with some common elements within their respective mandates. Some local analysts argue that this overlap is not currently a serious issue. Policymakers should be aware of the overlap and should consider whether it requires more formal resolution through a clearer separation of mandates. In recent years, overlaps in their responsibilities have been partly resolved through informal agreements among them. This runs the risk that conditions may change and the overlaps could increase to the point of becoming problematic. This situation calls for a restructuring of the division of responsibilities and functions, as well as assigning new functions to an appropriate body for supporting innovation, such as a dynamic VC industry, the development of which should be overseen by a coordinating body.

The Planning and Budget Organization (PBO) (formerly the MPO) is the main body responsible for drafting the FYDPs and also for drafting and supervising plans for their implementation on an annual basis. It is also responsible for allocating budgetary funds, which are the major sources of finance for R&D. Allocations are made across a vast institutional landscape, including ministries, research institutes, universities and S&T parks, among others. The powerful Supreme Economy Council (SEC) has the overall responsibility for approving major economic projects, while the MEAF is in charge of tax policy, the stock market, foreign investment and other financial decisions, as well as for designing overall FDI policy. Monitoring government spending on R&D is mainly the responsibility of the SCSRT, however, which has considerable authority over research projects.

At the second level, a set of ministries and other government bodies oversees the operationalization of high-level policy directions and strategic priorities through sectoral policies and implementation programmes. Under the judiciary is the State Organization for Registration of Deeds and Properties (SORDP) and the Intellectual Property Centre (an IPR agency), which is an affiliated body and a specialized centre.

The MIMT has undergone considerable reorganization, entailing the adoption of new instruments to strengthen management processes in support of economic diversification away from a heavy dependence on O&G. It designs industrial policy measures aimed at cluster development, building supply chains, attracting inward FDI and building local linkages. In the industrial policy design process, the MIMT coordinates relatively well with other relevant actors, notably with the VPST, and is pushing for innovation to be included as an integral part of industrial policy. Its key policy goals include promoting technology transfer, strengthening SMEs, using public procurement in favour of industrial development and developing firm-level skills and competences (MIMT, 2015). The MIMT oversees the two largest developmental organizations in Iran: the Industrial Development and Renovation Organization of Iran (IDRO) and the Iranian Mines and Mining Industries Development and Renovation Organization (IMIDRO), which control a variety of large industrial firms. The MIMT's role in promoting innovation in mature industries is therefore more critical than that of other industrial ministries. Established in 1967, the IDRO's main mission is to help develop industries and accelerate the country's industrialization process as well as boost industrial exports. The Technology Development and High-Tech Industries Center (TDHTIC) is the main division of MIMT that supports mature firms in technology development, R&D and the diffusion of advanced technologies in medium- and low-tech industries. It is also engaged in developing industrial and applied post-doctoral courses, internships, and vocational education and training via 200 dedicated branches of the University of Applied Science. These all reflect the MIMT's major responsibilities for promoting innovation by large and mature firms in key traditional industries.

The Ministry of Health blends traditional capabilities with modern, state-of-the-art insights into the value of integrating research and education into clinical practice. However, the domains of medical science and health have weak connections with other parts of the innovation system. On a smaller scale, other line ministries similarly cultivate their own combinations of councils and support organizations.

3.3.3. Intermediary organizations, and research and technology institutions

With a cross-cutting mandate, the MRST has overall responsibility for the university system, and is directly responsible for most of the public institutions of higher education. It is also responsible for most S&T parks and incubators (with some exceptions, such as PTP), which are usually developed in close collaboration with universities in different provinces. A handful of universities are highly ranked internationally, particularly the University of Tehran (UoT), Sharif University of Technology (SUT), and Isfahan University of Technology (IUT). Many others do not feature on international rankings but nevertheless have a strong standing in their respective fields. Today, Iran has a total of 1,133 universities, of which 150 are full-fledged government universities, 1,101 are universities of applied S&T (specialized vocational universities, mostly run by firms), 58 are medical universities and 354 are non-profit private universities (MSRT, 2016b). Non-profit universities are less regulated than private ones, and receive no public funding. Islamic Azad University is the largest private university originally established to meet the need to provide educational services in many underserved communities; with 567 branches, it has a presence in almost every town.

The MSRT implements, monitors and evaluates results of the bodies under its responsibility that are engaged in tertiary education, academic research and technology development within universities and research and technology institutions. A total of 26 independent research organizations are under its supervision, as well as 356 research institutes in universities. Senior management of public research institutes and universities are appointed following consultative processes, based on competence. New issues facing the MSRT today include promoting better university-industry linkages, building the capacity to manage IPRs and foster innovation, and encouraging the development of so-called entrepreneurial universities.

In terms of organization, the Government is promoting a shift towards less rigid and more functional structures, which are more autonomous but also more accountable for results. A review of the governance model of the PTP and other S&T parks in Iran indicates they are genuinely mandated to promote outputs by way of innovation, commercialization, start-up performances and the growth rate of tenant firms. Their management is reportedly appointed with due consideration to competence to handle these key performance indicators, and is evaluated on the basis of progress in meeting them.

In the past, there was a strict order of preference by the best-performing students for universities and subject areas for study, the highest preference being for engineering and technology at public universities. Public funding is under pressure, however, and universities are encouraged to specialize and engage in development-oriented and experimental activities. Meanwhile, the MSRT and other custodians of Iranian universities are shifting from a reliance on standard, traditional frameworks that focus purely on academic credentials and outputs, towards promoting innovative and entrepreneurial initiatives. Diverse indicators are used to track the results. Meanwhile, the percentage of Iranians with a PhD degree working in the business sector is on the rise, and many more private companies report undertaking R&D activity compared to a few years ago (UNESCO, 2015).

A special category is that of policy research institutes, including the National Research Institute for Science Policy (NRISP) and the Islamic Parliament Research Center (IPRC). The IPRC analyses specific issues for the purpose of assisting parliamentary committees in interpreting and analysing policy bills.[33] While quite small, the IPRC is effective in networking and coordinating with key actors, including the SCCR, SCSRT and the VPST. It engages proactively in identifying areas in need of reform and in the preparation of actual reform measures. In this respect, it is similar to what may normally be found within government ministries in other countries, rather than within parliamentary bodies. As it is not involved in ordinary executive operations in the way ministries typically are, the IPRC is able to combine think-tank capabilities of high policy relevance with the legal competence required for preparing new legislation.[34]

As previously noted, the private sector is relatively small in Iran given the predominance of SOEs in the economy. Private firms draw heavily on government support for R&D, much of it for adopting new technologies. Most firms, however, pay limited attention to innovation, and even less to university-industry linkages as a means to benefiting from research in academia, or to influencing the direction of higher education institutions. This applies also to bodies representing or linking private sector actors (e.g. the Iranian Chamber of Commerce and its regional bodies). The private sector meanwhile benefits from Iran's capable workforce, and is strongly seeking to gain access to capital, foreign technologies and market information in order to raise productivity and access local and foreign markets. Although the number of firms that invest in and undertake R&D has increased markedly over the past few years, the private sector as a whole is not greatly concerned with or motivated by innovation or collaboration with universities. Collaborative R&D is relatively uncommon, as noted in chapter 2 (see figure 2.16).

The establishment of the Industrial Management Institute (IMI) in 1961, has been a major step in efforts to develop management capacity. IMI's main aim has been to develop management capacity within Iran's industrial and services sectors. It offers integrated services in management, such as consulting, education and training, and research.

In addition, the State Organisation for Registration of Deeds and Properties (SORDP), the Institute of Standards and Industrial Research of Iran (ISIRI), and technology councils represent other important intermediary (or boundary-spanning) organizations. Iran gives strong emphasis to standards as an instrument to facilitate coordination and collaboration between diverse technical and industrial interests, and induces them to meet certain criteria, standards and measurement practices that have been adopted in other parts of the world. Its effectiveness in this regard influences the degree to which quality and reliability can be achieved across various industries. As is further discussed below, the IPR agency and the tax authority, along with the judicial system and associated mechanisms for dispute resolution, are also important in this context. Regional and local authorities are also of relevance, as are social networks representing local communities or special interest groups that engage in the pursuit of social innovations.

In the next section, specific policy tools and measures are reviewed, followed by conclusions and recommendations concerning the innovation system.

3.4. Main national policies relating to STI

The governance model for the innovation system draws on policy documents that set out additional directions, including for specific domains. These include the 2005 document, *Vision 2025,* drafted by the EDCS, the 2011 NMPSE (also commonly called the *Comprehensive Scientific Road Map*), and other important policy documents listed in table 3.8. Together, these serve to guide the national STI policy agenda, with stipulated objectives, milestones and processes for implementation.

With the NMPSE of 2011, Iran selected ambitious targets for 2025, including reaching expenditures on education of 7 per cent of GDP, as well as achieving a number of other specified targets. Its major targets to be reached include: 800 per million scientific publications, 3,000 per million full time equivalent (FTE) researchers, 10,000 and 50,000 nationally and internationally granted patents, the GERD to GDP ratio to reach 4 per cent, and half of all R&D to be performed by the business sector.

Two recent national policies – for S&T and for a resilient economy – were promulgated by the Supreme Leader, Ayatollah Khamenei, in 2014, reflecting a high level of support for STI development (see box 3.1).

3.4.1. National Policy for a resilient economy: Technology and innovation as a key enabler of economic growth

The National Policy for a Resilient Economy promulgated by the Supreme Leader in February 2014 have influenced many major decisions and regulations since their passage. They aim to encourage the development of indigenous capabilities through the adoption of a more outward-oriented development policy approach that improves indigenous technological development, raises local value added, and increases knowledge-based production and exports.

The following are some of the main goals of the resilient economy:

- Providing conditions and harnessing all facilities and financial resources as well as scientific and human capital to develop entrepreneurship;
- Creating a predominantly knowledge-based economy, implementing the NMPSE, and improving the NIS to increase production and the proportion of knowledge-based products and their export;

Table 3.8. Key policy documents of Iran relating to STI

Policy measures/documents	Year approved
Removing Production Barriers Act	2015
Amendments to Government Financial Regulations Act	2015
National Policy for S&T	2014
National Policy for a Resilient Economy	2014
Act of Maximum Use of Production and Services to Satisfy the Country's Needs and Enhance them in Exports	2012
National Master Plan for Science and Education (NMPSE) (Iran Comprehensive Scientific Road Map)	2011
FYDPs (containing STI-related articles)	Fifth FYDP approved in 2010
Supporting Knowledge-based Firms Law	2010
Act on Patents, Industrial Designs and Commercial Signs	2006
Vision Document (2025): 20-year vision plan	2005
Law for the Establishment of MSRT	2004
Foreign Investment Promotion and Protection Act	2002

Box 3.1. National Policy for S&T promulgated in 2014

For the first time in Iran's history, the Supreme Leader declared a National Policy for S&T in September 2014. Although each recent FYDP has included a chapter on S&T, it has been only temporary (covering five years) and narrow in scope. Key related articles regarding technology development and commercialization in this policy include:

1. Continuous scientific drive to achieve authority in S&T with an emphasis on:
    a. Science production and innovation development;
    b. Promoting the global position of Iran in S&T and making Iran the S&T hub among Islamic countries;
    c. Developing basic sciences and fundamental research;
    d. Transformation and development of the humanities and social sciences;
    e. Achieving advanced S&T through coherent planning and policymaking.
2. Optimizing the performance and structure of the education and research system to meet Vision 2025 goals and attain scientific progress through:
    a. Knowledge and research management, coherence in policymaking, and planning and strategic monitoring in S&T, both regionally and globally;
    b. Improving the university student admission system, paying particular attention to talent and increasing the proportion of students at graduate level;
    c. Organizing and promoting monitoring, accreditation and ranking systems of S&T;
    d. Organizing the national statistical and scientific information system;
    e. Supporting the establishment and development of S&T parks and towns;
    f. Increasing the share of the R&D budget to at least 4 per cent of GDP by 2025.
3. Reinforcing national determination and social perception of S&T importance by:
    a. Promoting a knowledge-based entrepreneurial culture;
    b. Raising the status and well-being of professors, researchers and graduate students.
4. Transforming the linkages between higher education, research and technology, and other sectors of economy:
    a. Increasing the share of S&T in the national economy and national income;
    b. Increasing the share of advanced domestic knowledge and technology-based goods and services in GDP;
    c. Prioritizing education and research according to advantages, capacities and demands of the country and the goal of becoming the top S&T country in the region;
    d. Supporting IPR and implementing the needed infrastructural and legal requirements;
    e. Reinforcing the role of the private sector in S&T;
    f. Developing and promoting national and international collaboration among universities, scientific centres, scientists and researchers, and local and foreign firms.
5. Expanding constructive collaboration in S&T with other countries and regional and global scientific and technological centres by:
    a. Developing industries and services, based on advanced S&T, and supporting their production and exports, especially in advantageous fields, with due consideration to legal requirements;
    b. Committing to technology transfer and acquiring know-how for domestic manufacturing, by leveraging large country markets;
    c. Using the scientific and technological capacities of the Iranian diaspora, and attracting prominent foreign experts and researchers;
    d. Transforming Iran into a hub for scientific publications, and applying results of regional and international researchers, experts and innovators.

- Enhancing the financial system of the country to support important areas of the national economy, such as S&T;
- Increasing exports of goods and services and value added;
- Developing economic free zones in order to foster advanced technologies; and
- Expanding the discourse on the Resilient Economy, particularly in scientific, educational and media circles, to make it inclusive and promote national dialogue.

In order to implement this policy and attain its goals, the Government established a special secretariat for the implementation of the Resilient Economy Policy in mid-2015. Before that, in mid-2014, the SEC had already been selected as the main body for approving Resilient Economy plans and projects.

In order to implement these national policies, the secretariat approved 12 national plans, 10 of which are relevant for STI based on the national priorities:

- Promoting productivity;
- Promoting diversification of the economy (development of non-O&G exports);
- Enhancing national production capabilities;
- Financial regulation of the public sector and reducing the budget's dependence on oil revenues;
- Developing the knowledge-based economy (KBE);
- Culture and discourse on the Resilient Economy;
- Economic transparency;
- Developing O&G production and completing downstream and market formation;
- Organizing subsides; and
- Highlighting the role of the private sector in the economy.

For each plan, a chair has been assigned and projects defined, with a ministry or independent organization responsible for implementation. Transition to KBE is a collective effort that requires the engagement of different bodies, particularly the MIMT and MSRT. The VPST, as the main body for overseeing the transition to a KBE, is in charge of two important projects, which have been broken down into two action plans as follows:

1. Developing technological interactions with the world economy and exports of knowledge-based goods and services by means of the following:
    a. Reaching 3,000 supported KBFs through the facilities provided under the Knowledge-Based Firms Law;
    b. Designing and implementing pro-market policies to promote the development of the knowledge-based ecosystem in selected sectors (e.g. aerospace, bio- and nanotechnologies, ICT, the environment and O&G) with the help of local content requirements and a "technology annex" to certain contracts (see below);
    c. Creating and promoting development of markets, and using KBFs' capacities to provide at least 15 per cent of required local material and equipment; and
    d. Promoting the development of financing mechanisms (e.g. VCFs and collateral) and insurance for knowledge-based production;
2. Strengthening the manufacture of innovative products by:
    a. Developing infrastructures for exports of knowledge-based products; and
    b. Designing a holistic system for technology transfer and an implementation plan.

3.5. Thematic and sectoral STI policies

This section reviews selected policies and programmes at the core of the innovation system, which have recently been pursued and/or are under further development in Iran, covering the issues addressed, what has been achieved, the challenges moving forward and the broader implications.

3.5.1. Financing R&D and innovation

The Government is the main source of funding for R&D and innovation. This is common in developing countries, and in Iran it may have been aggravated by financial constraints due to international sanctions. Within the Government, the PBO, which has the status of a Vice Presidency, has the main responsibility for resource allocation. Although such allocations have covered the R&D and other costs of universities and research institutes so far, this is changing. As a result of ongoing changes to the structure of funding, the university system is losing much of its core government funding and is being forced to seek alternative funding sources. Meanwhile, special financial instruments have been created, notably the IPF, to support innovation, including KBFs (discussed below). The number of S&T parks and incubators has also increased, implying direct fiscal expenditures as well as indirect ones in the form of fiscal incentives provided to them. With regard to R&D funding, the PBO controls spending for the education and training system, as well as for bodies with an industrial and economic focus. Other funding institutions include the Iran National Science Foundation (INSF), the IPF, and private banks or VCFs that have begun to design innovation financing instruments. The NSF supports academic S&T, while the IPF finances innovation through its mandate on supporting KBFs. In addition to supporting KBFs generally, there are some specialized funds that support specific industries, such as the Electronics Support Fund for Research & Development (ESFRD) under the MIMT.

The venture capital (VC) industry is still young, but dynamic and well networked. The first fund with a VC function was established 28 years ago. Today, Iran has 18 non-governmental research and technology funds. With the third FYDP in 2000, the Government has been tasked to aid the establishment and reinforcement of these funds. This task has become a permanent one. The Iranian Venture Capital Association (IVCA), hosted by the Iranian Technology Development Fund (ITDF), coordinates joint activities, arranges for the orderly sharing of information and serves as a node for linking with international organizations or prospective investors in other countries. The total volume of granted facilities for the funds that are members of IVCA amounted to about $340,000 up to 2013. The main beneficiaries of VC financing were biotechnology (15 per cent of the total), biomedical engineering and advanced drugs (14 per cent), nanotechnology (13 per cent), interdisciplinary research (10 per cent), and purchase of laboratory equipment (9 per cent).

In order to fulfil its objectives of increasing R&D significantly in the coming decade, Iran needs to diversify the sources of funding and reduce the dependence on public sector R&D activity. The only viable option is to raise the level of private sector investment in R&D and innovation. This poses a fundamental financial problem: the lower market rate of returns on R&D compared to its social returns. This widely recognized market failure leads to private sector underinvestment in R&D. Likewise, financing innovation, which is subject to uncertainty, is also a fundamental challenge in Iran, as in all countries. At the same time, cross-country studies have documented the complementarity between public and private research efforts (Guellec and van Pottelsberghe de la Potterie, 2001), implying the need for policymakers to achieve complementarity in public and private R&D spending.

Despite the introduction of new instruments by private firms to support R&D, there does not appear to be a close link between public and private sector R&D so far, and business expenditure on R&D (BERD) estimated at 20 per cent in 2010) remains relatively low. To achieve a high national rate of R&D investment – even 2 per cent of GDP – private investment in R&D, particularly by large established industries, such as those in O&G and the energy sector, will need to increase substantially. Experience from other countries, such as Chile, suggests that capital-intensive industries can play a role in increasing national R&D, but this requires public intervention through government programmes. Since 2014, the Iranian Government requires all public sector institutions to allocate 1 per cent of their annual budgets to research and technology development.[35] If the R&D allocation in the Government's 2016 annual budget is fully allocated, GERD will rise from around 0.5 per cent to 0.86 per cent of GDP in 2016, which would be the highest ever level of R&D spending until now. In addition, the MIMT provides incentives to mature firms to undertake R&D, such as granting a 10 per cent tax exemption to firms collaborating with universities on R&D, and a 10 per cent discount on mine exploration rights if there is collaborative research with universities. Iran has other potential financing sources at its disposal, including in the extensive semi-public sector, which controls significant financial assets and works towards achieving a blend of economic and social objectives, while also representing a powerful vested interest in the economy. Clearly, innovation goes beyond R&D, and therefore a sole focus on R&D represents an outdated and insufficient linear approach. Nevertheless, the R&D system and R&D spending remain critical elements of innovation policy, and are central to boosting technological upgrading and innovation performance.

3.5.2. Supporting knowledge-based firms

The Law Supporting Knowledge-based Firms, administered by the VPST, commenced implementation in 2010. This scheme also established the IPF in 2011 to channel funding to eligible firms, with an initial capital of around $300 million. After achieving full capitalization, the Government is to allocate 0.5 per cent of its annual budget each year as a grant to the fund (Iran Parliament, 2010). A committee chaired by the VPST, with the participation of the MSRT, MOH, MIMT, IPF and the Ministry of Defence, ensures approval and implementation of new legal regulations.

The law provides targeted support to firms defined as knowledge-based, and only private and/or cooperative, that aim to build synergies between science and economic outcomes via high-tech activities with high value-added products. The following are the main forms of support: exemptions from taxes, duties and export duties for 15 years; access to low-interest, long-term or short-term loans to cover all or part of production costs, supply or utilization of innovation and technology; allocation of high priority to determine eligibility for location in S&T parks, incubators and S&T districts; facilitation in government tenders and procurement; high priority on giving KBFs the right to buy shares of public research institutions that are being privatized; and provision of insurance to reduce risks associated with innovative and technological products in all stages of production, supply and use. KBFs are also authorized to be located in urban areas even though, since 1967, the establishment of industrial firms in urban areas has been banned. In all, the law offers 51 different schemes and incentives, of which 21 aim to promote exports of knowledge-based products.

KBFs are divided into three categories: type I (start-ups up to 3 years old involving product development in at least the pilot or laboratory stage); type II (usually SMEs with at least a 50 per cent share of knowledge-based goods and services in total revenue); and type III (firms, usually large ones that earn at least 10 per cent of revenues from knowledge-based products, or are active either in manufacturing knowledge-based equipment or using knowledge-based equipment for manufacturing). The only difference between KBF types I, II and III is that the type III KBFs cannot apply for tax exemptions. By October 2016, a total of 2,732 KBFs (1,648 type I, 840 type II and 244 type III), with a combined total of more than 70,000 employees, had been accepted for support through this scheme. Total revenues of these firms amounted to about $6.6 billion and are increasing. The plan is to reach 3,000 KBFs by March 2017.[36] In 2015, total tax exemptions for KBFs amounted to $66.6 million, up from $20 million in 2014. As of November 2016, about 200 KBFs had women chief executive officers, and around 700 had women on their boards of directors.

Knowledge-based products are goods and services that are complex, require in-house R&D and skilled employees to produce, are difficult to imitate by competitors, create considerable value-added, are differentiated from other similar products, and must be sold in the market or be at least in the pilot stage of production (services must already have brought in revenues) to be eligible for support. For knowledge-based products, a comprehensive index has been devised and is being updated. It comprises a range of technologies and applications, including their application in prioritized mature industries. In order to be eligible for the incentives provided by the Law supporting KBFs, they must be involved in any of 14 key priority areas: bio- and nano-technologies advanced materials, software, medicine, renewable energies, O&G equipment, cognitive sciences, medical equipment, and technologies addressing climate change, water, soil and erosion (table 3.9).

This program appears to be well designed and is promising, having led to the creation of many NTBFs,

Table 3.9. Number of firms benefiting from the Law Supporting KBFs, by activity, October 2016

	Number of KBFs	Percentage
ICT	476	20.1
Electronics and communication	368	15.5
Laboratory and manufacturing equipment	289	12.2
Biotechnology[a]	261	11.0
Advanced materials	163	6.9
Oil & Gas	161	6.8
Medicine	162	6.8
Medical equipment	130	5.5
Aerospace	119	5.0
Nanotechnology	75	3.2
Renewable energies	64	2.7
Optics and photonics	54	2.3
Commercialization service providers	9	0.4
Other areas	401	16.9
Total	**2732**	**100**

Source: VPST, 2016.
Note: [a] Includes only KBFs in biotech products.

but it remains at the early stage of implementation and its impact is not yet evident. It is nevertheless important to be aware of the risks entailed in this kind of programme. They include: (i) potential distortion in firm behaviour, such as changing their investments, recruitment or location simply to become eligible for support, even though they provide low commercial or social benefits; (ii) the amount of management time expended to become eligible at the expense of running the firm; and (iii) the possible neglect of other mechanisms for financing and business growth. It will be important to measure, monitor and evaluate its performance over time using suitable indicators.

