Israel needs to prepare for tomorrow's science-based industries.

Daphne Getz and **Zehev Tadmor**

A miniaturized device developed in Professor Moshe Shoham's robotics laboratory at the Technion Institute of Technology in Haifa. Based on micro-electro-mechanical systems technology, the tiny robot can theoretically be guided inside the body via an external controller to perform a variety of medical tasks in a much less invasive way than currently possible. *Photo: © Technion Institute of Technology*

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Daphne Getz and Zehev Tadmor

INTRODUCTION

A geopolitical landscape in rapid mutation

Since the Arab Spring of 2011, the political, social, religious and military realities of the Middle East have been profoundly remodelled through regime change, civil war and the emergence of opportunistic politico-military sects like Da'esh (see Chapter 17). In Israel's wider neighbourhood, relations between the Western powers and Iran could be at a turning point (see p. 387). In the past five years, there has been no tangible progress towards a peaceful solution to the Israeli–Palestinian conflict, a state of affairs which may have negative repercussions for Israel's international and regional collaboration, as well as its progress in STI. Despite the tensions, there are instances of academic collaboration with neighbouring Arab countries (see p. 427).

At home, the political leadership was renewed in the March 2015 elections. In order to obtain a ruling majority in the Knesset – the Israeli parliament –, the re-elected Prime Minister Binyamin Netanyahu has formed a coalition government with *Kulanu* (10 seats), *United Torah Judaism* (6 seats), *Shas* (7 seats) and *Bayit Yehudi* (8 seats), which, together with his own *Likud* party (30 seats), gives him a ruling majority of 61 seats in the Knesset. For the first time, a coalition of Arab–Israeli parties has obtained 14 out of the 120 seats in the new Knesset, making it the third-largest bloc in Israel's political landscape after the *Likud* and the *Zionist Camp* (Labour) party led by Isaac Herzog (24 seats). Arab Israelis are thus in a unique position to influence the legislative process, including as concerns issues related to STI.

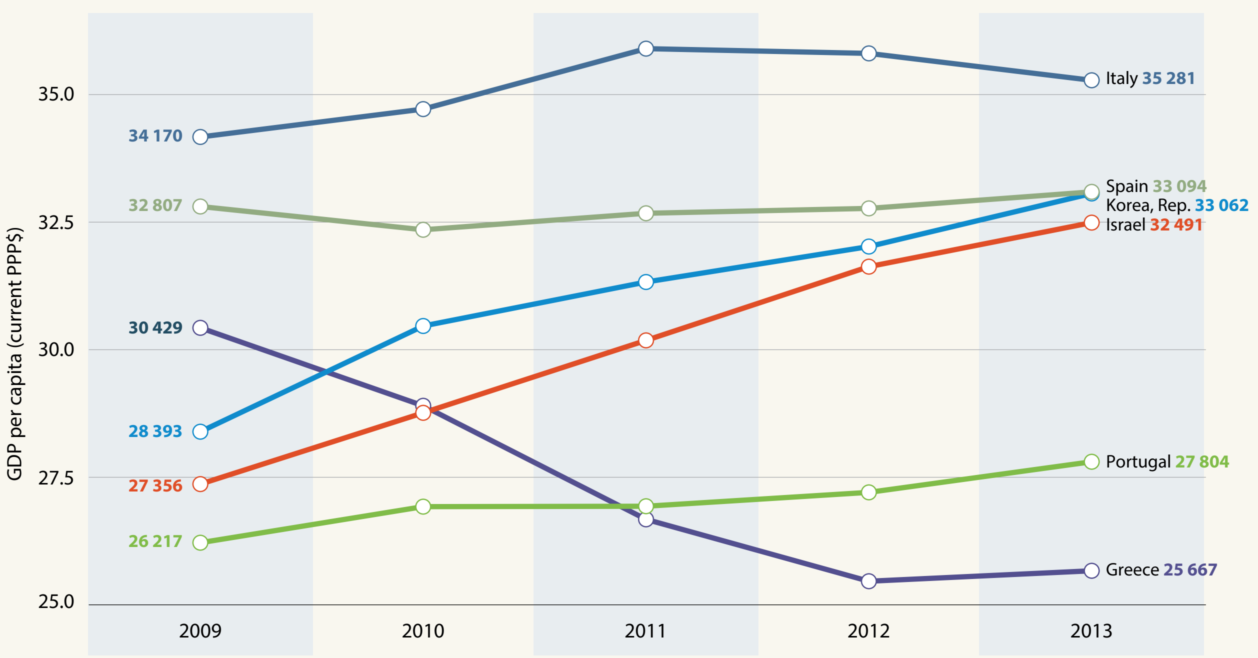
No lasting impact of global financial crisis

The Israeli economy grew by 28% between 2009 and 2013 to PPP$ 261.9 billion and GDP per capita progressed by 19% (Figure 16.1). This impressive performance reflects the dominance of the medium- and high-tech sector, which constitutes the country's main growth engine and contributes 46% of Israeli exports (2012). This sector is dominated by information and communication technologies (ICTs) and high-tech services. Given its reliance on international markets and venture capital, the Israeli business enterprise sector was fairly exposed to the global financial crisis of 2008–2009. The Israeli economy has sailed through the crisis mainly due to a balanced fiscal policy and conservative measures in the real-estate market. On the R&D front, government subsidies[1] introduced in 2009 have helped high-tech firms to weather the storm, leaving them relatively unscathed.

1. There was a 12% increase in funding from government sources and international funds.

Figure 16.1: **GDP per capita in Israel, 2009–2013**

In thousands of current PPP$, other countries are given for comparison



Source: World Bank's World Development Indicators, May 2015

Data released by the Central Bureau of Statistics in 2011 reveal that the manufacturing sector cut back its R&D expenditure by 5% and the services sector by 6% between 2008 and 2009. Each of these sectors performed about 30% of R&D in 2008 (UNESCO, 2012). As the business enterprise sector performs 83–84% of gross domestic expenditure on R&D (GERD), the cutbacks in the business enterprise sector caused the GERD/GDP ratio to falter in 2010 (3.96% of GDP). Israel has nevertheless managed to hold on to its place as world leader for R&D intensity, even if it is now being trailed by the Republic of Korea (Figure 16.2).

OECD membership has boosted investor confidence

Israel's admission to the Organisation for Economic Co-operation and Development (OECD) in 2010 has strengthened investors' confidence in the Israeli economy. Since its admission to this exclusive club, Israel has further opened up its economy to international trade and investment by lowering tariffs, adopting international standards and improving the domestic regulatory environment for business[2]. Israel now meets the OECD's policy framework for market openness, including as concerns efficient regulation and intellectual property. Israel's regulatory reforms have already led to significant growth in the influx of foreign direct investment (FDI) [OECD, 2014]. This inflow of FDI (Table 16.1) has given the Israeli high-tech sector greater access to much-needed capital which, in turn, has had a positive effect on Israeli GDP, which rose from PPP$ 204 849 million to PPP$ 261 858 million (in current prices) between 2009 and 2013.

2. See: www.oecd.org/israel/48262991.pdf

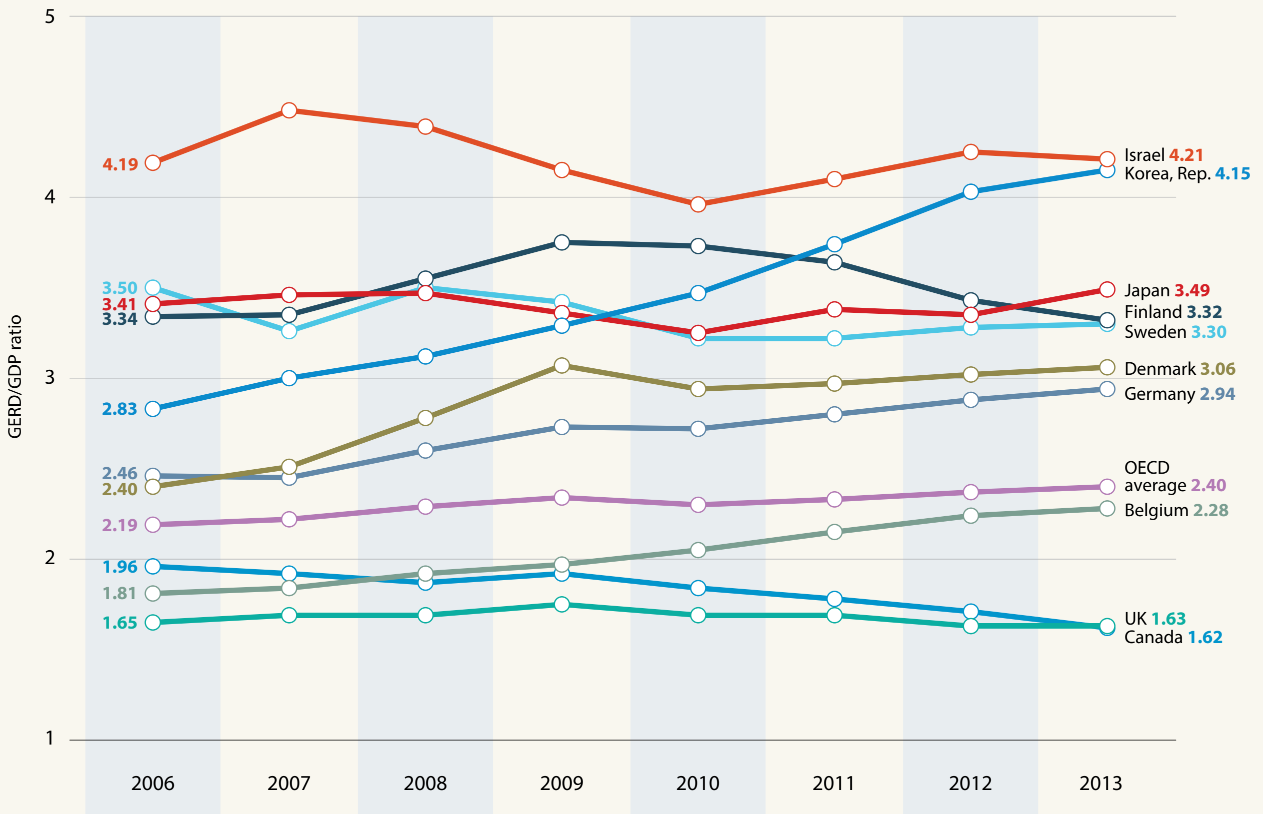
Table 16.1: **FDI inflows to Israel and outflows, 2009–2013**