3.5.3. Policies and plans in new growth areas

The Iranian programme for developing new growth areas supports specific technologies and the rise of networks or cluster-like sets of activities that create synergies and foster business growth and innovation, taking advantage of progress in new technologies for spurring innovation and enterprise development. It is a targeted approach to industrial policies by choosing activities that appear to be successful, or have a good chance of success, and involve new types of production.

As one element in the goal to diversify the economy and transition to a knowledge-based economy, the Government formulated a special scheme to develop knowledge-based production in different sectors based on Article 43 of the law Removing Obstacles to Competitive Manufacturing and Improving the National Financial System, which was approved in May 2015. Implementation of its plan, developed by the VPST, began in 2016 (see box 3.2). The VPST heads the programme and works in close collaboration with several line ministries, including the Ministry of Agriculture, the MIMT (as the chair of the law implementation committee), the Ministry of Power, the Ministry of Health and the Ministry of ICT. It aims at stimulating demand for knowledge-based production, and provides facilities tailored to the specifics of each priority area.

The most important new growth area is a special programme focusing on the development of nanotechnologies. The push for development of these technologies in Iran has been a tremendously successful experiment with an interesting history. Allegedly, an Iranian researcher abroad brought to the attention of the political leadership that nanotechnology was becoming a general-purpose technology with the potential to bring transformational opportunities. In 2002, the Government initiated a process of internal consultations, which led to the establishment of a committee with a mandate to communicate, raise interest, inspire and catalyse useful development strategies for this technology. There was a resounding response from the research community and from schools and students across the country. Over a few years, substantial resources and administrative support were provided, and the programme developed a host of well-organized activities and events that brought people together and propelled interest in science more generally and nanotechnology in particular. In parallel, several universities established research departments and training activities. Scientific publications started to appear and quickly grew in number. While engineering, followed by chemistry, medicine and physics, are the four disciplines in which Iran has the largest number of articles published in international scientific journals, nano-science, although a new area in Iran, has become the field where Iranian researchers are today the most successful. Iran now ranks 7th in the world in scientific publications relating to nanotechnology (UNESCO, 2014). This rapid advance to such a strong position is a noteworthy achievement, particularly considering the dominance of only a few locations globally in nanotechnology.

This "nano experiment" owed its success to the way it was implemented, starting with the formation of a council, backed by a small and nimble secretariat, which was able to involve a range of key stakeholders in consultative meetings and operational activities. A board of trustees was established, with ministerial representation from health, agriculture, energy, industry and trade and other important areas. Various activities were undertaken, for example in universities, with the participation of professors and students, and in high schools to inspire students. Unconventional methods were designed, such as the establishment of an "NT club". Students produced their own magazines and websites, which featured debates and comments among students and teachers. Virtual electronic teaching (online), nanotechnology exhibitions and imaginative ways of teaching students the subject in a simple way were used. Teachers were also given special training and specially prepared materials for use in physics and chemistry classes. Altogether, the scheme has trained more than 460,000 high school students in nanotechnology and established 49 nanotechnology laboratories for students (one in

Box 3.2. Development plan for knowledge-based products (Article No. 43 of the law for removing barriers to competitive production and improving the national financial system)

The realization of the KBE, with a focus on the production and export of knowledge-intensive products is one of the country's priorities. Article 2 of the Resilient Economy Policy states that creating a KBE is the main goal of these policies. It also emphasizes the necessity of improving production and export of knowledge-based products in the macroeconomic policies of the forthcoming 6th FYDP. The Government has committed to:

- Strengthening the KBFs in order to achieve a resilient and knowledge-based economy;
- Organizing the market and creating demand for knowledge based goods and services; and
- Fostering and institutionalizing an innovation and entrepreneurship eco-system based on S&T, and creating a culture of innovation and entrepreneurship.

This plan is complementary to the law for supporting KBFs. Article 43 of this law targets the removal of barriers to competitive production and is particularly relevant for supporting the expansion of knowledge-based products and their share in the domestic market, stimulating demand and promoting their export. The most important measures for achieving the goals of this plan include:

- Leveraging trade policy and stimulating demand for knowledge-based products;
- Organizing and promoting standards and accreditation systems for knowledge-based products;
- Designing and implementing technological and industrial policies concerning knowledge-based products;
- Clarification and implementation of a comprehensive statistical system for knowledge-based products; and
- Establishing appropriate monetary and financial institutions to support knowledge-based production.

The following are the visions, time horizons and areas of national priority:

a) The highest priority areas of the NMPSE in technology include aerospace, ICT, nuclear, nano- and micro-technologies, O&G technologies, biotechnology, environmental technology, and soft and cultural technologies.

b) National economic and social priorities to be addressed using these technologies include:
   1. Optimizing energy and water consumption;
   2. Reducing fossil fuel use and developing renewable energy;
   3. Improving food security and the healthiness of foods;
   4. Promoting provision of health care, drugs and medical equipment;
   5. Overcoming the problems of water shortage and drought;
   6. Controlling environmental waste and pollution; and
   7. Improving transportation, managing traffic and reducing accidents.

c) Supporting segments of the value chain with high knowledge value added within different sectors.

each geographical region).[37] There is also a "Nano Olympiad" – a national competition in nanotechnology for students.[38] Future plans include extending the scheme to encompass all regions and students in Iran, and to establish collaboration with nanotechnology teaching programmes in other countries.

The technology council concept was gradually adopted as a model for fuelling interest in other emerging technologies, including in biotechnology, even though it has been an established science in Iran for about a century, under the aegis of the Iranian Pasteur Institute. Today, similar councils, backed by secretariats, operate for 16 technology fields. They include, inter alia, water, drought and erosion, renewable energy, optical sciences, advanced materials, ICT, aerospace and aviation, and O&G.[39] Some of these are more active than others, and their degree of success in bringing together key actors in the innovation system varies. Factors that determine the degree of success are evaluated systematically, but it seems that these evaluations have not focused adequately on all the relevant impacts. For instance, economic outcomes, including the development of new goods, services and processes (three types of innovation) have received less attention. It would be important to design and implement a comprehensive evaluation system for the technology councils to assess their scientific and economic achievements.

The nanotechnology council model has become popular not only because of its success, but also because the model is flexible, has managed to attract key players from the start, while also attracting a diverse set of other actors as well. For each area, it is important to work out the key means for achieving such inclusion, and to manage an effective bridging between research and innovation. At the same time, the success of this model, and its subsequent adaptation to other areas, must not prevent the development of other approaches to stimulate innovation. A gathering of stakeholders may not be an effective or desirable tool in all areas. Processes leading to success in innovation can take entirely different shapes, and the policy framework should allow for this.

A potential issue in Iran is the strong policy emphasis on technology as a driver of innovation, without adequate attention to softer skills and knowledge. In practice, a successful shift from S&T to innovation requires space for active input from complementary competencies, such as entrepreneurship, management and marketing, which facilitate commercialization and access to markets and provide value for customers.

3.5.4. Local content and technology transfer policies

The Technology Annex and the Maximum Utilization of Local Capabilities (MULC) Law are two policy measures aimed at increasing local content in Iran (box 3.3). The latter was originally enacted in 1996 and revised in 2012. The former, which was approved in September 2016 after nearly two years of discussion, parallels efforts to aid the development of knowledge-based products. It applies to those international contracts (including, inter alia, inward foreign investment and technology licensing) to which the Government is a party or for which the Government is providing support for building domestic firm-level STI capabilities. Its main purpose is to ensure that contracts, including purchase of technologies, are accompanied by collaboration with the foreign firm(s) to contribute to local learning and promote other spillovers.

The Technology Annex seeks to leverage international contracts to foster STI capacity-building and is aligned with - indeed complementary to - the MULC Law. The Law aims at enhancing local firms' capabilities in terms of R&D, design and engineering, to be stipulated in international infrastructure and industrial contracts. The general regulations and requirements in each contract are similar to the Technology Annex. The MULC Law requires at least a 51 per cent share of inputs by local parties in international contracts, with respect not only to raw materials and construction, but also to technology and skills. Effective industrial development will depend on how industrial policy is designed and implemented, keeping in mind the need to ensure sufficient transparency to avoid capture of policymakers by vested interests.

Box 3.3. Technology Annex: A new programme to promote technological collaboration and learning in international contracts

In September 2016, the SEC approved the framework and its requirements, spearheaded mainly by the VPST. Promulgated as a new regulation in October 2016 to promote technological collaboration and learning, its objectives include:

- Assigning responsibility for the implementation of key parts of a contract to local parties and for joint ventures between local and foreign partners;
- Maximum utilization of local experts in implementing the contracts;
- Fostering technology transfer to domestic firms;
- Maximum procurement of goods and services from local suppliers;
- Ensuring a high level of learning, collaboration and joint R&D in order to develop the local capabilities needed at least for maintenance and repairs;
- Developing collaboration on entrepreneurial activities with foreign counterparts;
- Creating export-oriented partnerships between Iranian and foreign firms to allow Iranian firms to enter global value chains (GVCs) dominated by MNEs; and
- Promoting collaborative R&D with science and research centres and local KBFs.

3.5.5. Intellectual property rights (IPRs)

The first step towards industrial development in Iran involved the establishment of a trademark office in 1925, with a focus on the registration and protection of trade. The Act on Trademarks and Patents for Protection of Industrial Rights was introduced in 1931. And in 1951, Iran signed up to the Paris Convention for the Protection of Industrial Property, but there was no major upgrade of industrial property rights until a decade ago.

The present framework is based on the Patents, Industrial Designs and Commercial Signs Act, 2006 (which entered into force in 2007), which required a structured evaluation of the content of patent applications. Until now, patent protection has covered only products, not processes. Since early 1925, the judiciary had been directly responsible for IPR administration and enforcement. Now, there is an Intellectual Property Agency (IPA), placed under the judiciary, which is responsible for the administration and enforcement of the patent law. The original intention was for the new IP law to be enacted for five years, and then to be revised. In practice, the law has been extended for one year at a time since 2012, and most recently for two years.

As for other recent developments in IPR, the Electronic Commerce Law of 2003 introduced three articles covering issues such as domain names and some aspects of rights on the Internet (others being handled by the Ministry of Information Technology). Adoption of all standards and conventions of the World Intellectual Property Organization (WIPO) followed in 2009. In 2010–2012, the IPA introduced electronic tools to support firms and individuals with user-friendly procedures for online applications, filing and registration. Today, all procedures are fully operational electronically, including payments.

The IPA was partly restructured in 2013, when it gained more autonomy and was renamed the Intellectual Property Centre (IPC) headed by a Secretary General and five deputy directors. Three of the latter are responsible for patents, trademarks and industrial design registration, respectively. Two other deputies are responsible for awareness-raising and administration. An important objective for the IPC is to enhance the commercialization of patents in Iran, which it does through a broad range of activities, including building general awareness. It has arranged nearly 100 seminars for knowledge diffusion, and supports the generation of IP through communications with and visits to various research institutions. It collaborates with Tehran University in organizing a master's degree programme in IPRs, and recently commenced establishment of a training institute in collaboration with WIPO. The legal infrastructure has been put in place and upgraded with a view to the adoption of international best practices, and is generally considered to be of high quality. The IPC's operations and processes for law enforcement are reportedly TRIPS-compliant. From October 2013, Iran became bound by Chapter II of the Patent Cooperation Treaty (PCT), in addition to being a signatory to the Madrid Agreement (Concerning the International Registration of Marks) since December 2003.

The examination process that followed the introduction of the new law was, however, of an ad hoc nature. A major issue is the IPC's lack of in-house capabilities to analyse and assess the content of patent applications. For this reason, it relies on outsourcing of the evaluation process to available experts, generally based in universities or S&T parks, or to the councils responsible for different technology areas. On this basis, the patent system tilts towards an academic, rather than a professional, review of patent applications. During discussions, some stakeholders expressed serious concerns about the quality of the patent examination system, and indicated the need to develop a cadre of professional patent examiners. The reliability and predictability of courts' decisions is also a cause for concern. Thus, providing appropriate training to judges is an important issue.

Further, as the IPC operates under the judiciary, it is separate from the Government. This is unusual, as only a few countries in the world currently adopt this approach. Some analysts suggest it should relocate to the executive branch of government, which is much more commonplace. Efforts made so far to train judges in IP issues should be continued, including explaining to them the role of IP in innovation policy and development. Today, litigation processes are reportedly lengthy and unpredictable, although they have apparently improved in recent years. The most important issue for the IPR system is probably the lack of an effective IPR support structure, including the capacity to cope with the challenges of managing IP, its commercialization, and its role in fostering innovation and establishing successful businesses that have a positive economic impact. Whether it would be more effective and more appropriate in the executive branch is perhaps worth investigating, but the location of the IPC is perhaps of secondary importance compared to the other, more pressing issues. It will be important to consider the most effective form of administration of the patent office in the future, as well as the overall framework for IPR management to ensure that it is appropriately connected to the innovation system. In terms of improving the marketability of IP, the Iran Fara Bourse (IFB) established a special IP stock market in 2013. At present, there are 144 registered IP assets for sale, and a total of $480,000 worth of transactions have taken place,[40] with the PTP acting as the main broker for assessment and promotion of this market.

Copyrights are handled separately, based on a 1969 law, and, in contrast to patents, they are managed by the Government. Registrations are done at the Ministry of Culture while the Informative Council oversees software protection. A specialized court handles cases of infringement. Copyright is limited to Iranian content, but industry needs broader protection to cover international actors as well. This may become a major issue for IP reform as Iran accedes to the World Trade Organization (WTO). Indeed, a new draft copyright law is before Parliament and is expected to introduce new technologies, including the application of digital tools, and ensure compliance with international standards. As for other areas, the Industrial Design Law is seen as contributing to healthy competition and more diversity in industry. There is also a framework for protecting folklore, in line with WIPO recommendations.

3.5.6. Regional development schemes

National policymaking and economic power are relatively concentrated in the capital, Tehran. The Iranian Government is taking action to improve the participation of the regions in policy programmes and policy execution, including in STI and industrial development.

The research and innovation landscape consists of multiple bodies that report to different parts of the national administration. To facilitate integration at the regional level, it aimed to develop S&T corridors, a concept first introduced in 2004 and renamed in 2010 as the programme to develop "Iranian S&T districts". Initially there was slow progress, but in 2015 the programme received a major boost. Under this scheme, to be eligible for receiving financial and legal support, regions have to define and develop plans for strengthening specific industries in their region using a cluster approach. The idea is to build on existing strengths within regions, such as leather industries in East Azerbaijan, health and tourism in Khorasan, and O&G, marine industries and medicine in Bushehr province. The eligibility of a region is based on its identification of four relevant industries, along with relevant university and education activities, as reflected in their patent registrations and other relevant outputs. Pioneering handling of the national heritage and the furthering of cultural capabilities, such as having a specialized museum, are also among the priorities.

This regional development scheme represents an effort to generate stronger outcomes from investment in R&D and innovation by building more integrated, pragmatic clusters and projects at the local and regional levels, which are able to attract more capable staff and strengthen demand for supportive infrastructures, both hard (e.g. broadband, disposal systems) and soft (e.g. training systems). The aim is also to increase demand for soft services, provide a better working and living environment, and create more jobs at the local level. Better options in terms of health, education and entertainment are seen as a basis for more dynamic networks and for the development of soft skills.

Following acceptance by the scheme, regional projects will benefit from measures such as tax subsidies, reduced tariffs, visa support, easier access to financing (low-interest loans), improved transport solutions and better services such as joint laboratories. Regulations are not viewed as key, although they should set minimum requirements and design criteria for eligibility as an S&T district. Organizations eligible for receiving support include private sector firms (which at the centre of the programme), libraries, incubators and accelerators, placement services, and training and education programmes. KBFs are already eligible.

A secretariat is responsible for activities such as evaluating applicants to the program, facilitating international cooperation, enforcing statutes (e.g. Regulation for Establishment and Early Development of Iranian S&T Districts of 2010) and proposing joint projects. Currently, the scheme is led by a steering committee which operates associated working groups. It collaborates closely with the Supreme Council of Urban Planning and Architecture, which is responsible for policymaking and supervision. Meanwhile, each region is working separately on its own preparations. It is too early in the process of implementation to make a real evaluation of the programme, but it appears to be a promising start to improving regional integration. Suitable monitoring and evaluation will be important as the program proceeds.

3.6. Conclusions and recommendations: A diversified inward-looking economy in need of more industrial and technology exports

This chapter has reviewed the broader conditions framing the system for research and innovation in Iran. Although richly endowed in natural resources, including O&G and a wealth of minerals, along with excellent conditions for many agricultural products, Iran is today the most diversified economy in the Middle East.

Iran started out with a traditional science-push approach to innovation, with the MSRT as the core agency for STI policy. As noted, the 2005 STIP Review found distinct features of an "implicit" model (with mandates for STI across ministries and public bodies remaining largely implicit rather than explicit) at that time. Following institutional developments over the past decade, Iran has adopted a more explicit model, establishing extensive mechanisms in support of policy coordination. In this, it resembles Estonia, Finland, Ireland and the Republic of Korea – countries that have taken decisive measures to create effective coordination of their innovation systems. Like many developing countries, there has been the traditional split in focus between research (academia) and industry in Iran, with some policymakers operating on the basis of a linear science-push mindset and others with a more innovation systems mindset. The policy mix and innovation instruments in use so far have been inadequate to adequately leverage the country's fast-growing S&T capacity to create a dynamic industrial impact that drives rapid productivity growth, higher value added, accelerated diversification and rapid, sustained economic growth. There is also an important question about how an effective bottom-up impetus can be incorporated within its approach. Today, Iran's innovation system is clearly hampered by these limitations. The establishment of the VPST in 2007 was an effort to facilitate the commercialization of research and business innovation more broadly.

Some of the key bodies in the innovation system retain a focus on production without adequately considering the critical role that the development of innovation capacity must play in the ability of firms and industries to compete in the domestic market or to export abroad once Iran reintegrates into the global economy. The ability to raise productivity, add greater value locally, create new activities and industries, produce competitive products and gain greater market shares in export markets in all areas where products have some degree of product differentiation require innovative capacity and technological capabilities within firms. In their absence, the export targets established in the main policy documents are unlikely to be realized. The bodies with authority over the economy, such as the SEC, the MEAF, and even the Chamber of Commerce, need to revise their approach by integrating into their decision-making processes plans for boosting STI capacity as a basis for building a competitive economy in the coming years. This will be more essential than ever as trade and foreign investment regimes are liberalized and Iran joins international bodies, such as the WTO, and signs international trade and investment agreements.

Despite the large number of universities, science parks, research institutes, and growing number of KBFs active in R&D, it appears that there are relatively few bodies directly engaged in implementing innovation policy, compared to the number of bodies involved in processing policies for setting priorities. Meanwhile, the system of education is to some extent detached from industry. It is necessary to address the mismatch between the systems of education and training on one side, and industry on the other, by improving the design of education and training policies.

Others that play important roles in research and innovation include the Ministry of Health, which enjoys a particularly high degree of independence in its operations and in resource allocations for research and higher education. This is the result of its success in meeting national health needs. It is also successful in integrating medical education with clinical practice across the country. Extensive research and innovation facilities also reside in the Ministries of Petroleum (MOP), Power, Agriculture, Labour, Roads and Urban Development, ICT and Defence. Several of these ministries have their own internal councils which guide and help to coordinate their sector-based research and innovation agendas. They also administer specialized universities or special programmes in tertiary education, and collect data on and monitor scientific publications and registered patents. Examples of individual bodies known to be strong performers in innovation across these spheres include the public energy company, Mapna, and the Oil Turbine Compressor Company.

With most international sanctions being lifted in 2016, Iran is forging ahead to enhance its foreign exchange earnings and return to pre-sanctions levels of O&G production. At the same time, there is a vigorous drive to upgrade infrastructure in areas of high strategic importance, such as aviation, railways, power and logistics, and to make advances in research, innovation and the development of a stronger and more competitive private sector. Given the continued challenges in accessing international capital markets, new financial instruments are in high demand. Inward FDI is being promoted as a means to attract funding, technology, know-how and access to foreign markets. However, conditions must be created to realize the potential benefits from FDI beyond external financing (such as the acquisition of technology and knowledge and skills upgrading). These conditions include building firm-, cluster- and industry-level absorptive capacity, developing an enabling environment and implementing policies to promote local linkages and promote indigenous technological learning through technology and skills transfer and collaboration.

Overall, despite the significant progress made, Iran faces a range of challenges in several areas, including raising productivity, improving the business environment, modernizing the physical infrastructure, addressing environmental challenges and climate change impacts, stabilizing inflation, stimulating economic growth, creating jobs and raising GDP per capita. Considering Iran's sizeable infrastructure in ICT, transportation and power, the huge urbanization potential (around 73 per cent) and a big domestic market, there needs to be an organized effort to increase productivity through STI and better leverage its highly skilled workforce.

Following years of sanctions, Iran's access to foreign markets and technologies remains constrained, the infrastructure is old and the population and its institutions have limited opportunities for cross-border networking and learning. At the same time, Iran has ample resources, including massive natural resource wealth and a highly competent labour force. In looking ahead, the country places great emphasis on strengthening its capacity to take advantage of these resources, while resolving to excel in research and innovation, and to advance in building a knowledge economy. Elements of its approach need to change, however. Iran's emphasis on an inward-oriented development strategy based on import substitution can now begin to evolve into a more outward-oriented approach based on a coherent development policy mix, giving greater priority to innovation, while further improving its growing S&T capacity. Relying on oil to buy foreign equipment and technologies needs to give way to an approach that targets the building of indigenous technological and innovation capacity and collaborative and genuine partnerships between domestic and foreign providers of investment, technology and know-how. The main challenges/ weaknesses and strengths/ opportunities Iran is currently facing in its efforts to transition towards an innovative and knowledge-based economy are summarized in table 3.10.

In efforts to develop a new approach based on reintegration into the global economy, Iran faces a complex blend of opportunities and challenges. The country has enormous potential to develop a strong STI capacity and leverage it to support sustainable development. To realize its potential, policy reforms are needed. A number of recommendations are proposed, herewith, spanning measures to strengthen the governance of the country's innovation system and address specific policy issues.

(i) Upgrade the coherence between STI policy and other key areas of national policy in order to increase the positive economic impacts of STI. This involves developing an innovation-oriented policy mix as well as restructuring the division of functions and responsibilities for STI governance

Iran has a well-developed institutional set-up for governing the innovation system, which propels a strong commitment among diverse authorities and stakeholders to deliver on ambitious STI objectives. On the other hand, key responsibilities are fragmented, and there are gaps in coordination that hamper effective implementation of innovation. Diverse policy areas need to be better aligned in support of innovation, encompassing wider framework conditions as well as the mechanisms at the core of the innovation system, with the aim of boosting economic growth and having a positive impact on sustainable development.