	FDI inflow	FDI outflow	FDI inflow	FDI outflow
	In current US$ millions		Share of GDP (%)	
2009	4 438	1 695	2.2	0.8
2010	5 510	9 088	2.5	4.1
2011	9 095	9 165	3.9	3.9
2012	8 055	3 257	3.2	1.3
2013	11 804	4 670	4.5	1.8

Source: Central Bureau of Statistics

Figure 16.2: **Trends in Israel's GERD/GDP ratio, 2006–2013**

Other countries and regions are given for comparison



Note: The data for Israel exclude defence R&D.

Source: Getz *et al.* (2013), updated

Israel's binary economy threatens social equity and lasting growth

Israel's 'binary economy' consists of a relatively small, yet world-class high-tech sector which serves as the 'locomotive' of the economy, on the one hand, and the much larger but less efficient traditional industrial and services sectors, on the other hand. The economic contribution of the flourishing high-tech sector does not always spill over into other sectors of the economy.

Over time, this 'binary economic structure' has led to a well-paid labour force living at the 'core' of the country, namely the Tel Aviv metropolitan area, and a poorly paid labour force living primarily on the periphery. The growing socio-economic gap that has resulted from the structure of the economy and the concentration of wealth among the upper 1% is having a destabilizing effect on society (Brodet, 2008).

This duality is underpinned by a low rate of labour force participation, compared to other OECD economies, although the rate did rise from 59.8% to 63.7% between 2003 and 2013, thanks to improvements in the level of education (Fatal, 2013): as of 2014, 55% of the Israeli labour force had 13 or more years of schooling and 30% had studied for 16 years or more (CBS, 2014). The low rate of labour force participation in the general population stems mainly from low levels of participation by ultra-orthodox men and Arab women. The unemployment rate is also higher among Arabs than Jews, particularly among Arab women (Table 16.2).

Table 16.2: **Characteristics of Israel's civilian labour force, 2013**

	Total adult population*	Civilian labour force ('000s)	Civilian labour force (%)	Share of unemployed (%)
Total	**5 775.1**	**3 677.8**	**64**	**6.2**
Jewish	4 549.5	3 061.8	67	5.8
Arabs	1 057.2	482.8	46	9.4
Males	**2 818.3**	**1 955.9**	**69**	**6.2**
Jewish	2 211.9	1 549.8	70	5.8
Arab	530.8	344.4	65	8.2
Females	**2 956.7**	**1 722.0**	**58**	**6.2**
Jewish	2 337.6	1 512.0	65	5.8
Arab	526.4	138.4	26	12.4

Source: Central Bureau of Statistics

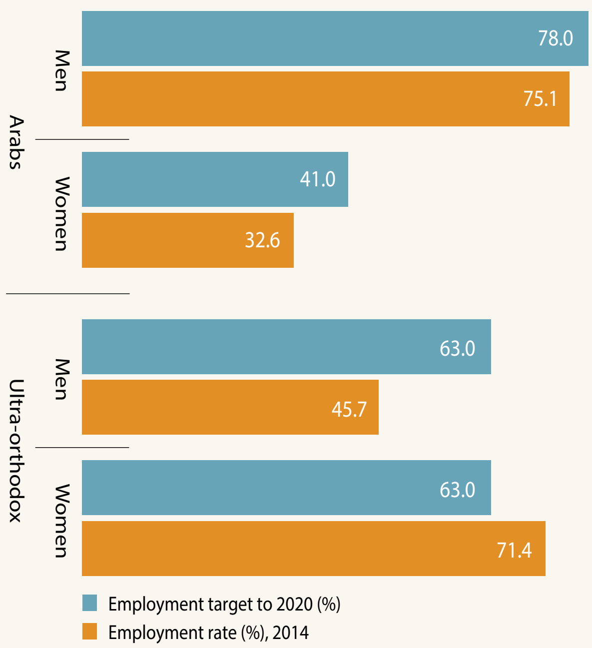
The latter phenomenon is attributable to the insufficient integration of Arab citizens into wider Israeli society, partly owing to their geographic remoteness and inadequate infrastructure; a lack of the social networks needed to find suitable employment; and discriminatory practices in certain segments of the economy.

To drive sustainable and long-lasting economic growth, it will be crucial for Israel to integrate its minority populations into the labour market. This realization prompted the government to fix a series of targets in December 2014 for raising the participation rate of minorities (Figure 16.3).

The country's transition from a semi-socialist economy in the 1980s to a free market economy has been accompanied by a rise in inequality, as illustrated by the steady rise in the Gini index (see the glossary, p. 738). As of 2011, nearly 42% of gross monthly income in Israel was concentrated in households which made up 20% of the population (the 2 top deciles). The Israeli middle class, occupying deciles 4–7, accounted for only 33% of gross income. Inequality after taxes and transfer payments has increased even more sharply, as the government has steadily reduced welfare benefits since 2003 (UNESCO, forthcoming).