The broader development policy mix is extremely important for Iran's successful economic development. There is an obvious need for closer links between industrial policy and STI policy. Also important is greater

Table 3.10. Iran's challenges/weaknesses, strengths/ opportunities in transitioning to a knowledge-based economy

Level	Strengths/opportunities	Challenges/weaknesses
General context of STI	• A large pool of young and talented university graduates, particularly in STEM subjects • A local market with high demand for knowledge-based products • Considerable diversity of industrial and production capacities in comparison with other natural-resource-based economies • Lower dependence of the government budget on O&G revenues compared to peer resource-rich countries • Highly developed physical infrastructure (though ageing in some areas) • High Internet and smart phone penetration; potential for e-commerce and e-services development • Substantial environmental challenges which could create new demand for knowledge- based products	• Shortcomings in the institutional setting, such as the business environment, level of competition and development of the private sector • Need for more investment in ICT infrastructure and its application in e-health, e-commerce and e-government • Low level of FDI inflows; heavy concentration of FDI in natural-resource-based industries; and inadequate contribution of FDI to building indigenous STI capabilities • Low level of technology- and skill-intensive export-oriented manufactures • Low productivity levels, particularly total factor productivity • Relatively high unemployment among university graduates • Need to address environmental challenges and climate change impacts
STI governance, policy formulation and coordination	• Emergence of institutions such as VPST and IPF to support innovation • Implementation of new measures (e.g. Technology Annex, KBF law) for improving STI capacity and strengthening economic impacts	• Insufficient linkages between STI policy and other key national policies such as industrial, trade and investment policies • Possible overlaps between the roles of STI policymaking agencies • Insufficient impact of FDI in terms of promoting local technological and innovation capacities
Intermediary and supporting organizations	• IPF support for research and technology funds • Expansion of technological infrastructure, such as S&T parks, incubators, accelerators, research laboratories and innovation centres	• Shortcomings in financing innovation by private institutions, in particular VCFs and business angels • Low effectiveness of intermediary mechanisms such as TTOs • Weak standards and accreditation systems, particularly for knowledge-based products
Education, research and technology institutions	• Expansion of university systems and infrastructures • Policies to promote market-oriented research at universities and research organizations • A strong culture supporting learning and STEM education	• Insufficient commercialization of research by universities and research organizations • Weak university-industry linkages • Funding system for universities and public research organizations not related to performance • Brain drain
Firms	• Large firms in mature industries as a possible market for knowledge-based products • Growth of KBFs due to government policies	• Inadequate R&D and innovation investment by large firms and mature industries • Low participation of business sector in total R&D expenditure • Heavy reliance of KBFs and small firms on government demand; weak capability of KBFs to engage in international collaboration and penetrate international markets • Weak inter-firm and firm-research collaborative linkages

Source: UNCTAD.

coherence between STI policy and policies relating to FDI, trade, education, finance, competition and SMEs/ entrepreneurship. Macroeconomic policies are crucial for creating economic stability and a pro-growth environment. The need for policy coherence also applies at the sub-national level. In this regard, efforts are under way for better coordination of programme delivery at the regional level, incorporating elements of industrial targeting and STI policy. The establishment of the VPST with a horizontal mandate to support innovation is a partial step towards addressing this prime governance challenge. Advancing in parallel, the VPST and MSRT have made progress in better aligning research and innovation, and promoting a more effective interface between industry, universities and research institutes.

The Ministry of Health, meanwhile, is effective in linking research and clinical practice, but is largely separate from the MSRT and other parts of the innovation system. The other major ministries run their own sizeable sub-systems of universities and research centres. The Ministry of Petroleum (MOP) focuses too heavily on production capabilities, and not enough on building technological capabilities. The best coordinated are the MIMT and the VPST. The former engages in various initiatives to place innovation at the core of industrial policy. The issue of potential overlaps among the key bodies playing a role in STI policymaking, design and implementation could be addressed by clearly specifying their mandates.

The actors involved in driving a stronger innovation focus, notably the VPST and the MIMT, should be supported in this endeavour. The VPST plays a key role in implementing innovation programmes, but its programmes are relatively small compared to the size of the industrial sector and the economy. Consideration should be given to strengthening it so that it is able to play a larger role. In addition, the MIMT should seriously pursue the goal of fostering technology and innovation in traditional industrial sectors of the economy, and should likewise receive the necessary support to be effective.

The third wave of STI policy added new functions that are important for promoting innovation and supporting the entrepreneurship ecosystem, but no formal body is currently responsible for coordinating and overseeing those functions. It is advisable to devise a holistic plan to create a clear division of STI functions and responsibilities among different STI policy bodies. In addition, other mainstream bodies active in industrial policy, as well as in economic and financial affairs, such as the National Development Fund (NDF), the SEC, IDRO and the Chamber of Commerce, pay limited attention to innovation. Likewise, most qualified bodies operating at the strategic planning level are more concerned mainly with research.

There needs to be a change in mindset so that all major players have a common understanding and appreciation of the role of STI and STI policy. What is needed is for all actors to adopt a systemic, rather than a linear, science-push, approach to innovation. This requires systematic and well-coordinated efforts, which may only become possible with the rise of *champions* for innovation at the highest levels of economic and industrial policymaking, and with a greater involvement of the private sector. Upgrading the representation of firms, especially private firms as well as industrial guilds and the Chamber of Commerce, in the bodies responsible for the design of STI policies would also help improve Iran's innovation performance. Such upgrading could improve communication flows, help determine the key impediments to business innovation and provide direct feedback on the effectiveness of STI policies in fostering an enabling business environment for innovation in the country.

(ii) Establish a short- to medium-term target for the level of R&D spending that could be attainable, with a focus on promoting and providing incentives for the business sector to increase its share in total R&D spending.

Iran has set the policy objective of raising the GERD to 4 per cent of GDP by 2025. By any measure, this is an extremely ambitious target, and will be difficult to achieve. Understandably, R&D spending has been relatively flat in recent years, given conditions of domestic financial constraints and the country's lack of access to international financial markets. Such spending is currently on a par with that of some other middle-income developing countries. With increased foreign exchange earnings and the expectation of economic expansion, post-sanctions, R&D expenditures would have to grow even faster for its ratio to GDP to increase.

In any country that invests extensively in R&D, the private sector is responsible for the bulk of such investment (OECD, 2014). Almost no government in the world invests public funds of more than 1 per cent of GDP in R&D, and part of that is used as fiscal incentives for private companies to invest. Iran might therefore wish to consider adjusting its GERD target to a more attainable level, while seriously pursuing the achievement of that target through a concerted effort. In the short to medium term, achieving a target of 1 per cent of GDP for *public* R&D spending would seem quite reasonable. Indeed, public authorities are obliged to invest 1 per cent of their total expenditures in R&D. Meanwhile, a target of, for example, 1.5 per cent of GDP could be set for *private sector* R&D expenditure by providing sound incentives. Altogether, this would represent a target for aggregate R&D spending of 2.5 per cent of GDP, which would be realistic and achievable with serious effort. In order for such an adjustment of the target to be compatible with the recommendation for an enhanced innovation effort, noted above, it needs to be accompanied by new means of funding R&D and innovation. Such a step-by-step approach to targeting could make it possible to move towards still higher goals in the long term, where public R&D spending might exceed 1 per cent, and private sector R&D more than1.5 per cent. The goals might need to be revisited at the time of the development of the FYDPs, or an evaluation might be made in five years, or closer to 2025, to devise a practical plan for fulfilling the 2025 goal.

Such high levels of public investment in R&D would merit, as a corollary, efforts to ensure that the measurement, monitoring and evaluation systems for R&D programmes are adequate to guide future decision-making based in part on evidence of a programme's performance and impact. This would enable the Government to direct more investments to areas of high technology and innovation potential rather than to those with less promise. One clear area that requires attention is improving the systems of data collection relating to R&D and innovation, as noted in chapter 2. Policymakers should ensure that investments are also made in design and engineering capabilities, which may not be included under R&D. These are also critical for improving technological capabilities in manufacturing, for example in O&G (see chapter 5). Ideally, efforts to improve measurement should aim to provide some idea of investment levels in these activities as well. Efforts should extend beyond better measurement (i.e. collecting better data) to also include data that enable improved monitoring and evaluation of outcomes and impact. In addition to the focus on R&D targets, policy attention should include continued investments in further strengthening design and engineering capabilities. Furthermore, policymakers should consider striking an appropriate balance between basic and applied research, as well as experimental development. In addition, it is advisable to leverage the potential complementarities of public-private R&D by promoting joint public and private R&D through the design of appropriate incentives. Finally, the focus on R&D targets should not result in neglecting the strengthening of other aspects of the innovation system that are unrelated to R&D.

(iii) Make funding of universities, research and technology organizations more competitive to drive improved performance by introducing an R&D "project" or "mission" funding scheme targeting prioritized areas.

Universities, higher education institutions and public research centres typically have higher levels of autonomy than they did 20 years ago, with their own boards of trustees deciding on many of the parameters that shape their orientation and development. On the other hand, in most instances they rely heavily on public funding and/or tuition fees. However, the level of core public funding is now under pressure, while other sources of revenue are hard to access. In this situation, resources are being too thinly spread, and institutions of higher education may be forced to dilute their efforts rather than sharpen their competencies. The Government's efforts to encourage better performance, in terms of both academic achievements and outcomes for innovation and entrepreneurship, should be supported by a shift from core to competitive funding based on performance. A possible model in this regard is the revamping of university funding that took place in Sweden a decade ago, when elements of core funding were removed, but compensated for by allocations based on a rolling scheme that took into account both scientific publications and attraction of research funding from non-government sources.

There is a need for targeted public support to stimulate R&D in areas of high social interest, combined with eligibility criteria that promote stronger linkages in the innovation system. A substantive programme offering funding on a "project" or "mission" basis is recommended. Greater industry-university collaboration could be encouraged by requiring active participation by private companies and the inclusion of obligatory but modest levels of matching funding.

Such reforms to funding should be coordinated with complementary measures in the following areas:

- A decentralized structure of research budgets of universities and public research organizations on a non-competitive basis – per student and professor – reflecting the need for restructuring the budget allocation system. It is recommended that a centralized budget allocation system be established through a national fund such as Iran's

National Science Foundation, on a competitive basis, depending on the performance of the universities and public research organizations.

- Introduction of public-private partnerships to increase funding for large infrastructural projects through a stronger customer orientation as a driver of innovation (Guinet, 2004).
- Implementation of public support for private sector R&D, with a broadening of fiscal incentives beyond KBFs.

(iv) Leverage human capital by advancing "lifelong learning", mobility and use of ICTs, upgrade soft skills improve the attraction and management of talent

Iran's strong educational system has produced a high quality workforce, including researchers and practitioners. A large number of institutions impart education and skills broadly in society. Enrolment is high among the still fairly young men and women at secondary and tertiary levels. Intense competition between both institutions and individuals has led to a proliferation of high level programmes, while a variety of complementary vocational training programmes support employability. Yet, thus far, Iran's formidable supply of skilled scientists, engineers and the population at large (both men and women) has not been fully harnessed to achieve the transition from oil-driven to innovation-driven growth. Areas that have suffered some neglect include primary education,[41] but also training in the work place, along with "lifelong learning".

Communications and the movement of people are key to strengthening linkages in the innovation system. University faculty and students need to connect more effectively with firms and other stakeholders that contribute to the creation of innovation and stimulate linkages across tight disciplinary or sectoral boundaries. Encouragement of diverse career paths is important for recognizing all aspects of the knowledge triangle (which aims to create synergies between education, research and innovation) and for strengthening cross-fertilization of skills within higher education and research as well as externally. With regard to the latter, better use could be made of individual industry and community "champions", for example by encouraging greater engagement in vocational training in the work place or inducing firms to expand offers of internships.

Use of ICTs in the education system in Iran is lagging behind most other countries, and should be redesigned to strengthen general-purpose skills, creativity, and "soft skills" such as entrepreneurship, management and marketing. ICT through "smart" schemes should be used to inspire people, including the young, to innovate in response to real local challenges in the work place as well as in civic and daily life across diverse urban and rural communities.

There is also a need to advance talent management more broadly. Iran's ambitions to promote high-tech industries and create a KBE will require attracting and engaging talented people in management, marketing and design. For many years, Iran has experienced a steady outflow of young people who wish to improve their skills in other parts of the world. This is no different than for many other countries, but the Iranian diaspora are among the most qualified and represent a potentially valuable, but mostly untapped, talent pool. Iran should devise a strategy for attracting them as well as talented foreign specialists, researchers, and entrepreneurs.

The experiences of China and India may serve as an inspiration in this regard: both these countries provided incentives to attract their high-performing nationals living abroad, which greatly boosted their efforts to achieve knowledge-based industrialization. Arguably, Iran is in a position to offer stimulating, quality work at home, but greater efforts are needed to convince its diaspora of a genuine welcome and long-term development opportunities upon their return. A limited number have in fact already returned, and their contributions should be harnessed more effectively. Social innovation in support of trust-enhancing community-building and forging entrepreneurial networks could help. Developing action-oriented networks can represent the first stage in a process of attracting some to return, and making others aware of the opportunities at home.

(v) Adjust the approach to evaluation and policy learning with a view to strengthening policy experimentation, considering the unexpected and taking both direct and indirect results and systemic innovation system linkages into account.

Today, evaluations are undertaken for several research and innovation programmes and activities in order to keep track of progress and help improve delivery on many of the stipulated targets for national development. There is a need, however, for a reorientation in this regard, so as to upgrade the use of evaluation as a tool to support innovation policy and pay more attention to evidence-based policymaking. Evaluations should be undertaken more systematically to support research and innovation, and their quality should be improved. The results should feed back into informing the revision of existing policies and the design of new ones.

Currently, most evaluations are more helpful in stimulating academic output, such as scientific publications, than in gauging outcomes that are supportive of innovation. This is largely because national systems for evaluating STI policies tend to be limited to linear relations, already known processes and traditional, piecemeal efficiency measures, rather than evaluating economic outcomes and wider impacts, including indirect impacts. This tendency is particularly strong where regulatory issues and financial constraints risk neglecting considerations of long-term effects and system efficiency (OECD, 1997). STI indicators should look at not only inputs and outputs, but also at outcomes for firms and industries and impacts on economic growth and sustainable development. Evaluation should not only involve follow-up by way of ex-post verification of whether stipulated objectives were realized; neither should it be viewed as a technical exercise using sophisticated methodologies for their own sake. Rather, it should be about embarking on a process that starts from an early stage, defines the policy objectives and helps guide the best ways and means for delivering results (Albert et. al., 2013). With this in mind, it is recommended that evaluation schemes in Iran aim at the following:

- Consider how to maximize "additionality" in public R&D support and procurement, that is, how the public spending on R&D can best induce an increase in private or industry sector investment beyond what would otherwise occur, and on terms that link R&D to innovation and outcomes that have economic, social and environmental impacts;
- Examine the "rationale" for policy support to research and innovation, including an appropriate hierarchy of objectives, and consider whether the best means have been adopted;
- Examine linkages between innovation processes and outcomes at the firm (micro), industry/sector (meso), and economy-wide (macro) levels, so as to capture combined outcomes at the system level;
- Consider the costs of using unsystematic approaches and short-term solutions, as may be the case in infrastructural projects that are crucially dependent on overcoming financial constraints;
- Venture into process objectives and ways to overcome ex ante, ex post contradictions, address stakeholder issues, highlight desirable effects of incentives, motivate data reporting, and make it feasible to draw lessons from the evaluation.

In brief, Iran should broaden its approach to evaluating innovation by giving less weight to measuring delivery against planned objectives and more to economic, social and environmental outcomes, evaluating the unexpected, taking direct as well as indirect impacts into account, and helping to design a more effective innovation system as a whole.

(vi) Adopt a comprehensive strategy for targeting and benefiting from FDI as well as other external sources of funding, implement policies and create conditions that promote linkages, technology flows and technological learning, and encourage mutually beneficial long-term partnerships.

Inward FDI flows can play a significant role in growth and development. Under the right conditions, FDI can lead to domestic economic linkages and contribute to local skills development and technological learning by providing a channel for knowledge and technology transfer. These contributions can arise either directly or indirectly (through spillovers), or through a combination of the two. These should be the major potential contributions of FDI to Iran, rather than simply the provision of financing. Policymakers need to be aware that these potential benefits of FDI do not accrue automatically; they require policy initiatives to create the conditions necessary to realize such benefits, as well as adequate absorptive capacity of local firms. Other types of foreign capital (such as bank loans or project finance) may be a more effective means of obtaining pure financing without much potential for, or expectation of, promoting local skills, knowledge or technology upgrading.

As the country attracts FDI, and as MNEs enter Iran through other modes than equity investment, policymakers should encourage the creation of such positive effects locally. Ideally, FDI could create deep local linkages and, over time, lead to joint collaboration with local firms on production, engineering and design, R&D and innovation. Trade policy and FDI policy should work together coherently in order to enable local firms to link into GVCs where this could be advantageous and maximize the potential for beneficial reintegration into the global economy. STI and education policies must be calibrated so that local firms can benefit from knowledge and technology flows from FDI, trade and other channels for technology transfer. Policy should ensure that local firms build the capacity to enable their absorption of knowledge and technology spillovers, and that they build capabilities that attract partners for deeper forms of collaboration than only production (including engineering and design, R&D and innovation).

In the post-sanctions era, Iran aims to promote high-quality foreign investments and technology providers. Major potential investors include developed economies that had a strong presence in Iran during its earlier stages of industrialization prior to the imposition of international sanctions. Many other countries could become interested in investing in what is perceived as a large and currently untapped potential market. Attracting FDI should be possible.

The following are some important questions for Iran's policymakers to consider:

- What type of FDI should be targeted and how can it be leveraged to promote domestic development?
- How can Iran move beyond being a mere market for foreign products to becoming a production site, and advancing beyond only production to forming deeper collaborative linkages in R&D, technology and innovation that will build indigenous technological capabilities?
- How can strong domestic linkages be created with local firms?
- How can active collaboration be achieved among local firms, foreign firms operating in Iran and local research institutes and universities?
- How can mutually beneficial, win-win outcomes be achieved for Iran and its domestic firms, as well as foreign investors, in order to promote long-term collaborative relationships?

Iran should consider the appropriate pace and depth of liberalization of FDI regulations. Policymakers should move swiftly to take advantage of foreign investor interest, and target investments in industries and activities identified as being of high priority. The Government should promote FDI that can be beneficial in creating local linkages and contributing to local skills, knowledge and technological learning. The policy framework for foreign investment is important. It could be linked to an investment promotion strategy that is derived from the national development strategy and key policies such as industrial and innovation policies.

Promoting supplier development, local linkages and technology flows is desirable. The design and implementation of policies on technology transfer and local content, such as the Technology Annex and the Policy on MULC, should be pragmatic and sufficiently flexible to draw benefits but not deter high priority investments by imposing unrealistic requirements and targets that will be difficult to meet in the near term. They should also aim to avoid potential capture of policymakers by vested interests.

There is need for sustained policy support for building local supply capacity and promoting upgrading in firms engaged in diverse industries over time. This includes the provision of sound incentives to stimulate firm-level investment in strengthening their production, engineering and design, and R&D capacities. The incentives may include the creation of an enabling business environment and encouraging greater competition, including through continued domestic private sector development.

In addition to environmental impact assessments for large FDI projects, it might be useful to conduct technology and innovation impact assessments to gain an insight into their potential impacts on technology flows, local technological learning and innovation in Iran. Due consideration should be given to the potential for establishing joint ventures and other types of collaborative ventures with foreign investors in specific industries, depending on the capabilities of local firms and the willingness of foreign investors to collaborate. Currently some joint venture agreements with foreign investors are in the pipeline. One approach might be to target specific investors who are open to local production and joint collaboration on production, and show an interest in developing closer collaborative activities over time on engineering and design, R&D, technology and innovation. The example of Singapore and other successful cases of anchoring FDI locally and fostering upgrading over time could provide lessons for consideration by Iran's policymakers. Other alternative approaches could also be studied and considered.

Other foreign investors can also play a beneficial role as Iran reintegrates into the international financial system and re-establishes full use of the international payments system. These include foreign venture capital funds, business angels and private equity funds, which may offer potential opportunities for local firms to access foreign capital. They could also represent important sources of financing for NTBFs as well as more established firms in traditional industries.

Enacting more effective dispute resolution mechanisms for the issues relating to cross-border business dealings should be a high priority. The types of dispute resolution mechanisms adopted require careful consideration. It would also be important to foster professional business services capable of beneficial matchmaking between foreign investors and domestic firms, as well as auditing and asset evaluation services, and the provision of stronger IPR protection. Some of these measures need to be adopted at the regional or local level, and could be implemented within cluster-based initiatives, where measures can be tailored to overcome sector- or context-specific impediments or distortions.

Qualified representatives of the private sector, such as the Chamber of Commerce, industrial guilds and the IVCA, could help identify, expose and overcome critical impediments to foreign investors committing to local partnerships. The Chamber of Commerce is already engaged in designing services support capable of receiving, informing and guiding foreign firms in identifying prospective partnerships with domestic firms. Such initiatives should be coordinated with efforts to strengthen the innovation system. The proposed new R&D funding programmes, along with reforms to universities and competence development, for instance, can increase the motivation of foreign investors to transfer R&D to Iran, collaborate with local universities and research organizations, and engage in training and other activities, thereby supporting the move towards a more knowledge-based economy.

(vii) Improve the credibility and usefulness of the IPR system through a comprehensive, gradual improvement encompassing the entire life cycle, from patent application to dispute resolution; this includes raising awareness and providing training and professional support for maximizing the contribution to innovation.

IPRs play a critical role in balancing the protection of inventors and innovators with the societal need for rapid knowledge diffusion. Despite the reforms undertaken over the past decade, including aligning with international standards and associated efforts to build awareness and capabilities in this area, Iran's IPR system needs further improvement. Patents are currently of limited relevance to what could be achieved through innovation and commercialization. Substantive scrutiny in the application process should be matched by better mechanisms for dispute resolution through legal settlement.

The Iranian Parliament is currently considering patent reform. In moving forward, Iran's IPR legislation needs to be revised to ensure maximum relevance for innovation. This will require institutional backing from Parliament and key decision-makers to ensure that the full cycle, spanning all stages of the IPR process, is well-functioning and its elements well aligned – from the application and filing stage to infringement and dispute resolution and/or rights enforcement. The following measures are proposed to achieve this:

- Strengthen the IPR institutional framework and align it to the promotion of technology development and innovation to use IPRs as a development tool rather than as a strictly legal instrument;
- Foster the creation of professional brokers and trained specialists capable of evaluating and assessing patents' contents with a view to their commercial application;
- Undertake a concerted effort to create a cadre of experienced lawyers who can handle infringement cases;
- Develop executive and leadership training that approaches IPR as an integrated aspect of the innovation system, so that IPR becomes a tool for development rather than an end in itself; and
- Proceed to align Iran's patent and broader IPR system more with those of other countries.

In parallel with the above-cited measures, there is a need to provide an impetus for improved management and collaboration around IPRs within research institutions and firms. Similar to some other countries, such as Sweden, in Iran individuals have full ownership of registered IP, unlike in other countries such as Italy. In reality, the key is to have flexible IP forms whereby firms, universities and institutes, on the one hand, and individual researchers on the other, can negotiate collaborative frameworks based on shared ownership rights to IP. This encourages both parties to take an active interest in dynamic and successful collaborative activities. Finally, in order to develop internationally competitive industries, (in existing as well as new growth areas) there is merit in considering shifting away from import substitution and reverse engineering as a means to building indigenous technological capabilities and creating local innovation, towards collaboration and partnerships on R&D and innovation projects. The former approach allowed technological capability building while sanctions blocked other standard channels of technology transfer. This type of transition could become more beneficial as real international collaboration becomes feasible following the removal of international sanctions. The issue of copyright protection will also need to be addressed as the IPR system is improved. It may be critical to already start planning for this transition if Iran is to eventually accede to the WTO.

(viii) Nurture the knowledge-based economy across sectors, with continued policy support for start-ups and new growth areas, including through professional business services and an upgraded innovation and entrepreneurship system.