The duality of the Israeli economy is also reflected in the low labour productivity, calculated as GDP per working hour. Israel

Figure 16.3: **Employment targets to 2020 for Israeli minorities**



Note: The employment targets were fixed in 2010 by a special committee charged with examining Israel's Employment Policy. The target for the employment rate for ultra-orthodox women was reached before 2014.

Source: General Accountant (2014) *Managing the Fiscal Policy Goals*. Ministry of Finance (in Hebrew) ranks 26th out of 34 OECD countries for this indicator and has been gradually slipping in the ranking since the 1970s (Ben David, 2014), even though it boasts some of the world's leading universities and cutting-edge high-tech firms.

Labour productivity in Israel varies strongly in technological intensity. In medium- and high-tech industries, labour productivity is significantly higher than in other manufacturing industries. In the services sector, the highest levels of production per employee are to be found in knowledge- and technology-intensive industries, such as the computer industry, R&D services and communications. The medium- and high-tech manufacturing sectors account for about 13% of GDP and 7% of total employment, even though their output contributes 46% of industrial exports, as mentioned earlier. The main industries in the manufacturing sector are chemical and pharmaceutical products, computers, electronics and optical products (Getz *et al.*, 2013).

Those industrial and services sectors that are classified as using low technologies or medium–low technologies account for the greater part of production and employment in the business sector, yet they suffer from low productivity per employee (Figure 16.4). The key to sustainable, long-term economic growth will lie in improving productivity in traditional industries and in the services sector (Flug, 2015). This can be achieved by giving firms incentives to innovate, assimilate advanced technologies, implement the requisite organizational changes and adopt new business models to raise the share of exports in their output (Brodet, 2008).

The government hopes to raise industrial-level productivity – the value added by each employee – from PPP$ 63 996 in 2014 to PPP$ 82 247 by 2020.

TRENDS IN R&D

Still the world leader for R&D intensity

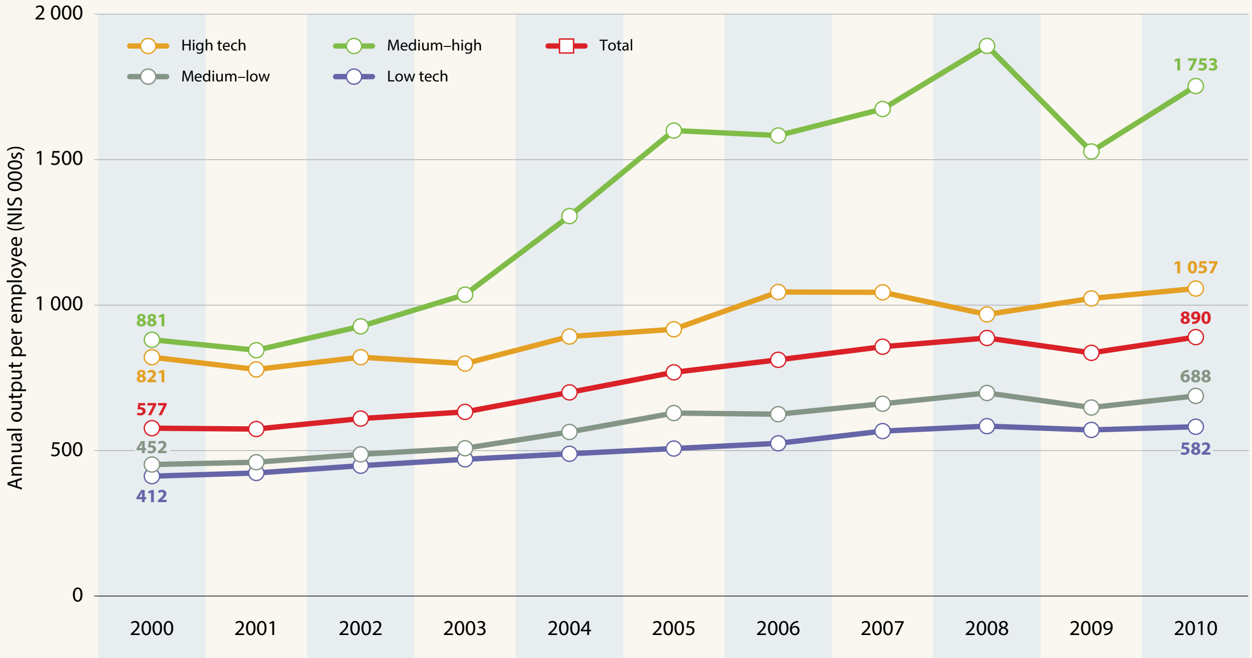
Israel tops the world for R&D intensity, reflecting the importance of research and innovation for the economy. Since 2008, however, Israel's R&D intensity has weakened somewhat (4.2% in 2014), even as this ratio has experienced impressive growth in the Republic of Korea, Denmark, Germany and Belgium (Figure 16.2) [Getz *et al.*, 2013]. Business expenditure on R&D (BERD)[3] continues to account for ~84% of GERD, or 3.49% of GDP. The share of higher education in GERD has decreased since 2003 from 0.69% of GDP to 0.59% of GDP (2013). Despite this drop, Israel ranks 8th among OECD countries for this indicator.