Government should continue to promote the development of KBFs, while simultaneously promoting innovation by mature firms in large, established industries, such as the O&G, automotive and steel industries. Iran's large traditional and mature industries, including energy, mining, and a spectrum of other basic industries, are impeded by ageing and underperforming infrastructure. The infrastructure needs major upgrading and expansion over the next decade. At the same time, its development should serve as a tool to help foster the rise of new KBFs and industries. Given the strengthened commitment to innovation, as well as the broadening of R&D support, organizational reforms and support for productive foreign investment and international engagement, basic industry itself should become more knowledge-based. At the same time, it is necessary to promote innovation in new growth areas and by new start-ups. The traditional debate over new (or young) small firms or older, large firms as sources of innovation should give way to a belief that both can and should become more innovative. Young firms may have high growth potential, and can be agile, but large firms can sustain R&D efforts and absorb losses from risky investments in innovation. Both have potential advantages. Mature firms in established industries should become more innovative. Part of the answer lies in finding ways of inducing large firms in traditional sectors to invest more in R&D and innovation, and to increase competitive pressures in the country in the coming decade. Policymakers may need to consider additional policy measures to stimulate innovation by these firms, for example, through regulatory action to raise quality standards or allow them to benefit from public programmes aimed at promoting linkages between local firms and MNEs. The key role of the MIMT with regard to large firms in traditional sectors (and mostly low- and medium-technology activities) should be recognized and supported in this regard.

The existing support programme for KBFs contains a well-designed package of instruments to identify and nurture vibrant young firms with high growth potential. It provides the impetus for the rise of a new generation of R&D-intensive firms. However, it will be necessary to avoid unwanted distortions in firms' behaviour motivated by the desire to comply with the eligibility criteria of this programme. Effective monitoring and evaluation of the programme should be undertaken when its impacts have become more evident so that success factors can be identified in order to inform decisions about scaling it up in the future. This programme is promising in terms of creating new firms in technology-intensive activities. However, it is relatively small in relation to the size of the economy. If evaluated as being successful it should be scaled up to create a larger impact.

Likewise, the establishment of councils for nanotechnology and other emerging technologies provide potent platforms for awareness-raising, networking and active collaboration between diverse players, ranging from universities and research institutes to business and local communities. They can play a useful role in supporting the expansion of promising activities in new growth areas.

While it is necessary to ensure the continued development of such programmes, greater efforts are needed to realize effective complementarity between public support and market contributions. Innovative activity entails high risks with typically unfavourable risk-reward ratios for private investors, especially in new activities. Therefore, there is a need to devise a set of instruments, including access to public seed funding, venture capital and business angel networks, which can support entrepreneurs and promote innovation. An "equity culture" needs to take hold. Meanwhile, a stronger presence of professional business service providers capable of assisting start-ups and young, growth-oriented companies in areas such as strategy, registration, funding, marketing and IPRs can promote healthy information exchange, business negotiation processes and more active engagement by VCFs.

(ix) Mobilize ICT for innovation, capitalizing on its broad applications (e.g. "big data" and "smart cities") through strategies that link technology

to people, support businesses and induce innovation in response to everyday challenges, including tackling sustainability issues.

Iran's ICT infrastructure is to some extent outdated, and, despite an impressive expansion of fixed broadband capacity and Internet bandwidth since 2013, the country is lagging behind in the development of mobile networks, e-commerce, e-government and m-services. Regulatory reform and the removal of existing barriers are required in order to induce stronger competition and diversity in ICT, including new services development. The lack of competition is a major factor that is hindering improvement in ICT infrastructure and services in many countries in recent decades. Regulatory reform has often played a significant role in stimulating positive change. Such reform is also essential in order for Iran to reap greater benefits from its ample supply of skilled engineers, as well as other well-educated and technology-savvy youth.

Many youth have been uniquely inspired to learn about nanotechnologies and their applications, as outlined in this chapter. At present, however, ICT use in the education system is weak. It needs to be integrated with other subjects for improved data management as well as creativity, communication and innovation. On this basis, ICT should be applied as a tool for broadening the basis for developing and diffusing new services in response to key challenges. In particular, the new generation of ICT tools – "big data" and "smart cities", distributed computing, the cloud and "smart" interactive data processing – enables users and citizens to generate feedback and take action in real time (Evans, 2009). It is important for Iran to improve some aspects of ICT infrastructure use and applications, especially in light of the continued rapid advances in ICT applications and digital innovation and because of the internet's important role as a platform for innovation.

IV

Iran's biotechnology innovation system

4.1 Introduction

Biotechnology has been frequently referred to as the technology of the twenty-first century along with information technology. Modern biotechnology has already made significant contributions to the health and agricultural sector. Development of various drugs, pharmaceuticals and vaccines using recombinant DNA technology has given rise to multibillion dollar industries. In addition, polymerase chain reaction- or PCR-based diagnostics has emerged as an important component of health care. It is estimated that the global biotechnology market will reach $414.5 billion in 2017 (TMR, 2014), and could deliver the next wave of technological change that could be as radical as or even more pervasive than that brought by other technologies such as ICTs. Therefore, it is a powerful and enabling technology for a country like Iran, and could revolutionize the pharmaceutical and other related industries.

Iran has set targets for biotechnology development to 2025, including becoming the leader in the Middle East in biotechnology and tenth in the world, and increasing its share of the global biotechnology market to 3 per cent from its present estimated share of less than 0.5 per cent. Achieving these targets will require rapid growth in this field. Biopharmaceuticals are estimated to account for around 60 per cent of the global biotechnology market (TMR, 2014), and are likely to be the most important area for potential commercial growth worldwide and in Iran.

The continued commercial application of biotechnology could lead to the development of a bio-economy, where a substantial share of economic output is partly dependent on the development and use of biological materials. The potential economic and environmental benefits of this technology could create a growing strategic interest in a bio-economy in Iran.

Iran already ranks high in biotechnology production: first in the Middle East and fifth in Asia. Pharmaceutical companies in Iran mainly focus on the production of generic medicines and biosimilar products. According to the Scimago database, Iran ranked 14th in the world in published articles on biotechnology, up from 40th in 2005, which certainly shows rapid growth (table 4.1).

Iran has attained a high degree of self-sufficiency in pharmaceutical supplies, with local producers accounting for 97 per cent of the total volume. This is due to the policy of protecting the domestic drug market and high local production capacity. Iran’s biotechnologies and biopharmaceutical have developed rapidly, benefiting from its strong higher education and research system and a growing number of domestic firms in these sectors. Despite these achievements, there are a number of challenges to realize desired commercial outcomes, especially in biopharmaceuticals and bio-agriculture, which are the two main areas of the bio-economy.

The aim of this chapter is to assess the biotechnology innovation system, and update the information provided in the biopharmaceuticals chapter of the 2005 STIP Review.

Table 4.1. Main indicators of biotechnology in Iran, 2014

Global ranking on published articles	14th[a]
Ranking in production of biotechnology products in Asia	Among top 5 countries
Ranking in production of biotechnology products in the Middle East	1st
Ranking in vaccine production in the Middle East	1st
Number of published papers on biotechnology in international journals	4 851
Global share of biotechnology publications	0.9 per cent
Regional share of biotechnology publications	27.2 per cent
Number of biotechnology companies	580
Value of biotechnology products (goods and services) (billions of dollars)	0.5

Sources: VPST (2014 and 2016b) and Scimago database (at: http://www.scimagojr.com/, accessed October 2016).
Note: [a] Data are for 2015.

4.2. Long history of biotechnology development in Iran

Biotechnology has a relatively long history in Iran. The necessity of establishing institutes for microbiology and immunology research was a response to the 1918–1919 influenza pandemic in the region, which killed hundreds of thousands of people. Later, the substitution of natural components by alternative medicines formed the basis of the country's modern biotechnology (Fard et. al., 2013), which emerged in the country nearly nine decades ago. It started with vaccine production in the Pasteur and Razi Institutes in 1920 and 1925, respectively. Later, the National Research Centre for Genetic Engineering and Biotechnology (NRCGEB), set up by the MSRT in 1988, took over from the Pasteur Institute in investing in molecular biotechnology. Its major activity is gene-based research in medical biotechnology, focusing on human genetic disorders, recombinant proteins and heterogeneous gene expressions.

In 1997, the Iranian Biotechnology Society (IBS) was established, followed by other important government bodies associated with biotechnology research in Iran. They include: the Biotechnology Council of Iran (BTC, established in 2005), the Center for Technology and Innovation Cooperation of the Presidential Office, the Medical Biotechnology Committee (established in 1998 under the Ministry of Health and Medical Education (MOHME)), the National Medical Biotechnology Network (established in 2002 under the Deputy of Research and Technology, MoHME), the High-tech Industry Centre (established in 2001 under the Ministry of Industry (now MIMT)) and the Iranian Molecular Medicine Network (established in 2001 with 34 research institutes and centres as members) (Fard et. al., 2013).

4.3. Policy framework, coordination and national policies for biotechnology development in Iran

The biotechnology sector has the potential to improve productivity, health and environmental sustainability, but it could change dramatically current business models and economic structures. In order to maximize the benefits accruing from this sector, it is necessary to devise long-term policies and action plans. Considering that no single organization oversees the whole sector, coordination among different policy bodies has been a challenge. Several bodies are involved in policy formulation, including the SCCR and Parliament at the policy level, and the Biotechnology Council (BTC) (under the VPST) at the level of implementation. The BTC's coordinating role is vital, but also difficult, as there are several powerful ministries responsible for biotech activities, including the MOHME for medical applications and the Ministry of Agriculture (MOA) for agricultural applications (box 4.1). The diversity of biotechnology applications and the resulting fragmentation of this sector in any country are major challenges to effective coordination.

The NMPSE, which has set policies and priorities for national STI development, accords top priority to biotechnology. Among the priority areas to develop within biotechnology, the plan identifies stem cells, herbal medicines and biosafety, among others. It further categorizes areas into first and second priority. It has identified key indicators accompanied by specific targets to 2025, including the number of scientific publications to reach 1,500, and for the share of biotechnology to reach 3 per cent of the global biotechnology market. To achieve the Plan's goals, Iran needs to have a pro-innovation and export-oriented policy mix.

Since 2004, three key national plans and policy documents in biotechnology have been approved in Iran, giving the BTC a distinctive role. The First National Biotechnology Plan was approved in 2004, which expired in 2015. Its implementation was coordinated by the BTC. In the past decade, policy documents have focused more on S&T development, infrastructure-building and training. Today, with the supply side of biotechnology having reached maturity, and the Government's new aim to create a knowledge-based economy, the Second National Biotechnology Plan (2016–2025) has shifted towards achieving a bio-economy and promoting innovation and entrepreneurship, and encouraging private sector investment (table 4.2).

The main policy instruments for promoting biotechnology development include low-interest loans, indirect funding through tax exemptions, direct funding for the relevant fields in the higher education system, and the use of trade protectionism and public procurement of local drugs. In Iran, public procurement of biotech products is widely used through the MOHME. However, the extent of its impact in supporting innovation in biotechnology is not clear. The country restricts imports of biotech products when their market share reaches 30 per cent, which

Box 4.1. The BTC: Creating effective coordination for biotechnology in Iran

The BTC was established in June 2005 as a biotechnology coordinating body and implementing agency to help the country reach the targets established by the SCCR in the NMPSE and the priorities set by Parliament's FYDPs. It is one of the 16 councils in Iran, mirroring those for nanotechnologies, ICT and other specific technologies and industries. Its members include deputy ministers from the MOHME, MOA, MSRT, directors of biotechnology research centres and five scientists specializing in biotechnology. Coordination of biotechnology research, priority-setting and implementation are its primary responsibilities. Its coordination of the key actors in the biotechnology innovation system is critical for development of these technologies which span many different industries, and therefore involve different ministries and agencies. The BTC has a national plan on biotechnology, which is in line with the key STI policy documents. The SCCR has designated the BTC the main reference of policy-making, planning, coordination and monitoring in the field of BT with the following approaches and policies:

- Market formation in biotechnology through guaranteed purchases of KBF products
- Establish, support and empower biotechnology KBFs
- Support human resources development in biotechnology
- Support biotech-related R&D
- Commercialize the results of that R&D

Activities and implementation:

- Amend and update the National Biotechnology Strategic Plan and roadmap
- Design and implement national mega projects such as bio-ethanol production, transgenic products and probiotic products.

Source: UNCTAD.

Table 4.2. The Second National Biotechnology Plan (2016–2025)

Policies	Important actions
• Develop and enhance domestic technical knowledge • Provide financial support for the development of highly skilled human resources • Increase the role of the private sector, KBFs and non-governmental organizations • Support basic research • Disseminate knowledge and new technologies in industry • Maintain and develop Iran's biodiversity and genetic resources • Increase competitiveness by improving productivity and promoting the efficient use of existing production facilities in the country	• Create specialized biotech incubators, science parks and science towns • Create national and regional accreditation systems and testing laboratories for quality control, and set measurement standards • Establish a fund for commercialization and export development of biotech products • Expand the scope of insurance coverage for biotech products • Allocate an appropriate share of production subsidies for and public procurement of domestic products • Facilitate increased domestic and foreign private sector investment in the biotechnology sector in Iran

Quantitative objectives

Indicator	2016	2025
Iran's share in global biotechnology market	0.5 per cent	3 per cent
Share of biotechnology products in Iran's total exports by value	10 per cent	65 per cent
Number of biotechnology firms	800	2 000
Jobs created in biotechnology	9 000	55 000
Revenues of biotechnology firms ($ billion)	2.9	31
Number of internationally registered patents	3	130
Number of graduate students in biotech	16 000	50 000
Number of scientific publications	700	1 500

Source: BTC, 2016b (in Persian).

encourages support for local production. The share of foreign biotech products is currently limited to 10 per cent of the local market, and tariff rates are about 30 per cent on certain products. These import restrictions are possible because Iran is not currently a member of the WTO. If Iran joins the WTO, these arrangements would need to be changed and a new strategy devised.

In addition to the major policies noted above, the legal framework is also important for biotechnology development. Several laws are relevant for biotechnology, including the laws on IPRs, the Biosafety Law, the Law on Access and Benefit Sharing on Genetic Resources, laws and regulations supporting the development of the private sector (such as the Law for Supporting KBFs) and laws relating to international collaboration and partnerships. In revising its policies on biotechnology, the Government is trying to create synergies between S&T policies, and steer them towards the demand side and market needs, focusing on the fields in which biotech innovations can be economically competitive.

4.4. Shaping the biotechnology innovation system in Iran

Since 1990, the development path of biotechnology in Iran follows the three STI policy waves, as outlined in chapter 3. Each wave has added a new element of focus to the policy framework for biotechnology. The first wave, starting in 1990, focused on building human capital and scientific biotech research. The second wave concentrated on strengthening applied research and on technology development. The third wave commenced with the emergence of biotech KBFs and included policy support for shaping the innovation ecosystem and promoting the commercialization of biotech products.

4.4.1. Building supply-side capabilities in biotechnology

The first generation of the knowledge creation process in biotechnology was based on a linear, supply-push approach. The Government has been attempting to build a strong science base for several decades, and has given high priority to biotechnology development, providing consistent support for this area. Since the mid-1990s, the development of higher education has been the most important component of science policy for biotechnology and related areas. Iranian universities offer courses in biotechnology, with some reputable ones offering post-graduate courses in this field. According to the BTC (2015), more than 80 universities and research institutes in Iran are engaged in biotechnology-related teaching and/or research (table 5.3). As a result, at present, the greatest advantage of the biotechnology system in Iran is its considerable pool of skills and knowledge in this field.

In recent years, the number of academic staff, universities and graduate students of medical sciences has sharply increased, and biotechnology-related disciplines have attracted increasing numbers of undergraduates. In terms of the governance of education in biotechnology, whereas the MSRT is responsible for most of the higher education system in general, the MOHME oversees medical universities that provide education in health sciences. Research centres for biotechnology relating to health and a biotechnology network are also governed by the MOHME.

In recent decades, the focus has been more on the supply-side, that is, building capabilities, such as training graduate students in biotechnology. Higher education programmes should be diversified to provide a better mix of educational and vocational

Table 4.3. Indicators of human resources development for biotechnology in Iran, 2015

Title	Total	Title	Total
Number of universities offering biotechnology courses	80	Cumulative number of students who graduated in biotechnology up to 2015	15 050
Number of research centres involved in biotechnology	6	Number of bio-tech students in 2014	7 284
Number of bio-tech sub-disciplines at the master's level	23	Number of bio-tech faculty members (2011)	1 058
Number of bio-tech sub-disciplines at the PhD level	12		

Source: BTC, 2015 (in Persian).

skills to meet the needs of industry and the labour market. Biotechnology is one of the most promising fields of technological entrepreneurship. To unlock the full potential of education as a driver of growth and jobs, the Government should pursue reforms to boost both the performance and efficiency of biotechnology education, as well as the business environment for biotechnology. Research centres and firms should become more involved in the design of university curricula in order to make graduates more employable.

Research efforts in biotechnology have grown rapidly in the past decade, as reflected in data on publications in scholarly journals. Between 2005 and 2015, there was a fivefold increase in the number of published articles in this field, from 767 to 4,851. In terms of cumulative scientific articles published, according to the Scimago database, Iran's ranking in the Middle East has been rising rapidly, surpassing Turkey, Egypt and Saudi Arabia (figure 4.1). This has been accompanied by a steady rise in biotechnology post-graduates in recent years from 3,820 in 2010 to 7,284 in 2014.

However, the growth in human capital and publications has not been matched by growth in the number of international patents. This reflects the need to change attitudes towards commercialization and supporting IPR registration, but also to improve the quality of research. This calls for promoting the use of the IPR system to protect IP, and developing the skills required to use the IP system. Collaboration with international research centres and scientists can be a major means of improving the quality of scientific output.

(a) *Developing the RTD system*

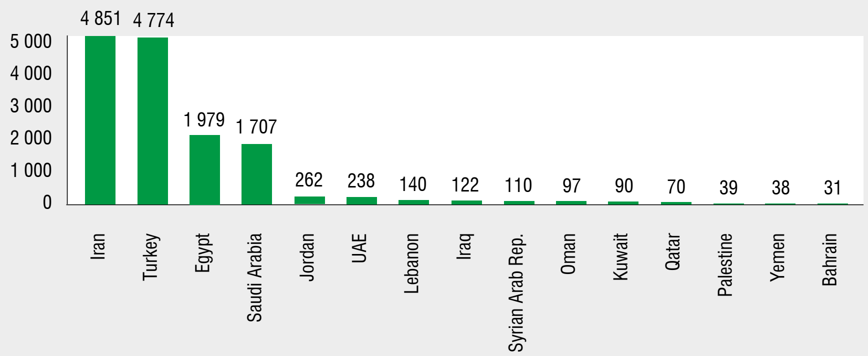
In the aftermath of the war with Iraq, the SCCR revived Iran's national research system in 1990. It stipulated the conditions for the establishment of research centers, identifying biotechnology as a top national priority. This led to a marked rise in the number of public and private research centres (Soofi and Ghazinoory, 2013).

Along with socio-economic policies in the post-war period, there were sustained efforts to build a research and technology development system for biotechnology. Technology transfer from abroad was combined with local R&D in biotechnology and biopharmaceuticals to drive transformation of the industry. The growth in S&T capabilities enabled Iran to acquire certain advanced technologies, such as production of new biotech and biopharmaceutical compounds.

In 2000, the deputy head of research and technology at MOHME developed a comprehensive health research network (HRN) to make research centres play a more active role in national and international scientific productivity. Today, the MOHME is the supervisory body for more than 58 public university faculties of medical sciences and their affiliated research centres. In 2011, the Medical Biotechnology Research Network was established.

Activities undertaken by public research institutes (PRIs) include publishing scientific journals, and providing education and training, and regulatory testing services. A number of these institutes are engaged in R&D covering a broad spectrum of

Figure 4.1. Number of articles on biotechnology in scientific publications in Iran and other countries in the Middle East, 1996–2015



Source: UNCTAD, based on Scimago Journal and Country Rank (at: www.scimagojr.com/, accessed October 2016).

applications, and they are affiliated to different ministries and government bodies, including the MOHME, MOA and MSRT. The number of dedicated biotechnology research centres increased from 5 in 2000 to 18 in 2016 (BTC communication). Researchers in these institutes are also well linked to local university departments and firms (both public and private).

Another major strength of R&D in biotechnology in Iran is that it has some outstanding institutes of long-standing (e.g. the Pasteur Institute and the Razi Institute and, recently, the National Institute for Genetic Engineering and Biotechnology (NIGEB)) that are involved in critical, applied R&D through to the development, production and diffusion of biotechnology products. The Razi Institute, established in 1925, is one of the oldest and most highly reputed scientific centres in Iran. It is a centre of research, training and technical assistance for vaccines needed in developing countries and the Middle East. One of its notable outputs was the development and production of a vaccine against Rinderpest, which had caused large casualties in the cattle population of the country. Since then it has developed and manufactured different vaccines for human and veterinary use. It is under the MOA, and works closely with the MOHME and with various veterinary organizations.

The Pasteur Institute of Iran (IPI) was established in 1920 to pave the way for advanced research, and to provide innovative programmes in basic and applied medical sciences. It also produces biopharmaceuticals and diagnostic kits with special emphasis on infectious diseases and vaccines. One of the modern departments of the Pasteur Institute of Iran, the Biotechnology Department, has been a pioneer in molecular biotechnology investment.

The NIGEB was established in 1989 under the supervision of the Ministry of Science, Research and Technology, with a mandate to undertake original, state-of-the-art research. It has the dual purposes of promoting research in avant-garde areas of biological sciences and biotechnology, and providing advanced training and education for scientists and students from various universities and academic institutions. The time preceding the foundation of this institute coincided with rapid growth of biotechnology and advances in the concepts and methods of genetic engineering in Iran. The centre has a record of consistent achievements in medical biotechnology, such as the successful production of a recombinant growth hormone and of a recombinant DNA hepatitis B vaccine.

The Royan Institute, established in 1991, is another leading research centre comprising three research institutes, each focusing on different fields of research, including stem cell biology and reproductive biomedicine. Its dedicated centre for stem cell research, set up in 1998, has become one the leading centres for research in this area. Today, with a staff of over 180, the centre is also one of the leading institutions for infertility treatment. Royan has published more than 600 scientific papers in national and international journals, 14 books in English and Persian, and has 26 registered patents in Iran.

(b) The emergence of biotechnology KBFs

Systematic policy support for biotechnology firms started in the early 2000s and was complemented by the law supporting KBFs in 2010, particularly KBFs engaged in biotechnology. The number of KBFs in Iran has been growing steadily, and the number engaged in biotechnology grew rapidly between 2000 and 2016, according to company registration data (BTC communication). Today, more than 300 of them are operating in different areas of biotechnology (table 4.4).

Table 4.4. Number of biotech KBFs by field of activity, October 2016[a]

Area of activity	Number Of firms
Agricultural (Agri/food biotech)	96
Biopharmaceuticals (Medical/ food biotech)	144
Environment and industrial biotech	47
Biotech material and equipment	18
Services	2
Total	**307**

Source: BTC communication.
Note: [a] Includes KBFs in biotechnology products, biotechnology equipment and biotechnology services.

There are many small and start-up biotech firms located in science parks and incubators, some of which have become commercially successful. Of these, two prominent and internationally reputed firms are CinnaGen and AryoGen, which, along with some others, are major exporters or biotech products (table 4.5).

Table 4.5. Leading Iranian biotech exports

Name of product	Producer	Explanation
CinnoVex®	CinnaGen	A drug for controlling the progression of multiple sclerosis (MS) by using recombinant DNA technology.
ReciGen® (Interferon Beta-1a)		
Cinnal-f® (follitropin alfa)		A recombinant DNA origin based hormone identical to a follicle-stimulating hormone (FSH).
CinnoPar® (Teriparatide)		Help to form new bone, increase bone mineral density and bone strength (osteoporosis).
Cenobone	Tissue Regeneration Corporation	Bone grafts and bio-implant tendons and ligaments
Pd Poetin	Pooyesh Darou	Recombinant human Epoetin Alfa.
ZIFERON® Interferon beta-1b	Zistdaru Danesh	Interferon in the treatment of relapsing-remitting MS.
Interferon gamma 1b	Recpharma and Exir	Interferon gamma 1b
Aryoseven	AryoGen BioPharma	Recombinant activated human blood coagulation Factor VII
Nitro Kara	Kara Industrial Biotechnology Company (KIBCo)	Nitrogen fixing biofertilizer

Source: VPST (2016b).

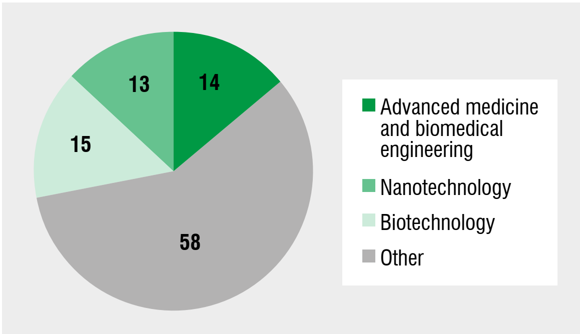
(c) Biotechnology financing

The Government has allocated an annual budget to BTC for the past decade. Other resources allocated to biotechnology are at the disposal of the MOHME, MOA and MSRT. The Government's total budget allocations for biotechnology increased from $4.7 million in 2008 to $6.4 million in 2014 (table 4.6). In addition, in 2015, the private sector and the BTC jointly created the Iran Biotech Fund.

Despite the dominant share of the business sector in pharmaceutical and agriculture industries in Iran, its funding of STI development has been limited. Also, venture capital remains poorly developed, and access to FDI is limited. The main forms of financial support are loans and grants. Since 2013, the IPF has provided a useful mechanism to finance the commercialization of the biotech activities of KBFs and start-ups. By October 2016, 203 biotech firms had received support from the IPF, and almost 23 per cent of the IPF's budget was allocated to biotechnology (IPF, 2016). Over the past decade, biotechnology and advanced medicine and biomedical engineering have accounted for 15 and 14 per cent, respectively, of total investment by private sector S&T funds (figure 4.2).

The first accelerator in the field of medical biotechnology (medicine and equipment) and regenerative medicine (stem cells), called Persis, began operations in August 2016. This is the ninth innovation accelerator

Figure 4.2. Cumulative financing of biotechnology by private sector S&T funds, 2005-2015 (per cent)



Source: Iranian Venture Capital Association, 2016.

Table 4.6. Budget allocations to biotechnology in Iran, 2008–2014 ($ millions)

	Annual budget ($ millions)						
	2008	2009	2010	2011	2012	2013	2014
Total support for biotechnology	4.7	4.4	3.5	3.5	2.5	4.7	6.4

Source: Islamic Parliament Research Center Report, 2015 (in Persian).

established at PTP. The accelerator supplies the necessary laboratory infrastructure, and technical and commercialization training, as well as investing in biotech start-ups. The Biotechnology Development Center (BioDC) is currently supporting eight start-ups at the first acceleration course of Persis.[42]

(d) Regulatory system for biotechnology

In Iran the national regulatory authority for all foods and drugs is the Division of Pharmaceuticals and Narcotic Affairs, which is under the supervision of the MOHME. The MOHME is mandated by law to set quality standards for regulation of all medicinal products. Other divisions of the MOHME, which are also involved in registration of medicinal products, are: the Food and Drug Control Laboratory, the ADR Centre, Clinical Trials Evaluation Committee and the Centres for Disease Control (Hadavand et. al., 2011). Quality standards in biotechnology and biopharmaceuticals are regulated by two major authorities: the Iranian National Standards Organization (INSO), and the Food and Drug Administration (FDA). The latter is part of MOHME, and is responsible for regulations covering pharmaceutical products, while the INSO is responsible for all non-medical biotech products. The two organizations work in parallel in the area of food safety. The FDA has a number of departments that handle the regulatory aspects of medical biotechnologies, including quality assurance, registration of approved products on the Iran Drug List, a research centre, and, since 2003, the Clinical Trials Committee. The FDA recently developed regulations for the approval of biopharmaceutical products. Every biosimilar drug must undergo head-to-head phase III clinical trials with the brand drug before it can receive FDA approval for sale on the market.

4.5. Biotechnology subsectors

Biotechnology is involved in four main sectors: agriculture, health, industry and the environment. Of these, medical biotechnology and bio-agriculture have progressed the fastest. Commercial biotechnologies in crop agriculture include largely bio-fertilizers and bio-pesticides for the domestic market. However, locally developed agri-biotech products have been struggling to compete with imported seeds, chemical fertilizers and pesticides, largely because of government subsidies for these products. Subsidies for seeds and pesticides have now been withdrawn, and those for chemical fertilizers have been reduced. This offers some opportunities for expanding commercial development and production of agri-biotech products, at least for the domestic market. In health-related biotechnology, two areas of application have become commercially successful. The first is the production of biological materials for use in R&D, including restriction enzymes and monoclonal antibodies, mainly for the domestic market. The development and commercialization of these biological products entail relatively low risk, and offer opportunities for small start-up biotech firms to enter the market and build technological and business capacity. The second area of success is biopharmaceutical products – a term used in Iran that broadly equates with biosimilars – the development and production of which are considered a major potential growth area for biotechnology in Iran.

4.5.1. Biopharmaceuticals, a leading subsector in Iran's biotechnology sector

Some Iranian pharmaceutical firms have been developing biopharmaceuticals for the past decade. The Government has allocated substantial resources for improving local pharmaceutical firms' production capabilities. The country produces 97 per cent of its medicines locally, of which 15 per cent are biopharmaceuticals.[43] Eight Iranian companies introduced 12 new products for the treatment of multiple sclerosis, cancer and diabetes in February 2015. In addition, 12 anti-cancer medicines were developed in Iran in 2014, unlike the majority of emerging markets which rely on importing most of the drugs used for chronic diseases (BMI, 2016).

Iran's biopharma products include different categories of biosimilars, such as alpha, beta and gamma interferons, a blood-clotting product and a vaccine, most of which are based on original biologics developed by big global pharma giants such as Roche, Sanofi-Aventis, Pfizer, and Eli Lilly.[44] However, only a small number of firms have been able to market these new products. They include CinnaGen and Aryogen, four local pharmaceutical companies and a public R&D organization – the Pasteur Institute of Iran. Iran now exports biopharmaceuticals to several countries, including Turkey and the Russian Federation.

Domestic drug production is gradually expanding, with Iranian authorities recently granting manufacturing licences to local private companies for more than

20 vaccines and sera products. Multiple sclerosis and cancer drugs – CinnoVex (Interferon β1a), ReciGen (interferon β1a), Zytux (Rituximab) and AryoTrus (Trastuzumab) – are now produced in Iran. In addition, the country has become a producer of several recombinant drugs which were previously produced by only a few developed countries. It is now the only country capable of producing the molecule of recombinant Factor VII biosimilar, which is used to treat haemophiliacs. The country's researchers have also produced a nano-drug, which has proved to be effective in treatment-resistant cancers (BMI, 2016).

Biopharmaceuticals remain dominated by the main public research institutes and a small number of more established biotech firms such as CinnaGen, AryoGen and Pooyesh Darou Biopharmaceutical Co (table 4.7). NRCGEB's research into recombinant DNA technologies, genetic engineering and DNA vaccine production has the potential to produce treatments for a number of pathogens.

Iran aims to become one of the world's leading producers of biosimilars, the market for which is expected to expand significantly in the coming years. However, it is unlikely that success in this area will, in itself, be sufficient to meet the Government's target share of 3 per cent of the global biotechnology market.

4.6. Recommendations

Biotechnology policies have focused mainly on the development of the relevant human capital and research capabilities. The approach has been largely a linear supply-push one. Imitative innovation through reverse engineering has helped to build strong basic innovation capacity, but has not so far resulted in strong original innovation capabilities in many firms. This is necessary to build a dynamic and internationally competitive biotech industry. There remain several major barriers to developing strong domestic capabilities in biotech innovation and developing novel biotech products for local and export markets, which could help Iran meet its ambitious export targets. A major obstacle to building effective international linkages has been the international sanctions over the past decade. Despite the recent FYDPs which have aimed to strengthen innovation and improve market linkages, more effective demand-side innovation policies are needed, giving a more pivotal role to public sector demand and support (e.g. through procurement, regulation, and standards-setting and certification). This requires investment in skills and competencies in public administration, as well as organizational and cultural changes.

The following are specific recommendations for fostering biotech innovation and development in Iran.

(i) Improve financing for biotechnology

Iran needs to develop additional effective financing mechanisms for funding biotechnology development. This includes financing for risky and long-term biotech R&D. Currently, R&D funding is spread across different biotech activities, and it is difficult to scale

Table 4.7. Major biopharmaceutical firms in Iran

Name	Profile
CinnaGen Company	CinnaGen, founded in 1994, is now a private company and part of the Cinnagen Group, which has over 1,300 employees. Starting with four scientists, it has grown to become one of the leading biopharmaceutical manufacturers and biotechnology exporters in the Middle East. Enzymes, molecular biology reagents and PCR kits were its first products. It is now active in producing recombinant proteins. It exports to the Russian Federation and other members of the Commonwealth of Independent States. It has international collaborations for technology transfer and joint ventures for production in Malaysia and Turkey.
AryoGen Biopharma	Established as part of the CinnaGen Group in 2009, AryoGen has focused on providing biopharmaceutical products that meet world standards. The production facility manufactures some of the latest biopharmaceutical compounds found on local and international markets, and is the world's first firm to produce biosimilar Blood Coagulation Factor VII, which required an investment of 50 million euros. In 2010 they established a modern knowledge-based facility for the production of therapeutic monoclonal antibodies.
Pooyesh Darou Biopharmaceutical Company	Founded in 1997, Pooyesh Darou is an established biotech firm producing six recombinant biopharmaceutical products. It has acquired technology exclusivity from the International Center for Genetic Engineering and Biotechnology (ICGEB) to manufacture recombinant DNA-based therapeutic proteins – the endogenous hormones and leukotriene that control essential body functions.

Sources: Razi Vaccine and Serum Research Institute (http://www.rvsri.ac.ir, accessed in August 2016); Pasteur Institute (http://en.pasteur.ac.ir/, accessed in September 2016); CinnaGen (http://cinnagen.com/index.php/home/history, accessed in August 2016); AryoGen (http://www.aryogen.com/english/aboutus.html, accessed in August 2016); and Pooyesh Darou Biopharmaceutical Co (http://www.pooyeshdarou.com/?page_id=3463, accessed in October 2016).

up R&D efforts in all areas due to the constraints on public financing for R&D. More active collaboration with foreign universities and public research institutes could help, and should be encouraged. The possibility of attracting foreign venture capital financing also warrants consideration, as this will become more feasible in a post-sanctions era. At the same time, the development of a more active local venture capital market should also be supported.

(ii) Enhance collaboration between biotechnology KBFs and mature firms

Some of the important, leading biotech KBFs produce products or technologies that can be used as inputs for large companies in different industries, especially pharmaceuticals. The latter are mature, large companies that can be good customers for KBFs, but as most of them are State-owned and are in a non-competitive environment, they have limited demand for novel knowledge-based products. They produce mainly traditional and non-innovative generic products that do not require high levels of R&D. Intensifying the competitive environment in which these firms operate and providing incentives for them to get involved in R&D activities and new product development could improve opportunities for collaboration and cooperation with KBFs through supply chain linkages, R&D collaboration, or through mergers and acquisitions.

(iii) Strengthen international collaboration and access to the international market

Commercialization and access to markets have been two major challenges for many Iranian biotech firms. Private sector biotech firms are mostly young SMEs and new start-ups that have been incubated in S&T parks. A minority have matured and migrated to industrial estates as larger industrial firms. This is perhaps in part because most production has been geared towards low-cost, low-profit generics and biosimilars, while more radical, original innovations at the innovation frontier have been less common. These firms will have to become more competitive, innovate more radically and improve the softer skills of marketing and management needed to penetrate foreign markets.

If these companies aim to reach the global market, they will need to reinforce marketing, branding and international negotiations, and build distribution networks. Some immediate and necessary policy actions include education and training, empowerment and creating consultancy services for such KBFs to encourage them to collaborate or engage in mergers and acquisitions with large national and international firms in order to access global markets. On the other hand, solving the challenges posed by IPRs and meeting the required standards of global markets are critical. In the future, if WTO accession discussions progress, Iran will be obliged to abide by WTO provisions, particularly those related to the Agreement on Trade-related Intellectual Property Rights.

Iran has had only limited international cooperation on biotechnology since 2006 because of international sanctions. Those sanctions hampered such cooperation as they excluded the possibility of making payments through the international payments system. Research outcomes in several biotech KBFs are near to the point of commercialization, but require collaboration to overcome the remaining obstacles. The required international collaborative linkages should become possible in coming years with the prospective lifting of sanctions.

(iv) Develop efficient TTOs in universities and research and technology organizations to accelerate the process of commercialization

Many universities and research centres have persuaded their academic staff and researchers to commercialize their findings, and have established university-industry cooperation offices for this purpose. But these initiatives alone are not adequate for assuring commercialization. University-industry linkages appear to be weak and should be strengthened. Selling royalties and know-how are the regular mechanisms which universities, research centres and SMEs (including KBFs) use to exploit their research. These mechanisms need to be reinforced through more effective TTOs in order to accelerate the formation of spin-offs in universities and research centres. In addition, technology brokering, filing patents, handling infringements, selling and buying IPRs and related services need to be provided.

(v) Improve the accreditation system by enhancing laboratory and testing equipment and facilities

In setting appropriate standards, the public sector's role is mainly one of facilitator or coordinator. Standardization can be financially supported by governments in order to facilitate market entry or the diffusion of innovations, notably in case of market failures. The issue of standards in biotechnology is not straightforward. High standards in drug regulation are desirable, as this is critical for controlling quality and safety. There are those who argue that unreasonably high standards are currently blocking the certification of some KBF products. This may warrant investigation to determine whether there are indeed issues that need to be addressed. Others report that the lack of established standards for some biotech areas is an issue that standards bodies should tackle. In order to penetrate global markets, and to be competitive, it is necessary to meet global standards and acquire the necessary certifications. Iranian biotech firms that plan to export their products, in particular to Europe, need to be certified as meeting the required standards. The testing and certification systems must be strengthened to ensure that accreditation is not a barrier to exports of biotech products.

(vi) Enhance local content policies as well as public procurement in favour of innovations in biotechnology

As the MOHME and MOA are considered the main buyers and customers for the bulk of agri-biotechnology and pharmaceutical products, they have an important role to play in stimulating innovation in this area. The MULC Law, which aims develop local production to meet public needs, should be leveraged to develop a pro-innovation market in bio-agriculture and health.

(vii) Strengthen applications of the four main sub-sectors of biotechnology

Biotech development in Iran has been strongest in the health and agricultural sectors. The country has encountered challenges such as air pollution from vehicle emissions (especially in urban areas) and from refinery operations and industrial effluents, deforestation, overgrazing, desertification, oil pollution, wetland losses from drought, soil degradation and erosion, inadequate supplies of potable water and water pollution from raw sewage and industrial waste. Biotechnology has the potential to provide solutions to these problems, but it requires a revision of the policy framework to address these challenges. The current national biotechnology plans ended in 2015, and policymakers are preparing a new 10-year roadmap for biotechnology. Planned priorities for the next 10 years in each of the four main application areas are outlined in table 4.8.

Table 4.8. Priorities areas for biotechnology development in Iran over the next decade

	Health	Industry	Agriculture	Environment
Sub-sectors	• Medicines and drugs • Vaccines • Diagnostic products • Regenerative medicine • Functional foods	• Enzymes • Biopolymers • Bioleaching • Industrial kits in biology • Microbial enhanced oil recovery • Bio-electricity from biogas	• Diagnosis kits • Biological fertilizers • Biological inhibitors • Molecular agriculture • Livestock, poultry and aquatic vaccines • Plant production and reproduction • Animal production and reproduction	• Water and wastewater treatment • Sewage treatment plant • Industrial waste treatment • Biologic mulches • Biofilters

Source: Biotechnology Council (2016a).

V

The oil and gas innovation system

5.1. Introduction

The history of Iran's O&G industry dates back to the early twentieth century, making it the oldest in the Middle East. Its importance for the Iranian economy cannot be overstated: in 2015, it accounted for around 20 per cent of the country's GDP. Iran has the fourth largest proven oil reserves in the world and the second largest gas reserves. In 2010, it exported around 2.3 million barrels per day and was the world's fourth largest exporter, but in 2014 and 2015 exports fell to1 million barrels per day due to sanctions. According to the latest published statistics, Iran's oil exports returned to 2.3 million barrels per day, or more, by September 2016. In contrast, despite holding 17 per cent of the world's total gas reserves and being the world's third largest gas producer, most production has been for domestic consumption, and gas exports have been limited so far.

Sharp losses in export revenues in recent years due to the fall in exports and low oil prices, coupled with constraints on financial transactions and limited access to frozen Iranian assets held abroad, contributed to limiting investment in O&G. Production of crude oil and condensates fell from almost 4.1 million barrels per day in 2011 to 3.1 million in 2013. Production increased rapidly during 2016. Export revenue was $118 billion in 2012, but fell by 47 per cent to $63 billion in 2013 (IMF, 2014). Oil exports later stabilized at around 1 million barrels per day, but were further negatively affected by falling oil prices, with fiscal oil revenue falling from 12.5 per cent before 2012 to around 6.3 per cent of GDP (IMF, 2015). However, during the last two years, oil exports have increased significantly.

During the past decade, policymakers and the main participants in the O&G sector have gradually paid more attention to the development of the technologies and capabilities needed to further boost the industry's production capacity and efficiency. Policies for O&G have recently given high importance to technology, innovation and capability-building through the use of local content requirements (LCRs).

By limiting access to flows of foreign technologies embodied in capital goods, services, design and operational know-how via imports, licences, and incoming FDI, international sanctions cut off the sources of technological change in the Iranian O&G innovation system. They exposed the extent to which the O&G SOEs and their subsidiaries, as well as engineering, procurement and construction (EPC) contractors had been over-reliant on imported technological inputs without substantial domestic matching efforts to master and improve upon imported technologies. As a corollary, it also revealed the shortcomings of an STI policy that had given heavy emphasis to the creation of production capacity, without due consideration to fostering capabilities of firms to innovate so as to contribute to the efficient utilization of resources and economic growth. This had been the strategy in Iran until the end of the last decade. International sanctions, however, compelled indigenous technological learning and innovation in O&G (as in the economy more broadly). They induced policymakers to shift from a focus on the creation and expansion of production capacity towards an emphasis on technological learning and building of technological capabilities of firms to promote technological innovation.

Recently, the Joint Comprehensive Plan of Action (JCPOA) between Iran and the five permanent members of the United Nations Security Council, plus Germany (P5+1), signed in 2015, marked a turning point in the development of O&G. As a result, inward FDI is expected to increase rapidly – indicated by the growing interest of international oil companies (IOCs) following the treaty – which could bring much-needed inflows of capital and technology (World Bank, 2015).

The industry was established in Iran long ago, but before the 2000s there was limited success in capability building in the sector, and firm-level technological capabilities remained at low levels. As part of the second wave of STI policy in Iran, policy started to focus more actively on building O&G firms' capabilities. This focus has intensified in recent years. Policy initiatives have sought to support innovation activities – not only R&D, but also, very importantly, engineering and design efforts, including of the imitative type – of business enterprises in various sectors, including suppliers to the O&G companies. Consequently, considerable import substitution efforts have been undertaken. Domestic private companies, mostly SMEs supplying the O&G industry, have taken the lead in investing in engineering and design activities and contributing to localizing the production of key equipment and services. Furthermore, a small sub-set of these companies has managed to develop R&D capabilities. Beyond that, a major expansion of O&G-related tertiary education has occurred over the past 10 years. This has contributed to increasing the pool of qualified human resources for the O&G industry, and creating a nucleus for the future development of research programmes in universities. These are all very important developments that are worth building upon. At the same time, there is need for a careful analysis of the types of obstacles that remain to be addressed.

Considering this background, it is important to examine some key issues relating to the future development and competitiveness of the industry, the current status of the O&G innovation system and its potential to support technology and innovation-driven economic development. First, there is a need to determine the technological preparedness of domestic companies, including State-owned O&G companies and their subsidiaries, integrated service companies and other goods and services suppliers in terms of their capabilities to use and change technologies to which they already have access, in order to maximize the benefits from the opportunities created by Iran's return to international markets. Second, it is important to evaluate the effectiveness of the research and education system in supporting innovation in the sector and the building of capabilities within various types of enterprises. Third, it would be useful to consider how the current STI policy framework is addressing the main challenges confronting the sector. This chapter addresses these issues.

This Review focuses only on the O&G industry, and mainly on upstream activities. The petrochemical industry is not the focus of this analysis, although it is also very important, considering that it alone accounted for around 30 per cent of Iran's non-oil exports in 2015. Moreover, 22 per cent of petrochemical production in the Middle East is located in Iran. In the past 10 years, over 65 large petrochemical companies have been privatized, and both the public and private sectors have exerted considerable efforts to enhance capabilities in this industry.

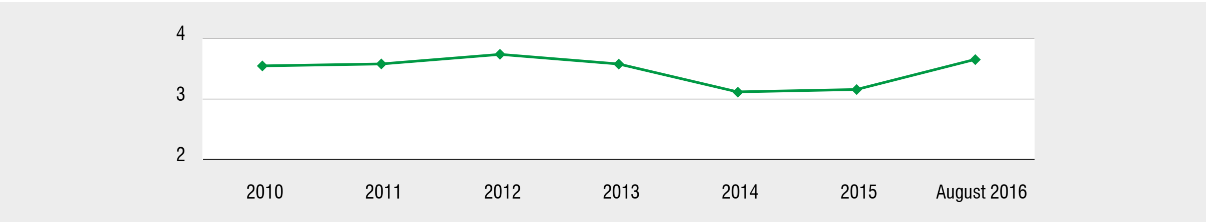
5.2. Overview of the O&G industry

Iran is one of the largest holders of proven reserves of O&G in the world. In 2015, proven oil reserves stood at158 billion barrels, ranking fourth in the world, while proven gas reserves, at 1,201 trillion cubic feet, were the second largest in the world after those of the Russian Federation. In 2014, Iran's proven O&G reserves accounted for around 10 and 17 per cent of the world's total respectively. Over 70 per cent of Iranian petroleum reserves are onshore, with offshore deposits in the Persian Gulf and the Caspian Sea constituting the remaining share. Most of Iran's proven onshore oil reserves are located in the south-west of the country, particularly in Khuzestan Province, and the major share of gas reserves are found offshore in the Persian Gulf. Exploratory efforts have led to the discovery of 177 fields and 371 reservoirs containing petroleum in Iran. Among the known oil fields, 28 are shared between Iran and neighbouring countries. Of these, 20 contain oil and 8 are gas fields, including the South Pars field, the world's largest non-associated natural gas field, jointly owned by Iran and Qatar. There were 94 producing oil and gas fields in Iran in 2015.

Despite declining oil production in previous years due to sanctions and still largely underdeveloped gas exploitation, Iran is a leading O&G producer, and production of both crude O&G has increased rapidly in recent months (figure 5.1). At 3.2 million barrels per day of crude oil and condensates produced in 2014, Iran ranked eighth globally. In 2013, gross gas production was 8.1 trillion cubic feet, the third largest in the world. Production of crude oil and condensates fell sharply to 3.1 million barrels per day in 2013 from almost 4.1 million barrels per day in 2011, in contrast to the all-time high of 6 million barrels per day reached from the mid- to the late 1970s. Oil exports fell 50 per cent between 2009 and 2014. Gross gas production had been increasing consistently until 2012, but saw a slight fall in 2013 to 8.1 trillion cubic feet, though it resumed growth in 2014 to reach 8.6 trillion cubic feet.