The lion's share of GERD (45.6%) in Israel is financed by foreign companies (Figure 16.5), reflecting the large scale of activity by foreign multinational companies and R&D centres in the country.

The share of foreign funding in university-performed R&D is also quite significant (21.8%). By the end of 2014, Israel had received € 875.6 million from the European Union's (EU's) Seventh Framework Programme for Research and Innovation (2007–2013),

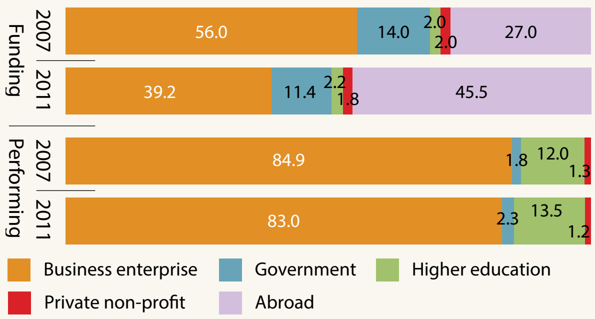
3. refers to GERD performed by the business enterprise sector

Figure 16.4: **Annual output per employee in Israel, 2000–2010**
In thousands of NIS, breakdown by technological intensity



Source: Central Bureau of Statistics

Figure 16.5: **GERD in Israel by funding and performing sectors, 2007 and 2011 (%)**



Note: Excluding defence R&D.

Source: Central Bureau of Statistics

70% of which had gone to universities. Its successor, Horizon 2020 (2014–2020), has been endowed with nearly € 80 billion in funding, making it the EU's most ambitious research and innovation programme ever. As of February 2015, Israel had received € 119.8 million from the Horizon 2020 programme.

In 2013, more than half (51.5%) of government spending was allocated to university research and an additional 29.9% to the development of industrial technologies. R&D expenditure on health and the environment has doubled in absolute terms in the past decade but still accounts for less than 1% of total government GERD (Figure 16.6). Israel is unique among OECD countries in its distribution of government support by objective. Israel ranks at the bottom in government support of research in health care, environmental quality and infrastructure development.

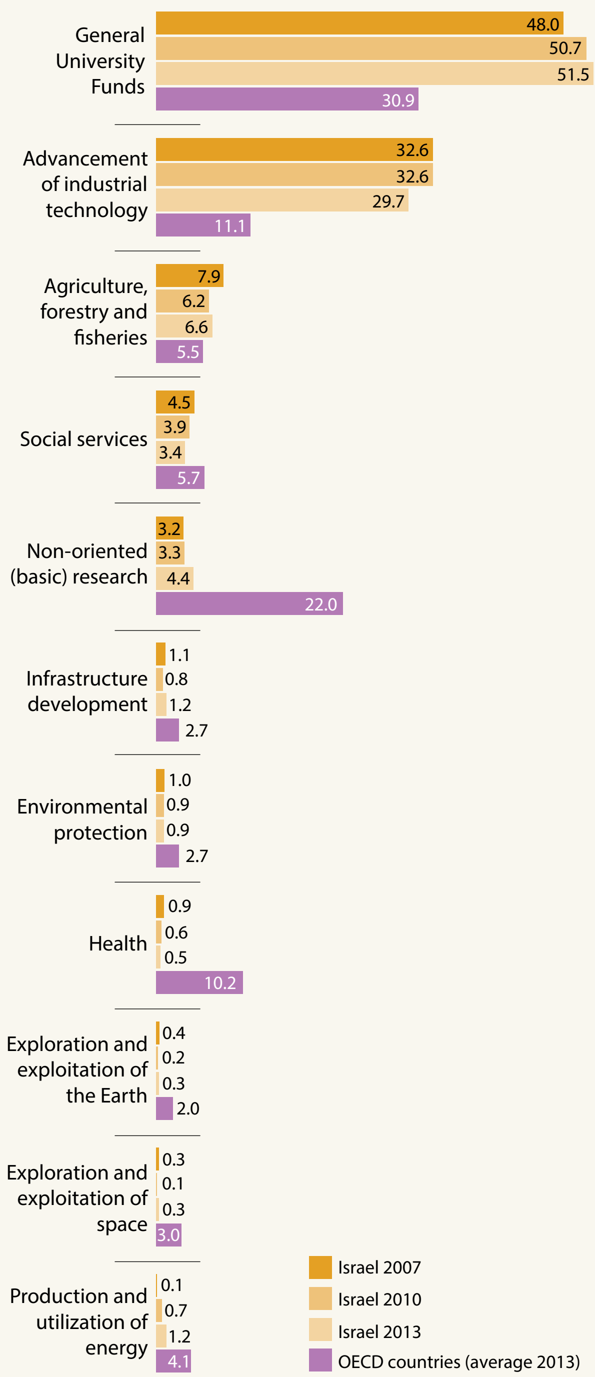
University research in Israel is largely grounded in basic research, even though it also engages in applied research and partnerships with industry. The increase in General University Funds and non-oriented research should thus provide a significant boost to basic research in Israel, which only accounted for 13% of research in 2013, compared to 16% in 2006 (Figure 16.7).

In 2012, there were 77 282 full-time equivalent (FTE) researchers, 82% of whom had acquired an academic education, 10% of whom were practical engineers and technicians and 8% of whom held other qualifications. Eight out of ten (83.8%) were employed in the business sector, 1.1% in the government sector, 14.4 % in the higher education sector and 0.7% in non-profit institutions.

In 2011, 28% of senior academic staff were women, up by 5% over the previous decade (from 25% in 2005) [Figure 16.8]. Although the representation of women has increased, it remains very low in engineering (14%), physical sciences (11%), mathematics and computer sciences (10%) relative to education (52%) and paramedical occupations (63%).

Figure 16.6: **Israeli government outlay for R&D by major socio-economic objective, 2007, 2010 and 2013 (%)**

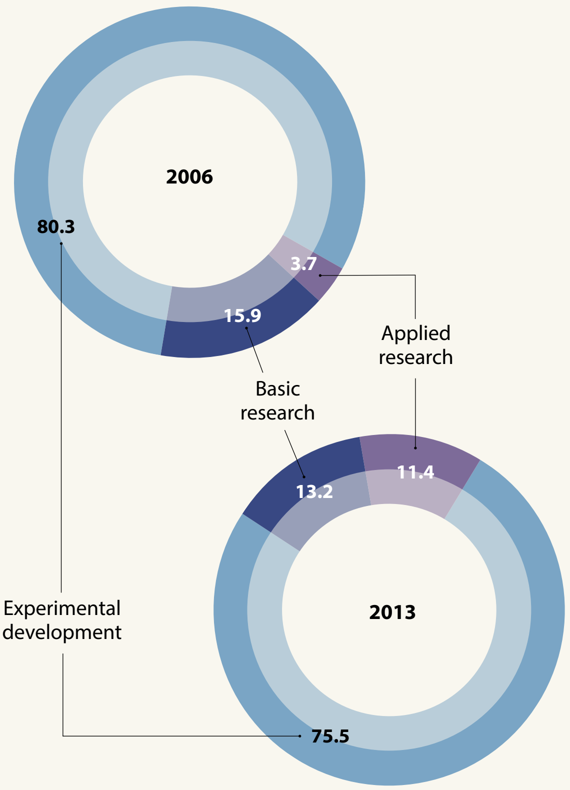
The OECD is given for comparison



Note: The data for Israel do not include defence R&D. The data for Israel diverge strongly from those for the OECD in two categories: health and non-oriented research. The low percentage for health can be explained by the fact that, in Israel, R&D in hospitals is assigned to the business sector and not to the government sector. The high percentage for non-oriented research for the OECD (22%) and the low percentage for Israel (4.4%) can be explained by the fact that the OECD indicator encompasses a variety of subjects.

Source: adapted from Getz *et al.* (2013)

Figure 16.7: **GERD in Israel by type of research, 2006 and 2013 (%)**



Note: The data do not include defence R&D.

Source: UNESCO Institute for Statistics, June 2015

TRENDS IN STI GOVERNANCE

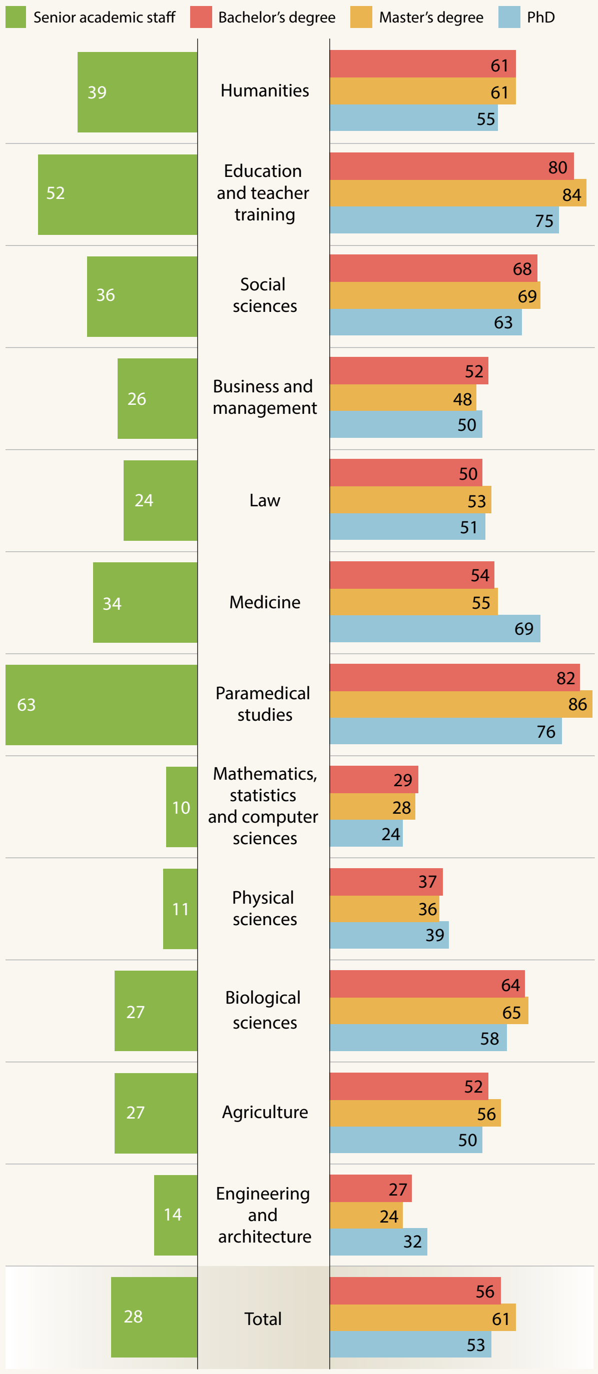
A six-year plan to revamp higher education