In 2015, the Iranian crude oil refining industry comprised nine operating refineries with a total crude distillation capacity of about 1.8 million barrels per day (table 5.1). Seven new refinery projects are currently under way (BMI Research, 2015), which would increase refining capacity in coming years.

Figure 5.1. Crude oil production in Iran, 2010–2016 (millions of barrels per day)



Source: Based on OPEC annual and monthly reports (available at: http://www.opec.org/opec_web/en/publications/338.htm).

Table 5.1. Iranian refineries and distillation capacity, 2015 (barrels per day)

Refineries	Crude distillation capacity (Thousand barrels per day)
Abadan	390
Isfahan	375
Bandar Abbas	320
Tehran	250
Arak	250
Tabriz	110
Shiraz	58
Lavan	50
Kermanshah	22
Total	**1 825**

Source: MOP communication.

The conversion of wet natural gas to dry natural gas in Iran was carried out in 12 natural gas processing facilities with a total capacity of 577 million cubic metres per day in 2015 (table 5.2).

According to the MOP, domestic supply industries account for a considerable share of supply inputs for the upstream and downstream O&G industries. Local suppliers of equipment, components, materials and services are active in the various segments of the O&G value chain. The MOP estimates that the local share of domestic supply of goods and services ranges from 30 per cent in offshore drilling to about 100 per cent in pipeline engineering and installation (table 5.10). However, some firms are importing some of the inputs for production, which may reduce the actual proportion of local content.

5.3. Oil and gas innovation system: Main players

The main players in Iran's O&G innovation system are introduced and discussed below. They can be divided into three categories: the main national companies − SOEs − and the business sector, actors involved in research and education, and finally policy and governance bodies responsible for STI policy.

5.3.1. National companies and business enterprises

Large SOEs controlled by the MOP dominate this sector. Upstream and downstream processes are vertically segmented, with three different SOEs and their subsidiaries controlling exploration and production, refining and gas processing segments, while a fourth SOE is responsible for petrochemical activities. The National Iranian Oil Company (NIOC) is responsible for exploration, development, production and transportation, the National Iranian Oil Refining and Distribution Company (NIORDC) for refining and distribution, and the National Iranian Gas Company (NIGC) for gas processing and distribution. The National Petrochemical Company (NPC) is in charge of petrochemical production and marketing. Each of the four main SOEs have several regional subsidiaries that are responsible for undertaking production activities in particular regions of the country, and other subsidiaries handle specific functions, such as offshore engineering, gas processing engineering and pipeline management.

A second important set of players consists of hybrid public-private companies, which gained prominence from the late 1990s when O&G activities were opened to private investment. This category encompasses major service and equipment providers for the upstream and downstream industries, and engineering, procurement and construction (EPC) contractors.

Private domestic companies also participate in the market as suppliers of equipment, components and services to the O&G sector. Domestic manufacturers of capital goods, typically SMEs, have emerged, especially during the sanctions period, to produce import-substituting domestic equipment and services. The MOP estimates that, at present, around 2,000 Iranian companies are involved in the design and manufacture of upstream and downstream O&G equipment and as service suppliers, of which around 500 are associates of the Society of Iranian Petroleum Industry Equipment Manufacturers (SIPIEM). Presently the vendors list of NIOC, NIORDC, NIGC and NPC include 1,104 local suppliers and 1,660 foreign suppliers.

MNEs have been only marginally involved in the Iranian O&G industry over the past five years. Western O&G companies withdrew from Iran after successive rounds of sanctions, while Chinese and Russian ones have remained active (EIA, 2015). China Petroleum & Chemical Corporation, China National Petroleum Corporation (CNPC) and the Russian companies, Tatneft and Gazprom, were involved in the development of various O&G fields in the early 2010s. After the signing of the JCPOA in 2015, several Western IOCs such as Total, Eni, Royal Dutch Shell and British Petroleum, as

Table 5.2. Gas processing facilities and capacity in Iran, 2015 (cubic metres, tons)

Gas processing complexes and companies	Refining and dehydration capacity (Million cubic metres/day)	Feed gas (Billion cubic metres)	Gas condensates (Million cubic metres)	Ethan (Thousand tons)	LPG (Thousand tons)	Sulfur (Thousand tons)	Delivery to pipelines (Billion cubic metres)
South Pars Gas Complex	210	107.34	21.43	1 478.9	2 033.3	337.46	82.68
Fajr Jam Gas Refining Company	125	29.09	1.57	0.00	32.78	0.00	32.44
Parsiyan Gas Refining Company	82	25.20	1.82	0.00	0.00	0.00	24.88
HashemiNejad Gas Refining Company	58	14.17	0.14	0.00	0.00	618.3	13.70
Khoozestan Gas & Liquid gas	---	8.69	0.00	0.00	0.00	0.00	7.48
Bid Boland Gas Refining Company	27	4.77	0.00	0.00	0.00	0.00	7.68
Sorkhoon and Gheshm Gas Refining Company	17	4.25	0.32	0.00	25.77	0.00	4.15
Dalan Dehydration	20	5.13	0.00	0.00	0.00	0.00	5.13
Ilam Gas Refining Company	7	1.77	0.36	0.00	0.00	50.10	1.66
Saraje Dehydration	10	0.85	0.00	0.00	0.00	0.00	0.85
Shoorije Dehydration	20	0.82	0.01	0.00	0.00	0.00	0.81
MasjedSoleiman	1	0.11	0.00	0.00	0.00	0.00	0.11
Total	**577**	**201.8**	**25.6**	**1 478.9**	**2 091.8**	**1 005.9**	**181.6**

Source: MOP communication.

well as Russia's Lukoil and Gazprom and India's Oil and Natural Gas Corporation Limited (ONGC) Videsh, expressed interest in investing in the Iranian O&G industry after the lifting of sanctions (*Tehran Times*, 2015; EIA, 2015). Section 5.3.1.1 discusses more fully the capabilities of Iranian O&G firms.

5.3.1.1. Iranian O&G firms' innovative efforts and capabilities

O&G firms in Iran vary from being less to more technologically dynamic, depending largely on the level of complexity of the technological activities they are able to undertake and the degree of novelty of their innovation outputs. These, in turn, indicate their level of capabilities (table 5.3, second column).

More than a century after the emergence of the petroleum industry in Iran and its becoming one of the main sectors of the economy, the paths towards greater technological dynamism among the firms in the Iranian O&G industry have been diverse. Most firms in the industry are located at the least technologically dynamic end of the spectrum. These include engineering and procurement firms, refining and gas-processing companies, NIOC, NIORDC and NIGC, and their regional and engineering subsidiaries, EPC contractors, and the majority of equipment and service suppliers for upstream and downstream segments. However, a growing number of suppliers have progressed to engineering and design capabilities, and a small sub-set has reached the level of capabilities needed to undertake R&D.

The NIOC, NIORDC and NIGC and their regional subsidiaries are able to introduce technological change through the adoption of new equipment, or the acquisition of services or complete production systems. They themselves do not perform either in-house R&D or conceptual and basic design and engineering. Instead, they allocate 1 per cent of their operating budgets to R&D which is undertaken by other actors such as the Research Institute of the Petroleum Industry (RIPI). However, their internal research and technology directorates play a managerial role. Like some other O&G-rich countries that have national oil companies, Iran's O&G SOEs consider technological development as being the work of suppliers and not part of their core business; they believe their function is to only guarantee output.

Correspondingly, the assigned technological priorities of the engineering and procurement, refining and gas-processing companies are met through projects implemented by other actors in the innovation system, particularly RIPI and universities, but also suppliers. In addressing technological bottlenecks, the NIOC, for instance, aims to be "a user of the latest technologies," according to one of its senior managers.[45] In contrast, technologically dynamic O&G companies approach technology quite differently (box 5.1). Even when they consider themselves primarily as "users" of technology, and view commercialization of technology as being outside their core business, they are forced to proactively undertake technological development when they need to use new technologies.

In Iran's upstream segment, technological change is normally introduced during field development projects by sourcing engineering and project management services as well as complete production systems from EPC contractors and IOCs through buy-back agreements.[46] Once granted, field development projects have been driven by EPC contractors or IOCs with little involvement of the NIOC and its operating subsidiaries. However, a significant impediment in developing fields is the lack of capabilities to undertake more complex project execution and management activities in the investment phase of projects.

Historically, the motivation for investment in refining of crude has been to guarantee the domestic availability of refined products and reduce Iran's dependence on imports, rather than profit-seeking. Thus, technological development to increase efficiency has not been a priority. Because production costs are low and profit margins higher in the upstream sector, it made better economic sense to export crude and import refined products rather than investing in refining. However due to the sanctions, restrictions on imported fuels and budget constraints, as well as recent changes in policymakers' visions (discussed below), there has been a major emphasis on increasing the production of refined products, particularly gasoline, to achieve self-sufficiency. Existing refineries have operated above full capacity and some petrochemical plants were converted to produce gasoline. The main source of technological change has been the acquisition of external technologies during expansion projects. However, the core product and process technologies are old and the companies have made limited alterations over the operating lifetime of their production facilities.[47] There have been some limited innovative efforts to raise the quality of products.

There are relatively few competent domestic engineering companies that can act as EPC contractors. Most of them can only replicate existing designs of production facilities and carry out routine design operations. Their current strengths lie more in the construction and procurement component of investment projects. In upstream projects, domestic EPC companies are able to carry out detailed engineering, but they have limited capabilities for basic engineering and conceptual design, and none for changing conceptual and basic designs. When they undertake basic engineering activities they tend to adopt a trial-and-error approach. Thus, they are limited to copying, imitating and making minor changes. Similarly in refining and gas processing, there is a shortage of engineering and design capabilities for basic and conceptual designs. In new facilities and expansion projects, minimal changes are made to designs originally provided under foreign licences.

Table 5.3. Firms' capabilities in the Iranian O&G innovation system, 2015

Levels of capabilities	**R&D** Novel products and processes			Small sub-set of service and equipment suppliers
	Design and engineering Adaptations to products and/or processes			Growing number of service and equipment suppliers
	Production/operation Minor changes in products and/or processes and acquisition of new technologies	E&P, refining and gas processing SOEs	Engineering, procurement and construction contractors; Engineering SOE subsidiaries	Majority of service and equipment suppliers

Source: Information from interviews in Iran in November 2015.

Box 5.1. Statoil's active engagement in technology development

Statoil, the Norwegian State-controlled multinational O&G company, sees itself principally as a "user" of the technologies deployed in its operations, and does not consider licensing of technologies as part of its core business. However, that does not mean it assumes a role of passive user of ready-made technologies acquired via arm's-length transactions. Like other technologically dynamic international O&G companies, Statoil is involved in the development of the core technologies it deploys or would like to see developed to advance its business objectives. It has defined four core areas of technology it sees as fundamental for meeting its objectives: seismic imaging and interpretation, reservoir characterization and improved recovery, well construction and subsea gas compression. It believes that development of technologies in these areas can contribute to further discoveries in complex geologies, increase production and recovery rates and reduce costs.

Beyond the core areas of technology defined in its technology strategy, Statoil also invests in R&D in a wide range of technologies covering the complete O&G value chain. One example of the level and nature of its efforts even in areas of technology not considered central to its technology strategy, is its involvement, since 1986, in the development of gas-to-liquids (GTL) technologies. GTL is a refining process to convert natural gas into liquid synthetic fuels via, for instance, the Fischer-Tropsch (F-T) route, a catalytic chemical process. Because of restrictions in licensing existing F-T technology, Statoil started R&D work on its own version of the F-T process to convert gas into diesel and naphtha. In the early 2000s, it collaborated with the Petroleum Oil and Gas Corporation of South Africa (Petro SA) and the RIPI in Iran, and subsequently with Petro SA and Lurgi, a German engineering company at the time (from 2007, a subsidiary of the French company Air Liquide). Statoil developed a proprietary catalyst and elements of an F-T reactor, and installed a semi-commercial demonstration plant at the Mossel Bay Refinery of Petro SA in South Africa. In 2005, it entered into a joint venture – GTL.F1 – with Petro SA and Lurgi to further develop and commercialize the F-T technology, and in 2011 the licence phase was launched. Since Statoil did not consider commercialization as part of its core competitive domain, it sold its stake at GTL.F1 and negotiated future access to the F-T technology on a preferential commercial basis. However, even after divestment from GTL.F1, Statoil continued its R&D efforts on F-T technology both in-house and with R&D institutes and universities.

This active involvement in technology development, even when the goal is not to commercialize any resulting technologies was aimed at remaining competitive, through timely, swift and efficient application of new technologies. Remaining competitive in the O&G industry demands in-house learning to acquire the skills, technical knowledge and experience to monitor the technological frontier, identify new technologies, provide detailed technical specifications, integrate new technologies in complex systems and manage their interfaces. And the only way for O&G companies to master the technologies they use (or want to use) to be able to perform their operations competitively is by undertaking technology-changing activities themselves through R&D, or non-R&D engineering and design activities, rather than just passively using the technologies

Sources: Statoil (2015); Statoil website (http://www.statoil.com); GTL.F1 (2011); Olsvik and Ødegrd (2004).

Suppliers of equipment and services have been the main loci of innovation and capability-building. Most equipment suppliers for both upstream and downstream sectors still replicate or make minor changes to product designs obtained from old licence arrangements that have been discontinued because of the sanctions. However, a growing number of established or start-up companies – some of the latter still operating in incubators and science parks – have been trying to introduce adaptations of designs through engineering activities.

Two goals relating to the resilient economy emphasize *"Increasing added value through completing the oil and gas industry value chain, and developing products with optimum efficiency"*, and the *"Dominance of a knowledge-based economy, and improving the NIS to increase the production share of knowledge-based products and their export"* (Resilient Economy Policy, 2014). Both of these have provided a major impetus to engage in learning and shift from a passive to an active involvement in technology imitation and adaptation of essential foreign technologies to meet the demand for domestic products. This normally has involved, initially, considerable reverse engineering efforts to master the design of existing equipment and, subsequently, introducing modifications to the designs. However, in recent years, some private supplier firms have emerged with stronger technological capabilities. A small sub-set of equipment and service suppliers, including 150 private KBFs, have managed to introduce new products based on more formalized R&D activities, At present, over 1,100 firms are on the MOP's vendor list.

5.3.2. Research and education institutions

In addition to the research and technology management departments within the NIGC and NIOC, there are 38 universities and technical schools that provide tertiary education relevant to the O&G sector in Iran. In addition, there are four main research institutes in the sector, the most important being the RIPI. The others are the Improved Oil Recovery Research Institute (IORI), the Institute for International Energy Studies (IIES), and finally the Petrochemical Research and Technology Company (NPC-RT), which focuses on downstream fields (and hence is not discussed further in this Review).

Research Institute of the Petroleum Industry (RIPI)

The RIPI is a public research organization in charge of undertaking O&G-related R&D activities for both upstream and downstream technological areas. It was founded in 1959, originally as a research institute affiliated to the NIOC, but it now reports directly to the MOP. It has more than 1,600 employees, 700 of whom are funded by the NIOC, with 7 per cent holding a PhD, 27 per cent an MSc, and 18 per cent a BSc. It receives 50 per cent core funding from the MOP, which is supplemented by income-generating activities such as services and licensing.

The RIPI's mission is to undertake scientific and technological activities on behalf of the NIOC, NIORDC, NIGC and NIPC. Originally, its main activities were the provision of laboratory and testing services, but now they cover a wide range, including applied research, experimental development, training and education, and technical services. Besides applied research (for instance, on nano- and bio-technologies to explore applications for the O&G industry), it focuses more on experimental development, covering design and engineering, bench, pilot and semi-commercial activities.[48] Technical services cover technical assistance, for instance to NIOC subsidiaries and IOCs operating in Iran, troubleshooting, carrying out laboratory and test services and providing expert advice. Its other types of consultancy services include technology monitoring, devising roadmaps and selection of technologies.

The R&D efforts of the RIPI have led to various innovation outputs. By 2015 it had been granted 144 local and 133 international patents. In 2014 it published 60 papers in journals indexed by Thomson-ISI. Between 2008 and 2015, it introduced 11 new software programmes and licensed 47 technologies to domestic companies. Five companies have also been spun off to further develop and commercialize the technologies it has developed.

The MOP, together with O&G producers, define the R&D agenda of the RIPI based on their operational needs. Its activities are based on an innovation model which sees the role of R&D institutes as providers of ready-made technologies to firms – either O&G producers or suppliers – that will be the users of those technologies. This contrasts with the common practice in developed economies in which public R&D institutes undertake exploratory R&D to build capabilities in specific fields and work collaboratively with industry to develop applications. With the prevailing model followed by RIPI, reaching commercialization remains a challenge due in part to the lack of specific skills that are usually available in firms in developed countries.

Improved Oil Recovery Research Institute (IORI)

It is estimated that ordinary technologies are capable of producing only about one third of Iran's oil reserves; production of the remainder requires an enhanced or improved oil recovery (E/IOR) method. To address this need, the IORI started activities in 1980, operating under the NIOC at that time. In 2005, the organization was elevated to the status of a research institute functioning under MSRT regulations and affiliated with the NIOC. This institute has research groups for the following categories: water injection, gas injection and gas condensate reservoirs, tertiary recovery techniques, and production optimization.

There are also other research centres related to oil recovery operating within universities. For example, the EOR Excellence Research Center at Sharif University of Technology conducts experimental and modelling investigations for oil recovery techniques, and for its educational activities it collaborates closely with other universities, national companies and suppliers. Over the past decade, several technologies for enhanced oil recovery have been developed in these research institutes and by some KBFs. Some of these technologies have been exported to other countries in the region.

The Institute for International Energy Studies (IIES)

The IIES is a post-graduate educational and research institute functioning under MSRT regulations and affiliated to the MOP. Starting as a research centre in 1991, its mid- and long-term responsibilities now include helping to meet the goals of the twenty-year Vision of Iran and enhancing the significant role of the oil industry in the scientific, economic, social, political, and international activities of the country. It also assists high-ranking directors in the oil industry in their decision-making by focusing on energy economics, human resources management, planning and financial management, technology strategies, global energy scenarios, international oil and gas markets, and strategic issues relating to the large-scale oil industry. Accordingly, the IIES is mandated to conduct its activities in collaboration with within the framework of the following research centres:

- The Energy Economics Research Center;
- The Management and Human Resources Research Center;
- The Strategic Studies of Technology Research Center; and
- The Law, Environment, and Sustainable Development Research Center.

As a result, the IIES is now considered the hub of the MOP's strategic research activities, taking on the responsibility of managing, outsourcing and attracting scholars.

Universities

The main focus of universities' O&G-related activities has been on education and training. Over the past 10 years, with the increasing demand for the expansion of graduate programmes, some efforts have gone into establishing university groups working on various engineering disciplines and sub-disciplines of relevance to the industry, and in increasing research activities to support these graduate programmes. By 2015, there were 38 universities and technical schools in Iran providing tertiary education of relevance to the O&G sector. Of those, 25 offered bachelor's degree programmes, 18 master's degree programmes and 10 at the doctoral level (table 5.4). In 2015, there were 23,664 students enrolled in petroleum-related tertiary education programmes.

There are currently 34 undergraduate programmes related to O&G in Iran. Table 5.5 shows the number of technical, bachelor's, master's and PhD programmes by petroleum-related disciplines.

Over the past 10 years, several universities have gained prominence in the O&G innovation system following their introduction of various undergraduate and graduate programmes in petroleum-related disciplines. The Petroleum University of Technology (PUT), affiliated with the MOP and originally founded as the Abadan Technical School in 1939, is one of the leading universities for the O&G industry offering BSc, MSc and PhD programmes. In addition, O&G-related research at universities has become much more mature in recent years. Based on the Scimago database, Iran ranked 5th in the world in publications related to chemical engineering and 4th in the number of their citations (table 5.6).

Table 5.4. Student enrolments and organizations in O&G-related disciplines at tertiary level, 2015

Level	Number of organizations	Number of students enrolled
Technical	2	1 914
Bachelor's	25	17 746
Master's	18	3 670
PhD	10	310
Total	55	23 664

Source: IRPHE database.

Table 5.5. Tertiary education programmes by petroleum-related disciplines, 2015

Disciplines	Technical	Bachelor's	Master's	PhD
Petroleum engineering	2	14	15	6
Chemical engineering	2	15	6	2
Oil and gas law, economics and management	0	1	8	4
Petroleum geology	0	0	4	1
Instrumentation engineering and automation in Oil	0	0	2	0
Electrical engineering	0	1	0	0
Civil engineering (marine structures)	0	0	1	0
Mechanical engineering	0	1	1	0
Total	4	32	35	13

Source: IRPHE database.

Table 5.6. Iran's global ranking in chemical engineering publications, 2005 and 2015

Subject	2005	2015
Documents	19	5
Citable documents	19	5
Citations	19	4
Self-citations	15	4
Citations per document	50	27
H Index	24	23

Source: Scimago database (available at: http://www.scimagojr.com).

Table 5.7. University groups involved in O&G-related engineering and geoscience research, 2015

Sub-disciplines	Number of groups
Petroleum engineering/hydrocarbon reservoirs	10
Petroleum engineering/petroleum reservoir engineering	3
Petroleum engineering/petroleum extraction and drilling	10
Petroleum engineering/oil exploration	9
Petroleum engineering/refining	1
Petroleum engineering/petroleum equipment	1
Chemical engineering/gas industry, process and transport	8
Chemical engineering/transfer phenomena and separation processes	1
Chemical engineering/health, safety and environment	1
Chemical engineering/process design for oil industry	1
Chemical engineering/petroleum engineering	1
Petroleum geology	4
Instrumentation engineering and automation in O&G	2
Civil engineering/marine structures	1
Mechanical engineering/applied design for O&G	1
Total	**54**

Source: IRPHE database.

In addition, research groups have been forming around graduate programmes mainly linked to upstream technologies (table 5.7). Since 2015, some of the universities that already have PhD and/or MSc programmes in O&G-related engineering disciplines have been commissioned by the O&G companies affiliated to the MOP to carry out R&D on their behalf in technological areas identified as priority areas. In upstream technologies, the focus of R&D activities is on increased/enhanced oil recovery methods, which are carried out by the Petroleum University of Technology, Sharif University of Technology, Shiraz University and the Islamic Azad University, together with the RIPI. In refining technologies, Tehran University, Shiraz University, Amirkabir University, Sharif University of Technology and Isfahan Universities are undertaking R&D on the upgrading of heavy oil and heavy residues, heavy naphtha isomerization, catalytic conversion of naphtha (CCR), desulfurization of naphtha and middle distillates (HDS) and hydrocracking respectively. In gas processing, Tehran University and Iran University of Science and Technology are undertaking R&D projects on liquefied natural gas (LNG), refining and sweetening methods, the development of gas turbines and smart metering.