Israel's higher education system is regulated by the Council for Higher Education and its Planning and Budgeting Committee. The Israeli higher education system operates under a multi-year plan agreed upon by the Planning and Budgeting Committee (PBC) and the Ministry of Finance. Each plan determines policy objectives and, accordingly, the budgets to be allocated in order to achieve these objectives. The annual government allocation to universities totalled about US$ 1 750 million in 2015, providing 50–75% of their operating budgets. Much of the remainder of their operating budget (15–20%) comes from annual student tuition fees, which are uniform at about US$ 2 750 per year.

The *Sixth Higher Education Plan* (2011–2016) makes provision for a 30% rise in the Council for Higher Education's budget. The *Sixth Plan* changes the budgeting model of the PBC by placing greater emphasis on excellence in research, along with quantitative measures for the number of students. Under this model, 75% of the committee's budget (NIS 7 billion over six years) is being allocated to institutions offering higher education.

In the 2012/2013 academic year, there were 4 066 faculty members. The targets fixed by the PBC for faculty recruitment are ambitious: universities are to recruit another 1 600 senior faculty within the six-year period – about half of whom will occupy new positions and half will replace faculty expected to retire. This will constitute a net increase of more than 15%

Figure 16.8: **Share of women among Israeli university students (2013) and senior academic staff (2011) (%)**



Source: Central Bureau of Statistics

in university faculty. In colleges, another 400 new positions are to be created, entailing a 25% net increase. The new faculty will be hired via the institutions' regular recruitment channels, some in specific research areas, through the Israeli Centres of Research Excellence programme described below (Box 16.1).

The increase in faculty numbers will also reduce the student-to-faculty ratio, the target being to achieve a ratio of 21.5 university students to every faculty member, compared to 24.3 at present, and 35 students for every faculty member in colleges, compared to 38 at present.

This massive increase in the number of faculty positions, alongside the upgrading of research and teaching infrastructure and the increase in competitive research funds, should help Israel to staunch brain drain by enabling the best Israeli researchers at home and abroad to conduct their academic work in Israel, if they so wish, at institutions offering the highest academic standards.

The new budgeting scheme described above is mainly concerned with the human and research infrastructure in universities. Most of the physical development (e.g. buildings) and scientific infrastructure (e.g. laboratories and expensive equipment) of universities comes from philanthropic donations, primarily from the American Jewish community (CHE, 2014). This latter source of funding has greatly compensated for the lack of sufficient government funding for universities up until now but it is expected to diminish significantly in the years to come. Unless the government invests more in research infrastructure, Israel's universities will be ill-equipped and insufficiently funded to meet the challenges of the 21st century. This is very worrying.

Renewed interest in academic R&D

The *Sixth Higher Education Plan* launched the Israeli Centres of Research Excellence (I-CORE) programme in 2011 (Box 16.1). This is perhaps the strongest indication of a reversal in government policy, as it reflects a renewed interest in funding academic R&D. This novel programme envisions the establishment of cross-institutional clusters of top researchers in specific fields and returning young Israeli scientists from abroad, with each centre being endowed with state-of-the-art research infrastructure. The *Sixth Plan* invests NIS 300 million over six years in upgrading and renovating academic infrastructure and research facilities.

Although Israel does not have an 'umbrella type' STI policy for optimizing priorities and allocating resources, it does implement, *de facto*, an undeclared set of best practices combining bottom-up and top-down processes via government offices, such as those of the Chief Scientist or the Minister of Science, Technology and Space, as well as *ad hoc* organizations like the Telem forum (see p. 420). The procedure for selecting research projects for the Israeli centres of research excellence is one example of this bottom-up process (Box 16.1).

Box 16.1: **Israeli Centres of Research Excellence**

The Israeli Centres of Research Excellence (I-CORE) programme was launched in October 2011. It is run jointly by the Council for Higher Education's Planning and Budgeting Committee and the Israel Science Foundation.