5.3.3. Governance bodies involved in STI policy

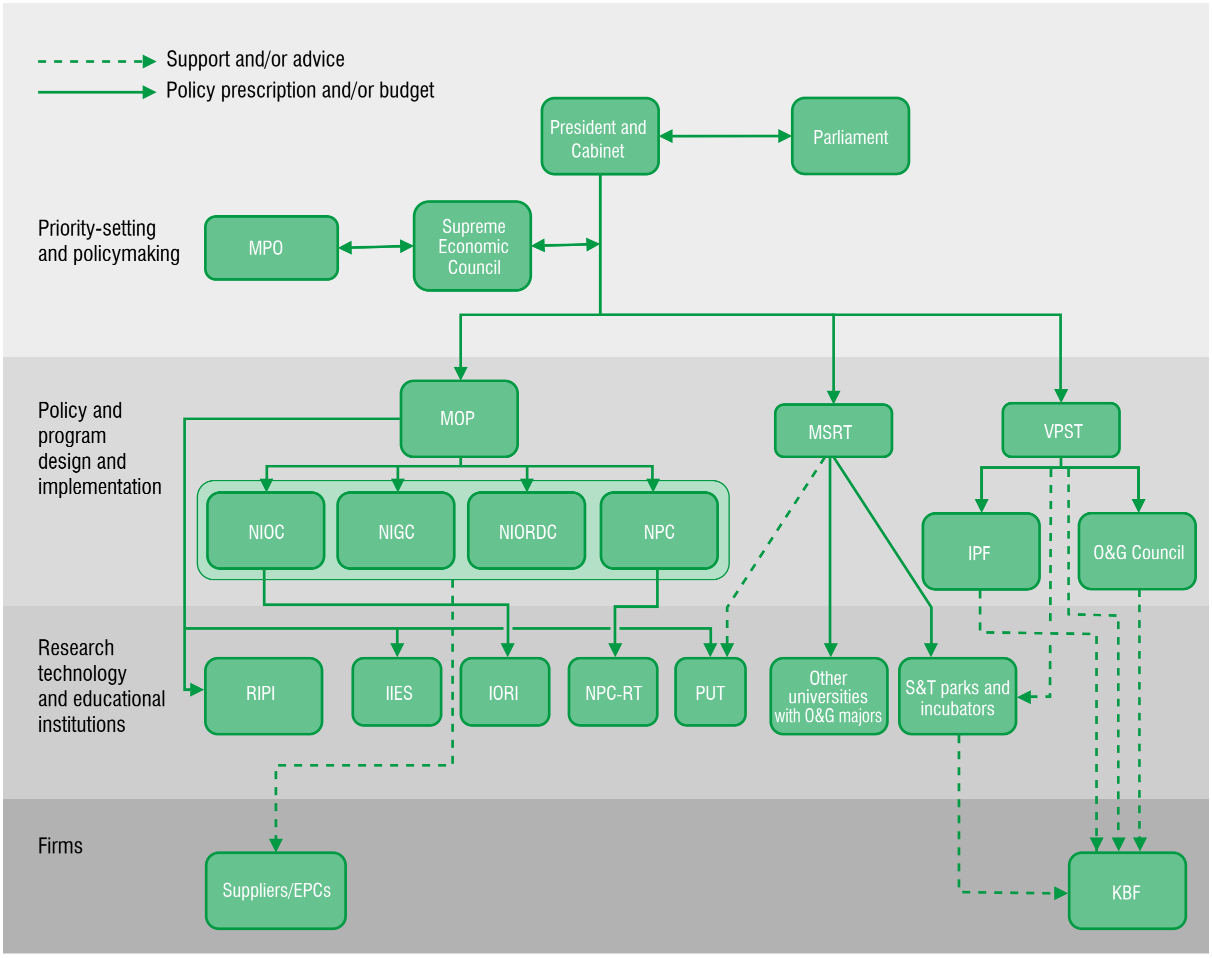
The governance of O&G-related STI policy involves a complex system comprising different actors in charge of strategic priority-setting, defining programmes, policy implementation, the execution of research and innovation projects and related coordination mechanisms. STI policy priorities are generally set at the highest level, by the Supreme Leader and the SCCR. However, they do not play a specific policy formulation and implementation role in O&G beyond the assigning of high priority to the development of O&G under the NMPSE. Prime responsibility for priority- setting in the industry rests with the executive (President and cabinet) and with Parliament. The SEC and Planning and Budget Organization (PBO) play a key role in approving large projects and in allocating funds across bodies in the NIS. Three main bodies are in charge of designing and implementing O&G-related STI policies and programmes (figure 5.2).

The MOP is mandated to oversee all activities related to the exploration, production, distribution and export of crude oil, gas and petroleum-based products in the country. In addition, it takes the lead in defining the policy initiatives to support innovation in the sector. In 2009, the MOP set up a Vice-Ministry of Research and Technology with responsibility for supervising and steering the development, application, transfer and absorption of technologies in the O&G sector. It has four departments: management of technology, high technology, research and commercialization. The Vice-

Ministry carries out a number of programmes to foster innovative efforts (table 5.8). In 2015, a dedicated body, the Organisation for Manufacturing Support and Procurement of Goods for the O&G sector, was created to manage the supply development programme of the MOP and allocate funding for firms.

The MSRT and the SCSRT (especially through its Commission for Energy) are mainly responsible for supporting basic and applied research at universities and research institutes, for human resources development through higher education programmes and for technological development in incubators and S&T parks (table 5.8). The VPST has multiple functions, including contributing to strategic priority-setting, designing innovation policy programmes (see table 5.8) and implementing programmes. Its programme to support innovation by firms covers many industries, including O&G. The VPST hosts the secretariat of the O&G and Coal Council, which runs sectoral programmes to support innovation. The O&G and Coal Council, which was established in 2013, is composed of various stakeholders in O&G, including policymakers, representatives from academia, O&G companies, EPC contractors and private sector suppliers. It conducts strategic analyses of the sector, and has tried to establish channels of communication with the MOP to provide inputs and advice on policy initiatives and regulations of relevance to the O&G industry, particularly on technological development issues. However, such inputs have remained ad hoc. Besides its advisory function, the Council provides financial support for private O&G supplier companies that are already engaged in innovative activities, and thus qualify as KBFs.

Figure 5.2. Institutional mapping of the innovation system for oil and gas



Source: UNCTAD.
Note: Actors involved in petrochemicals are included in this figure but are not discussed in this Review.

5.4. Science, technology and innovation policy in the O&G sector

5.4.1. Visions and assumptions underlying O&G-related STI policies

Historically, policies concerning the O&G sector in Iran have emphasized the creation of production capacity to generate revenues from exploiting these natural resources, relying on international economic transactions (mainly trade and FDI) for the necessary technology inputs. Over the past few years, partly because of sanctions, but also because of the changing mindset of policymakers, there has been an important shift in the overarching vision for STI. There is now greater emphasis on technological learning and on the creation of innovation capabilities to catch up with developed economies. Many (though not all) stakeholders share this broad aspiration, which is also supported by the main policies of the country, such as the Resilient Economy Policy. In this new context, the main vision for the sector is the promotion of upstream and downstream technological development as the means for Iranian firms to enter the regional market as creators of technology.

However, entrenched conceptions of technology and innovation based on a linear perspective of innovation – though increasingly contested – persist and shape various policy initiatives. This has led to a dualistic system in which more system-oriented views of innovation coexist with still dominant linear conceptions about innovation and the way it should occur (see table 5.9). An indication of this duality is how the policy debate perceives technology as a means for catching up. A widespread assumption underlying the design of some STI policy initiatives for O&G is that passive engagement with technology can achieve catching up. In that view, domestic industry and actors can rely on the acquisition of foreign technologies (e.g. ready-made designs, services, capital goods and operational know-how) via imports and FDI inflows without necessarily making simultaneous major commitments to learning efforts by acquiring companies. However, over the past five years, the importance of a more active approach to technology has started to take hold in the policy debate. This perspective emphasizes fostering innovation by local actors to generate substantially changed or new products and processes based on R&D, but also encouraging imitative engineering (see tables 5.8 and 5.9).

Regarding the division of labour in innovation, a sharp distinction is still made between the supposed users and producers of technology, though contesting views are starting to emerge. According to the dominant view, users completely outsource knowledge production to producers, and the producers of technology deliver ready-made technologies to the users, with virtually no interaction envisaged during the innovation process. This perspective views O&G companies as the users of technologies provided by foreign and domestic suppliers, research centres and universities; and suppliers are seen as users of the technologies developed by research centres and universities. Accordingly, the major loci of innovation efforts are the research centres dedicated to O&G, the RIPI and universities. However, the innovative efforts of local suppliers, as the producers of technology for O&G companies are now gradually being recognized and underpin various STI policy initiatives for the O&G sector. Thus, the dominant beliefs have been increasingly contested in policy decision-making processes over the past decade, with a growing recognition that innovation requires a substantial share of innovative efforts to take place in firms, including in SMEs. As a result there is now greater emphasis and support for innovation activities by private SMEs working as suppliers for O&G companies (table 5.9). However, even this new, more systemic conceptualization of innovation in the STI policy arena does not explicitly acknowledge the importance of national oil companies as co-producers of technology, rather than only as users, for fostering innovation in the overall system and increasing their own efficiency. Moreover, owing to insufficient recognition of the interactive nature of the innovation process, none of the policy initiatives for the sector support linkages between firms and other actors.

There is also a major emphasis in policymakers' views on R&D as the main source of innovation, but an alternative perspective has acknowledged imitative engineering and design activities as important innovative efforts that also deserve to be supported. On the one hand, the most common presumption is that more investment in R&D will lead to more innovation. This perspective underpins one of the most important mechanisms to foster innovative efforts in the O&G sector in the form of support of the sector-oriented R&D institutes whose main purpose is to produce technologies on behalf of the industry. On the other hand, other programmes, such as the O&G component of the IPF and KBF Programme of the VPST, nominally support R&D in firms, but they

Table 5.8. STI policy initiatives of relevance to the O&G industry, 2015

Policy initiatives	Instruments	Objectives
Technology Transfer and Development Programme/IPC	Joint ventures with IOCs; other instruments currently being defined.	Promote the transfer of technology from IOCs to domestic EPCs and goods and service suppliers, and increase local sourcing of technologies; improve access to finance.
Programme to source 10 groups of production equipment locally	Public procurement, 85 per cent advance payment of orders.	Foster the local production of 10 types of upstream production equipment considered strategic.
EOR/IOR Megaproject	R&D programme, competitive funding.	Develop EOR methods for specific O&G fields.
Science parks and incubators	Support services for innovating firms.	Promote the establishment of innovative start-up companies.
O&G component of the Innovation and Prosperity Fund	Interest-free or reduced-interest loans, credit guarantees, interest payments on bank loans.	Foster R&D by firms, and support import-substituting reverse engineering.
KBF programme of the VPST	Interest-free or reduced-interest loans, loan guarantees, tax incentives, reduced tariffs, export incentives, venture capital.	Nurture innovative efforts of companies involved in research and technology development; but in reality most of the support is for reverse engineering for import substitution, and not for R&D for development of novel products/processes.

Source: Based on interviews in Iran (November 2015).

also include reverse engineering and imitative design activities for localizing technologies in their definition of R&D, and thus qualify for financial support. However, there is much less attention to supporting, more generally, design and engineering activities of firms that still do not perform R&D. Greater support would enable them to make the shift to formal R&D.

On the issues related to capability-building and innovation, there are two main conflicting views. According to the more established perspective in the O&G sector, innovation is supposed to take place along a linear path, moving from research and development towards commercialization. Similarly, building the capability of various actors is seen as originating in R&D activities and progressing to commercialization. A contrasting view has gained ground in the past five years, which focuses on innovation processes that do not necessarily start with formal R&D, but instead can involve imitative engineering efforts. The emphasis is more on reaching innovation outcomes domestically and building innovation capabilities within firms (see table 5.9).

5.4.2. STI policy initiatives of relevance to the O&G sector

Technology Transfer and Development Programme within the Iranian Petroleum Contract (IPC)

This initiative is being developed and will be set within the broad regulatory framework governing the Iranian O&G sector. The Iranian Constitution forbids foreign actors from owning O&G fields. But to be able to access foreign sources of financing and technology in the implementation of O&G projects, since 1995 buy-back agreements have allowed IOCs to function as service providers to the O&G SOEs. Currently, there is an ongoing revision of the Iranian O&G contract model to resemble a production-sharing agreement, but within the bounds allowed by the Constitution. The contract will allow the NIOC and its subsidiaries to enter into joint ventures with IOCs, but it will require the former to cooperate with local contractors, and it will offer more favourable conditions than buy-back agreements. The contracts will have longer time frames of 20–30 years. Rather than paying a fixed fee to IOCs, as in buy-back agreements, compensation will be flexible, varying according to volume of production, oil prices and the risks involved in single projects. This would make them more attractive to foreign investors. However, unresolved issues remain, such as giving IOCs the right to report reserves in their balance sheets, which could suggest an ownership of reserves and thus be unconstitutional from Iran's perspective.

The new Iranian Petroleum Contract (IPC) will include a Technology Transfer and Development Programme annex, which will outline the mechanisms to promote technology transfer and set local content requirements for foreign firms that operate in Iran. The main objectives of the Technology Annex are to make the

Table 5.9. Framing STI policy in the O&G innovation system, 2015 [51]

Strategic priority setting	Visions	Examples of priority-setting
Overarching STI policy goal	Technological learning and development of capabilities to generate and apply innovation.	• The NMPSE (2011) aims to build capabilities to generate and apply scientific, technological and innovation outputs by 2025. • Statements of the Supreme Leader, Ali Khamenei, and the President, Hassan Rouhani, emphasizing the importance of innovation and technology development.
Sectoral innovation policy goal	S&T development related to O&G as one of the main priorities for the country and basis of regional leadership.	• The NMPSE (2011) assigns top priority to the allocation of resources to S&T efforts in O&G activities, highlighting their importance to boost Iran's competiveness in this sector.
Programme design	**Assumptions**	**Examples of programme design**
Engaging in technology development	Passive: accessing foreign technologies (e.g. ready-made designs, services, capital goods, operational know-how) through imports and FDI inflows.	• Proposal for long-term strategic alliances with oil-importing countries, "oil for technology" arrangements. • Technology Transfer and Development Programme (TTDP)/IPC.
	Active: innovation-driven, generating substantially changed or new products and processes based on R&D, but also reverse engineering.	• O&G component of the IPF • KBF programme of the VPST
Division of labour in innovation and interactivity	R&D to be undertaken by public research institutes, universities and suppliers, as providers of technology. O&G companies use the technologies of research institutes, and suppliers use the technologies of research institutes and universities.	• R&D programme in public research institutes: R&D on behalf of firms, with output commercialized "ready-made" for them. • Technology Transfer and Development Programme/ IPC. • Programme to source10 groups of production equipment locally. • EOR/IOR megaproject
	Substantial share of innovation to take place in firms, including in SMEs and KBF suppliers, as sources of technological dynamism in the system.	• O&G component of the IPF • KBF programme of the VPST
Innovative efforts to be undertaken	Focus on R&D leading to commercialization.	• R&D programme in public research institutes. • EOR/IOR megaproject
	Emphasis on R&D, but also on reverse engineering for import substitution included in the definition of R&D, and qualifying for financial support.	• O&G component of the IPF • KBF programme of the VPST
Path of capability-building and innovation	Follow innovation stages along a linear pattern, from research to commercialization.	• R&D programmes in public research institutes. • EOR/IOR megaproject
	Focus on innovation processes that do not necessarily start with formal R&D, but with imitative engineering and design.	• O&G component of the IPF • KBF programme of the VPST

Source: UNCTAD.

O&G contracts serve as mechanisms for the transfer of technology from IOCs to domestic EPCs, and from them to goods and service suppliers, thus increasing local sourcing of technologies. The initiative intends to implement the MULC Law that requires local sourcing of goods and services amounting to at least 51 per cent of the overall value of projects. The instruments to be used to stimulate the flows of knowledge and increase local sourcing, as well as the expected roles that MNEs and large domestic private firms should play are currently being decided. Moreover, technology transfer and local content requirements are under discussion only in the context of oil-field development projects.

Programme to localize production of 10 groups of oil production equipment

The MOP has initiated a public procurement programme to support the local production of 10 kinds of what it considers to be strategic equipment, namely equipment for wellhead and downhole completion, drilling equipment, pumps, valves, pipes, motors, rotating equipment, downhole tools and intelligent pigs. The Organisation for Manufacturing Support and Procurement of Goods, founded in 2015, has started to place orders on behalf of the MOP for upstream equipment for the O&G sector that is either not produced domestically or is currently below international standards. This organisation procures the equipment on behalf of the NIOC and its subsidiaries, manages the purchasing process and oversees the development of the equipment by the suppliers. The MOP aims to stimulate the innovative efforts of supply companies through various incentives, including guaranteeing a market, committing to purchase the products that are to be developed and offering financial support for the introduction of new items through an 85 per cent advance payment of the orders.

Enhanced oil recovery/improved oil recovery (EOR/IOR) megaproject

The MOP and the MSRT signed a memorandum of understanding to launch an R&D programme on enhanced oil recovery. The programme will involve nine universities, including the University of Tehran, University of Shiraz and Sharif University of Technology among others, and the RIPI will implement R&D projects on EOR. Post-sanctions, it might also include participation by IOCs. The projects will focus on different technologies, such as gas injection and polymer injection, and be application-oriented, with each organization being responsible for different oil fields.

O&G component of the KBF programme and the IPF

The programme has two main components: a horizontal one applying to firms across a broad range of sectors; and a vertical (or sector-oriented) one, including support for O&G companies via financial resources channelled through the IPF. The programme aims to foster the development of firms engaged in the development of new technologies and implement the Law on Support for Knowledge-Based Firms and the Commercialization of Innovations and Inventions. A process of evaluation of applying companies based on peer review has been established. Although the objective is to back R&D and reverse engineering in firms, in reality, most of the support – about 80 per cent – goes to reverse engineering for import substitution.[49] By 2015, 35 projects in the O&G sector had been funded, and by September 2016, 152 O&G firms had requested funding from the IPF, while around $25 million had been approved to support these firms.[50] This scheme uses various measures such as soft loans, loan guarantees, tax incentives, tariffs, export incentives, and, more recently, venture capital. By September 2016, 154 O&G firms were confirmed to be KBFs, including about 25 large companies and many SMEs.

5.5. Assessment of the O&G innovation system

UNCTAD's 2005 STIP Review observed that a linear perception of the innovation process was widespread in the formulation of STI policies in Iran, and that a vision linking innovation to economic growth was lacking. While such linear perceptions have not been completely overcome, there have been important steps in the right direction. There have been efforts to formulate macro and O&G-related visions for STI policy, and these tentative visions have shifted attention in a positive direction by giving increasing emphasis to technological learning and innovation as the foundation of economic growth and competitiveness. Nevertheless, in translating visions to policy programmes for the O&G sector, there are still important contradictions and conflicting views about how innovation should occur, and how the resulting policy mix should foster innovation in the sector. On the one hand, a systemic perspective that emphasizes an active engagement with innovative efforts by firms has gained strength since 2007, following the creation of the VPST. On the other hand, dominant perceptions of innovation as linear, and technology as something that can be transferred in a "plug-and-play" mode remain significant within the MOP and O&G SOEs. As a result, in horizontal policy programmes that are relevant for many sectors and benefit the O&G sector, there has been a greater focus on the active involvement of firms, especially private firms in innovative efforts, broadly defined to include engineering and design activities. In contrast, sector-specific programmes have not created incentives for firms (NOCs, EPCs and other supplier firms) and other actors to master and build upon acquired technologies, but simply to act as recipients of technologies developed elsewhere. Overall, efforts made so far need to be expanded, as development of the sector specifically from an NIS view is only half way to full development.

This review of the Iranian O&G innovation system has identified a number of positive developments that have taken place over the past decade, and several challenges that hinder its functioning and its potential to contribute to long-term knowledge-based development. The main advances in recent years include: (i) the shifting emphasis of policy thinking from creating production capacity to learning and innovation, and emerging views contesting the dominant, "passive" approach to technology and underscoring the importance of R&D, but also engineering activities for innovation; (ii) increasing support through various initiatives (e.g. IPF, S&T parks, incubators, public procurement) for promoting innovation activities of private firms supplying O&G companies; (iii) the emergence of a rather small, but very dynamic business sector that took advantage of the situation created by the sanctions to undertake import-substituting reverse engineering, or to advance beyond imitation and engage in creative engineering and R&D for the introduction of novel products or processes; and (iv) a major expansion in the number of S&T organizations providing O&G-related tertiary education.

In the past decade, suppliers of equipment, services and materials have made considerable efforts to build capabilities to innovate. Although the majority still rely on minor improvements, an increasing number are involved in engineering and design activities, often starting with reverse engineering before creating their own designs. A few domestic suppliers have even managed to develop R&D capabilities. However, most are SMEs, while the start-ups are particularly small and struggle to expand their market shares and compete with international suppliers.

The role of the accreditation system (testing and certification) for equipment suppliers in O&G is important and merits policymakers' attention. Local equipment supplier firms experience difficulty in obtaining the certifications needed to operate in the O&G sector, either domestically or internationally. National certification bodies and testing infrastructure (for example, experimental wells) that could help supplier companies acquire greater capabilities are lacking. The O&G sector would benefit from the Standards Research Institute (the Iranian standards organization) strengthening its standards and certification services. This should include testing and engineering consultancy services that contribute to problem-solving aimed at assisting O&G firms to meet international standards and obtain the required certification of their products.

In contrast, oil-refining and gas-processing SOEs have not taken significant steps on the cumulative path towards greater technological dynamism since the 2005 STIP Review. They continue to rely on the acquisition of new equipment, services, designs or complete production systems, with perhaps minor changes during operational activities, as the main means of introducing technological changes for improving efficiency. EPC contractors rely on existing designs with minimal changes. The limited capabilities of the lead firms in the O&G value chain have system-wide implications beyond their own operational performance. The sector views FDI as a necessary source of new technology to assist in reaching production targets. However, unless the national oil companies engage with technology, and build their own technological capabilities to help meet their business objectives, FDI inflows may do little to alter their passive dependence on imported technologies in the long run.

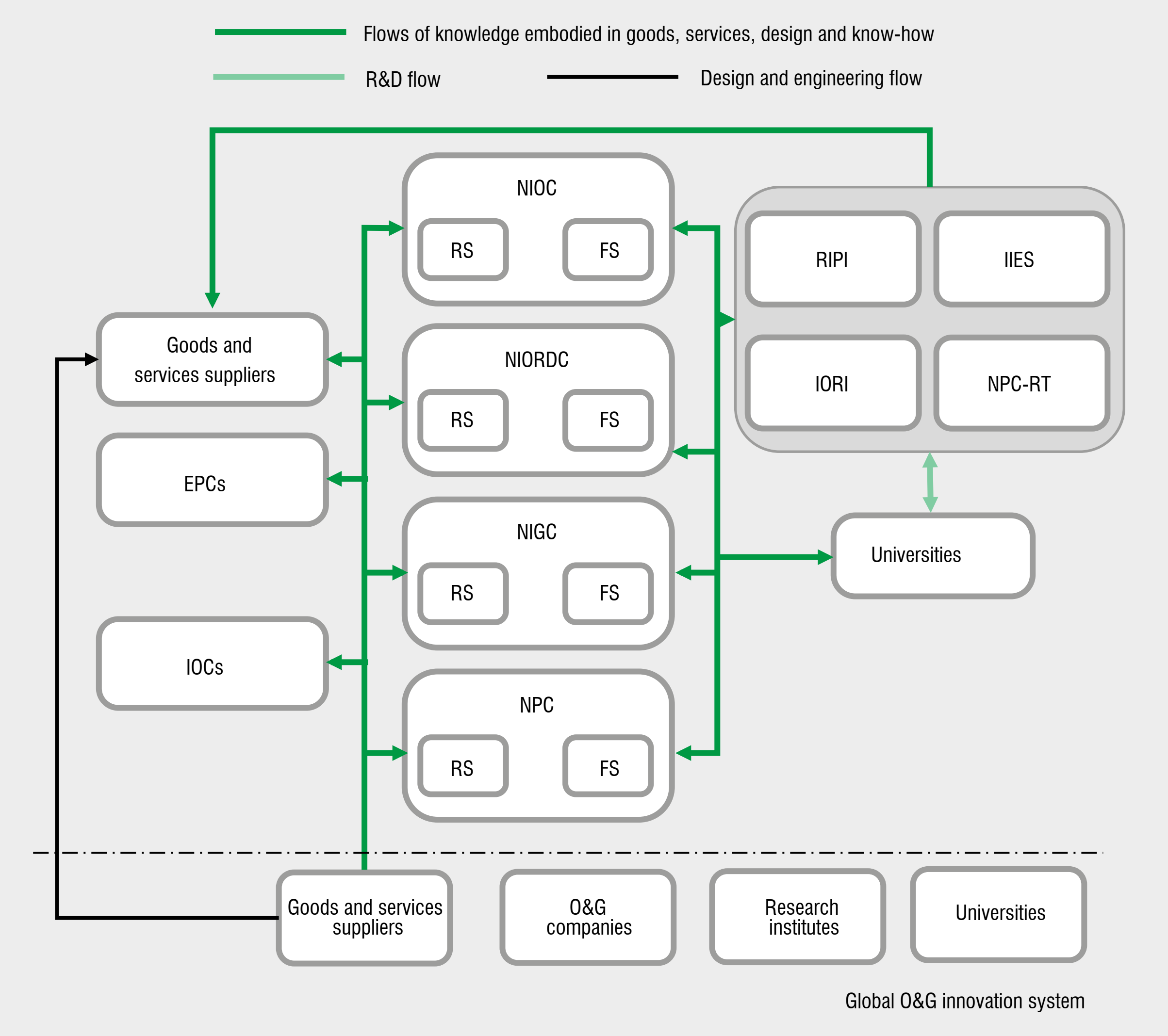
The most widespread types of linkages in the Iranian O&G innovation system involve flows of knowledge

Table 5.10. Local content and technological capabilities in O&G

Number of supplier companies in the vendor lists of the four main companies	Number of local suppliers: 1,104 companies Number of foreign suppliers: 1,660 companies
Number of KBFs in the O&G sector	154 companies
Share of local content in the O&G value chain	
Exploration, geophysics and geology	45–67 per cent
Drilling engineering (onshore & offshore)	Around 100 per cent
Drilling services	70 per cent
Drilling goods and well completion	60 per cent
Local marine pipeline engineering	80 per cent
Local onshore pipeline engineering	100 per cent
Installations of oil processing, and gas and oil refining	More than 60 per cent of the whole project

Source: MOP communication.
Note: Depending on the methodology used to calculate these figures, actual local content may vary, for example due to imported components by some firms.

Figure 5.3. Linkages among actors involved in innovation, diffusion and use of technologies in O&G



Source: UNCTAD, based on interviews (November 2015).
Notes: RS: regional subsidiaries undertake production activities in particular regions; FS: functional subsidiaries handle specific functions such as offshore engineering and procurement.

embodied in goods, services and "ready-made" designs, knowledge of the use of technologies, and information about technological needs for production or operations. Such flows are also the main types of connections with the global O&G innovation system (figure 5.3). The linkages among the lead firms – NIOC, NIORDC, NIGC and NPC – and their regional and functional subsidiaries, as well as EPCs, other goods and service suppliers, and the IOCs operating in Iran comprise knowledge that is embodied in turnkey production facilities, equipment, services, ready-made designs and specifications, as well as knowledge on the use of technologies and requirements identified during the operations of production facilities. The lead firms in the O&G value chain and their subsidiaries, but also EPC contractors, are mainly concerned with operational performance. Because they do not themselves engage in developing new technologies – besides those that are a by-product of operations – for which more complex engineering, design or scientific knowledge would be required, there is no demand for such types of knowledge. Instead, their demand is for knowledge that is embedded in tried and tested commercial goods or services, often as part of a complete turnkey production system.

The number of S&T organizations providing O&G-related tertiary education in Iran increased from only 1 in 2005 (as reported in the 2005 STIP Review) to 38 in 2015. In the university system, research activities of relevance for the O&G industry are still at an initial stage, but gaining strength, and universities and technical schools are beginning to play an important role in providing qualified human resources for the O&G sector. Similar to the RIPI, universities still pursue a linear path of innovation, and are suppliers of complete innovations to firms. This is problematic and not conducive to the development of capabilities within firms, which should form the core of the innovation system.

Petrochemicals actors are included in this figure but are not discussed in the report.

Linkages based on flows of engineering and design skills and expertise in learning to carry out basic designs and change technologies are notable for their absence. Upstream investment projects through buy-back contracts involving IOCs and foreign contractors, and domestic EPCs and engineering subsidiaries of the NIOC have not given due attention to transfers of design and engineering knowledge for learning to design production facilities and increase innovation capabilities. Equipment and service suppliers have relied more on their own in-house engineering efforts, and do not seem to have drawn on links to the RIPI or universities to acquire engineering and design expertise.

In a fully fledged innovation system, linkages among producers, suppliers, R&D institutes and universities, both within the system and with external sources of knowledge, comprise not only flows of knowledge embodied in goods, services, ready-made designs and knowledge in the use of technologies; they also comprise important flows of engineering, design and scientific knowledge to master and/or change technologies. This is because innovation and learning are inherently interactive. Innovation does not require only R&D inputs; fundamental inputs for innovation also come from production and non-R&D engineering and design activities performed by firms. The linkages among actors in the system articulate and create these interdependencies among various types of knowledge inputs and technological activities demanded in the innovation process.

In Iran, the articulation among the actors involved in technology production, diffusion and use is underdeveloped (see figure 5.3). Currently, linkages among Iranian actors within both the domestic and international O&G systems are confined to flows of knowledge embodied in equipment, machinery, components, materials, services, ready-made designs, and operational know-how. Domestic and international linkages comprising flows of engineering and design skills and expertise in modifying technologies, or R&D linkages concerned with more novel scientific and engineering knowledge inputs, are an exceptional occurrence or non-existent. The RIPI and innovative suppliers undertake innovative activities in isolation from other key actors, and are expected to deliver ready-to-use technologies to final users.

The 2005 STIP Review had identified the importance of fostering R&D collaboration with foreign O&G companies and R&D institutes for the development of the sector. However, since then, this type of collaboration has all but disappeared due to the sanctions and the resulting difficulties to engage in international collaboration. Existing linkages within the system and with the global system involving knowledge embodied in goods, services and operational know-how are so weak they are not conducive either to innovation or to learning to adopt new technologies. The existing flows of knowledge embodied in capital goods or operational know-how, for instance, are very important, but not sufficient to enable the mastery of and changes to technologies. The latter require design, engineering, and scientific knowledge flows to build the appropriate capabilities. According to the results of Iran's second national innovation survey, only 16 per cent of O&G firms have been involved in collaborative R&D, while 64 per cent have purchased machinery and equipment needed for their production. The survey also identified the lack of financing as a major barrier to innovation.

5.6. Recommendations

Based on the above analysis of Iran's O&G sector, this section proposes a number of policy recommendations to capitalize on the achievements made so far and address the challenges.

(i) Promote collaborative learning and the development of knowledge linkages in the O&G innovation system combined with capability-building strategies

Key aspects of innovation and learning processes, including their peculiarities in a developing-country context, should be taken into consideration when promoting collaborative learning and capability-building strategies. Policymakers, executive officers and firms' managers should consider the following:

(a) The importance of engaging actively with technology to promote technological learning for technological catching up. The acquisition of the skills and knowledge necessary for changing technologies does not arise as an automatic by-product of firms' production activities or routine operations; rather, it requires active learning efforts, and therefore implies additional expenditures by firms.

(b) R&D comprises only a narrow sub-category of the innovation activities needed to achieve innovation outcomes, whether in developed or developing economies. Other, non-R&D activities important for the innovation process include conceptual, basic and detailed engineering knowledge and skills, trial production capabilities, scaling up to reach a commercial scale, redesigning, tooling up, imitative engineering and industrial engineering.

(c) An imperative element of a mature sectoral innovation system concerns the relations and networking between the actors in the sector. Collaboration is essential both among domestic actors and with foreign firms for the evolution and development of the sector. For policymaking, interactive learning is a key process that must be enabled through the design of appropriate mechanisms for promoting a smooth transition to a much more mature sectoral innovation system. Developing clusters is a common approach used to promote active collaboration. The knowledge flows between S&T organizations and companies need to be strengthened. In this regard, the design of mechanisms to support knowledge-related linkages involving enterprises and the S&T infrastructure should consider including the following:

- Measures to stimulate linkages among actors in the innovation system should be tailored and appropriate to the varying levels of capabilities of existing firms and the different types of knowledge and expertise they demand.
- Envisaged linkages should not be geared to delivering ready-to-use goods and services to firms; instead, they should aim to involve firms as active learners, and subsequently, as co-creators of technology.
- Consequently, the types of knowledge flowing through these linkages should take the form not only of information on how to use a technology or routine services, but also engineering, design and eventually scientific knowledge and skills that underlie the particular technologies being dealt with.
- Those linkages and the internal activities of S&T organizations should not be seen as substitutes for the internal technological efforts of enterprises, but rather as complementary and mutually reinforcing.

(ii) Promote supplier development, including through MNE-local firm linkages.

This could be supported through suitable local content requirements and the design of a technology strategy for the sector. Diverse policy options are available. Several middle- and low-income O&G-producing developing countries, such as Brazil, Malaysia and Nigeria, have used local content policies to foster the development of supply industries with some success. This has involved the establishment of specific regulations and local content targets relating to value added and/or employment. There can be considerable variation in the design and implementation of local content policies with respect to mandatory targets, definitions of local content, types of incentives and sanctions, the range of activities to be promoted (e.g. technology transfer, training and local R&D) and forms of collaborative arrangements among stakeholders involved in policy implementation (e.g. types of involvement of MNEs, domestic O&G companies and EPC firms). Another approach widely used in various countries and in different sectors is the implementation of supplier development programmes involving MNE subsidiaries without explicit targets for local content. Often-cited examples of the successful use of this approach, although not in the O&G sector, are Singapore's Local Industry Upgrading Programme and Ireland's National Linkage Programme. Policy measures to encourage MNE subsidiaries to establish linkages with domestic suppliers include public-private partnerships, cost-sharing arrangements between the government and MNEs, public financing of selected activities linking MNE subsidiaries, use of suppliers credit and tax credits.

(iii) Foster the accumulation of innovation and managerial capabilities by O&G SOEs and private large companies as lead firms in the O&G value chain.

Because of the contractor-driven nature of development projects common in the O&G sector, and widely adopted in Iran, capacity-building in engineering firms acting as EPC contractors should be a major policy target. In addition, national O&G companies are the lead operators and project owners, and as such, they are the ultimate source of demand for innovation in the system. If they are locked in at the lowest level of technological dynamism, innovation in the whole innovation system is hindered. Thus, it is strongly advised that the MOP also target the O&G SOEs (including parent companies, regional subsidiaries and functional subsidiaries) and encourage their active participation in technology development and transfer arrangements.

Furthermore, the O&G SOEs should understand the importance of developing management capabilities for large projects as this is a soft technology needed even prior to achieving hard technological capabilities. Since O&G is the main sector of Iran's economy, developing the managerial capabilities (in addition to technological capabilities) of the actors in this sector will improve overall innovation performance. An effective tool for this could be government support for the establishment of strong private general contractors and large EPC and engineering, procurement, construction and finance (EPCF) companies that can actively engage in major MOP development projects in the O&G sector. These firms could develop the capacity to arrange complete project financing using a mix of domestic financing (via domestic financial institutions and financial instruments) and foreign financing. It might be argued that for such a large sector, big actors are needed that can implement different parts of large projects and manage key issues, especially financing. Hence, it is desirable to create powerful enterprises fully involved in the development of major projects.

The main instruments could be the use of engineering service contracts and joint ventures involving IOCs and O&G SOEs, domestic EPC and engineering and procurement firms and the regional and engineering subsidiaries of SOEs under the Technology Transfer and Development Programme (TTDP) of the Iranian Petroleum Contract. The TTDP should incorporate a major component involving complementary learning by the domestic companies that are supposed to be the transferees of acquired technologies. For this purpose, the programme could follow a two-pronged approach. First, under the programme, the domestic SOEs and EPCs would create in-house facilities and resources for undertaking basic engineering and conceptual design, both at the corporate level and at the level of each subsidiary, and aim to expand and formalize these resources and structures progressively over time, undertaking increasingly complex and formalized R&D. These initial basic and conceptual engineering resources and facilities will act as the in-house repository of absorptive (see Bell, 2007, for examples in various sectors) and creative capabilities enabling a progressively active engagement with technology via joint ventures and engineering service contracts. The SOEs should be able to use acquired technologies, integrate systems and sub-systems, and manage and oversee development and expansion projects carried out with other partners. The EPCs should be able to formulate technical problems and research questions for the further development of technologies, provide detailed specifications, and engage in problem-solving, both in-house and in joint projects.

The second component of the programme would comprise active engagement with external sources of knowledge (engineering service suppliers and IOCs) to receive three main types of knowledge flows: knowledge embodied in production facilities, equipment, services, designs and specifications; operational know-how; and engineering and design skills to change technologies (see Mitchell et. al., 2011; Ockwell et. al., 2010 and Bell, 1990). The first two components are the main staple of service contracts. The third normally needs to be negotiated as a separate component. SOEs and EPCs should embed such explicit components in each development project contract, and in greenfield projects for O&G fields, refineries, and gas-processing plants, but also in expansion, upgrading, maintenance and other service contracts (e.g. EOR/IORs), until a critical mass of engineering and design knowledge has been built in-house and the firms are able to undertake their own R&D.

(iv) Develop public procurement instruments and shape the financial institutions and tools needed to support both the supply and demand side.

In order for a sectoral innovation system to become fully effective, it needs a supportive financial system that provides three kinds of financial services: venture capital and angel investors for entrepreneurial and innovative activities that enable the creation of a body of pioneering SMEs; institutions that fund development projects, especially major ones, so that domestic firms can manage the entire project in collaboration with KBFs or international firms; and mechanisms for covering risk, such as insurance funds, and institutions that spread or manage the risk that is inherent in innovative activities.

The general focus of existing incentives should be on firms that already carry out R&D activities. However, only a few O&G suppliers possess R&D capabilities and can take advantage of these mechanisms to further build their capabilities. To some extent, it will be necessary to allow some flexibility in determining the kinds of innovative efforts that qualify for support, such as engineering and design activities, rather than just R&D. It would be advisable to formalize the eligibility for funding of engineering and design activities geared to the development of technologies that are new to the market under the existing schemes, and to scale up this element of the programme, focusing not only on start-ups, but also on established firms. It would be useful to also establish the financial institutions needed to finance the different firms over different life cycles. Possibly this could be complemented by a grant scheme to stimulate firms to strengthen their engineering and design activities, allowing them subsequently to transition to R&D activities. Instruments that help boost the demand for innovation could also be strengthened, as limited demand can be a major constraint.

A public procurement policy to help motivate technology development projects and support the development of O&G suppliers' capabilities was introduced in 2015 for 10 categories of O&G equipment. This could be expanded beyond the selected upstream technologies. Financial support for standardization and certification could also be introduced to assist market entry. In addition to these two measures, engineering and consultancy services for firms could be provided to assist them in meeting the requirements contained in procurement contracts and in certifying their products. Also, policy measures could be extended to include the majority of O&G firms that are non-innovators, or whose innovative activities are based on very minor changes during production activities or through the acquisition and assimilation of external technologies. Important instruments for this would be tax incentives and grants to support firms' investments in training to build human capital for undertaking more complex, technology-changing activities.

(v) Revise the O&G sector's institutional set-up to improve coordination and foster a more modern, systems approach to innovation

There is room for improving STI governance by ameliorating horizontal coordination among the key O&G policymaking bodies and changing the mind-set of some policymakers so that they adopt a systems approach to innovation policy. Along with a revision of the sector's institutional set-up, it would be desirable to increase the participation of the productive sector in high-level decision-making for both strategic priority-setting and programme design. Increased horizontal coordination in programme design and implementation among the main policy bodies should also be fostered to align programmes in the implementation of strategic priorities and create synergies among industrial, research and innovation policy objectives and initiatives.

In conclusion, a policy mix that caters to the differing demands for knowledge-oriented linkages of various types of firms should be put into place. First of all, SOEs and large EPC companies should engage actively with technology development. The MOP and affiliated companies need to realize that they are responsible not only for O&G production, but also for technology development.

For the small set of enterprises that already possess R&D capabilities, grants for firms to collaborate with R&D institutes or universities, matching grants and tax deductions for collaborative R&D are potential instruments to stimulate joint R&D. Those firms whose current efforts at innovation are centred on imitative and creative engineering and design activities, rather than on formalized R&D, could be assisted with grants to undertake joint design and engineering work with S&T organizations, and with the provision of innovation vouchers allowing them to purchase services (e.g. standards, certification and testing, consulting for problem-solving, training) from those organizations. As for firms whose innovative efforts are related to the acquisition and assimilation of external technologies, policies should be concerned with creating incentives for flows of qualified human resources from S&T organizations to those firms and for introducing training mechanisms. This could include, for instance, subsidized training programmes, placements of engineering graduates, and temporary secondments of personnel from R&D institutes to firms. Furthermore, local content policies could be designed and implemented widely throughout the sector in order to enhance technological collaboration between local firms and international companies, and foster the development of local firms' technological capabilities.

NOTES

[1] Source: Scopus database at www.scopus.com.

[2] R&D has accounted for about 0.5 per cent of GDP during the last decade. The current target is 4 per cent by 2025.

[3] The rate of unemployment for educated people is around 20 per cent compared with the overall unemployment rate of around 10 per cent.

[4] For example, the VPST, the Innovation and Prosperity Fund (IPF) and 16 strategic and emerging technology councils.

[5] In 2016, the shares were estimated to be around 20 per cent and 35 per cent respectively.

[6] There are discrepancies in R&D figures reported by different data sources. According to the data submitted by Iran to the UNESCO Institute for Statistics, GERD increased from 0.50 per cent in 2001 to 0.67 per cent in 2008, fell to 0.28 per cent in 2009 and then increased again to 0.33 per cent in 2012. More up-to-date figures provided by the VPST are higher than the UNESCO figures (0.55 per cent in 2012). These differences are indicative of inconsistencies in methodology and reporting.

[7] See: http://statnano.com/ and http://www.biotechmeter.ir/

[8] In Iran, firms that have been certified by the VPST as being knowledge-based are eligible for support from the IPF and other public agencies.

[9] High-technology-intensive goods account for 4.1 per cent of Iran's merchandise exports (see World Bank, at: http://data.worldbank.org/indicator/TX.VAL.TECH.MF.ZS). However, World Bank and UNCTAD data differ owing to differences in methodology.

[10] Currently, the *Oslo Manual* (OECD/Eurostat, 2005), which provides guidelines for collecting and interpreting innovation data, only deals with the business sector. Guidelines for innovation in the public sector are under development. The revised version of the Oslo Manual, currently in progress, will also deal with other types of innovation and innovation in other sectors, such as agriculture.

[11] In countries of the Gulf Cooperation Council (GCC), the share of oil and gas in GDP is generally between 30 and 50 per cent.

[12] The share of agriculture in GDP has remained stable at just below 10 per cent according to national data from the MPO, but according to international data, it shows a gradual decline (table 3.1). Meanwhile, the share of industry is about 40 per cent, of which manufacturing accounts for one quarter (about 10 per cent of GDP).

[13] See: http://donya-e-eqtesad.com/SiteKhan/995619 and http://www.isna.ir/news/93092012362/ (in Persian).

[14] See WTO database at: http://stat.wto.org/CountryProfile/WSDBCountryPFView.aspx?Language=E&Country=IR.

[15] See: http://data.worldbank.org/country/iran-islamic-rep. The latest report by Iran's Statistical Centre indicates an 8.3 per cent inflation rate in September 2016 and 4.4 per cent GDP growth in the second quarter of 2016 (https://www.amar.org.ir/).

[16] See UNESCO's UIS database at: http://data.uis.unesco.org/Index.aspx?queryid=166.

[17] Based on interviews.

[18] Ministry of ICT database at: http://mis.ito.gov.ir/web/en/core-ict-indicators (accessed in September 2016).

[19] See:http://www.cra.ir/Portal/View/Page.aspx?PageId=78048598-94b9-4d71-8f22-5ad95db8b784&t=24.

[20] http://www.airbus.com/newsevents/news-events-single/detail/from-the-a320-to-a380-iran-air-selects-the-full-airbus-jetliner-portfolio-for-its-fleet-modernisation/.

[21] EnerData, 2016, at: https://yearbook.enerdata.net/#energy-intensity-GDP-by-region.html.

[22] The ecological footprint per capita is a measure of human impact on the earth's ecosystems, and measures the use of biological resources per person in the country. This data is produced by the Global Footprint Network.

[23] World Health Organization, at: http://www.who.int/country/irn/en.

[24] However, interviews suggest that complex reimbursement practices are an issue, and delays in payments by insurance companies are common. A wave of privatizations has created more competition among insurance companies, though, which may lead to improvement.

[25] Informal estimates based on interviews.

[26] Based on interviews.

[27] Based on interviews.

[28] Iran Satistical Center *Labour Force Survey*, 2016.

[29] World Bank (2014). http://data.worldbank.org/indicator/SP.POP.GROW?cid=GPD_2&end=2014&start=2001&year_low_desc=true (accessed 7 July 2016).

[30] http://nano.ir/index.php?ctrl=section&actn=get_section&lang=2&id=22.

[31] It was initially a technology cooperation office and was later renamed.

[32] See: http://www.scimagojr.com/countryrank.php?year=2015.

[33] Recent examples of its important reports on STI include those on Iran's FYDPs, how to strengthen the institutional frameworks for technology transfers (IPRC, 2015a), VC activity (IPRC, 2015b), biotechnology regulation, the national organization of IPR support (IPRC, 2014), and an assessment of the activities of the VPST.

[34] The preparation of key innovation policy regulations, such as the NTBF programme (Law of Knowledge-Based Firms) or the IPR law, currently under consideration, has typically gone back and forth between the IPRC, Parliament, its legal bodies and relevant arms of government.

[35] Article 56, Amendments for Government Financial Regulations Act (2) of 2015, approved by parliament in March 2014.

[36] This is one of the main responsibilities of the VPST in the Resilient Economy programme's action plans. See: KBF law database, at: http://daneshbonyan.isti.ir/ (in Persian).

[37] The laboratories were devised based on a scalable model, with features to facilitate "training-the-trainers", at an approximate cost of $150,000 per laboratory. The costs were shared as follows: 40 per cent by the VPST, 30 per cent by the Nano committee and 30 per cent by participating schools.

[38] The format is a 10-day workshop, including both theoretical and practical training. The latest Olympiad was attended by 18,000 girls and 10,000 boys at high school level.

[39] For a complete list of areas, see: http://en.isti.ir/index.aspx?fkeyid=&siteid=30&pageid=7547.

[40] See: http://www.ifb.ir/cms.aspx?tabId=207.

[41] Based-on international rankings such as Trends in International Mathematics and Science Study (referred to as TIMSS).

[42] Source: http://en.techpark.ir/ (accessed in September 2016).

[43] From FDA database.

[44] Charaghali (2013): See GaBI Online, at:www.gabionline.net/Biosimilars/News/Production-of-24-biogeneric-products-in-Iran-by-2012.

[45] Based on interviews in Iran in November 2015.

[46] Iran has used buy-back agreements covering exploration and field development since 1995. They consist of contractual arrangements whereby a contractor, normally an IOC, carries out exploration and field development activities for which it is remunerated in the form of a share of petroleum produced during a limited 5–7-year payback period.

[47] Based on interviews in Iran in November 2015.

[48] In experimental development, the performance and reliability of a new or changed process need to be demonstrated at different scales. In the petroleum industry, bench scale plants use micro-reactors, pilot scale plants rely on reactors and catalyst volumes of up to 100 litres, and demonstration and semi-commercial plants contain equipment and processes similar to a commercial scale plant.

[49] Reported in field interviews in Iran in November 2015.

[50] Source: *IPF Report*, September 2016.

[51] See Lall and Teubal (1998), Bell (2014) and OECD (2014) on the role of visions, models and conceptual framing of STI policy.

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