So far, 16 centres have been established in two waves across a wide spectrum of research areas: six specialize in life sciences and medicine, five in the exact sciences and engineering, three in social sciences and law and two in humanities. Each centre of excellence has been selected via a peer review process conducted by the Israel Science Foundation. By May 2014, around 60 young researchers had been absorbed into these centres, many of whom had previously worked abroad.

The research topics of each centre are selected through a broad bottom-up process comprising of consultations with the Israeli academic community, in order to ensure that they reflect the genuine priorities and scientific interests of Israeli researchers.

I-CORE is funded by the Council for Higher Education, the host institutions and strategic business partners, with a total budget of NIS 1.35 billion (US$ 365 million).

The original goal was to set up 30 centres of research excellence in Israel by 2016. However, the establishment of the remaining 14 centres has provisionally been shelved, for lack of sufficient external capital.

In 2013–2014, the Planning and Budgeting Committee's budget for the entire I-CORE programme amounted to NIS 87.9 million, equivalent to about 1% of the total for higher education that year. This budget appears to be insufficient to create the critical mass of researchers in various academic fields and thus falls short of the programme's objective. The level of government support for the centres of excellence has grown each year since 2011 as new centres have been established and is expected to reach NIS 93.6 million by 2015–2016 before dropping to 33.7 million in 2017–2018. According to the funding model, government support should represent one-third of all funding, another third being funded by the participating universities and the remaining third by donors or investors.

Source: CHE (2014)

A shortage of professionals looms

During the 2012/2013 academic year, 34% of bachelor's degrees were obtained in S&T fields in Israel. This compares well with the proportion in the Republic of Korea (40%) and most Western countries (about 30% on average). The proportion of Israeli graduates in S&T fields was slightly lower at the master's level (27%) but dominated at PhD level (56%).

There is a visible ageing of scientists and engineers in some fields. For instance, about three-quarters of researchers in the physical sciences are over the age of 50 and the proportion is even higher for practical engineers and technicians. The shortage of professional staff will be a major handicap for the national innovation system in the coming years, as the growing demand for engineers and technical professionals begins to outpace supply.

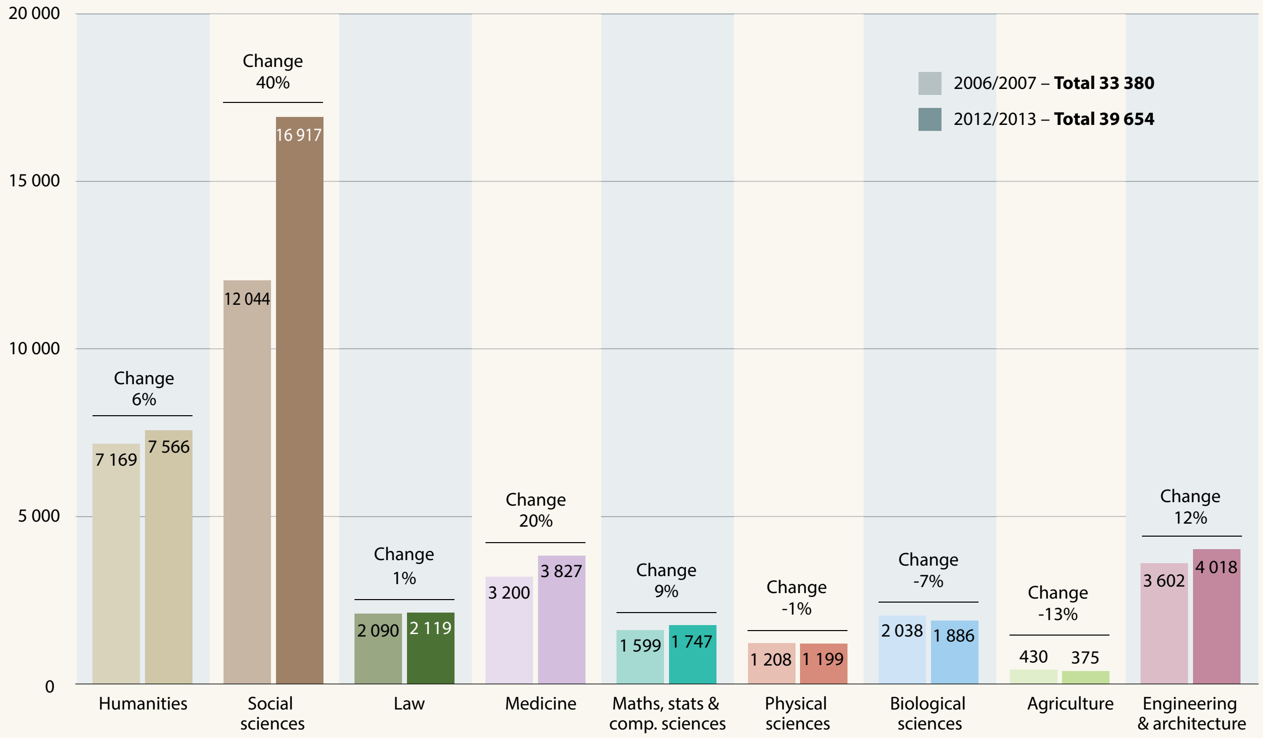
Israel has offered virtually universal access to its universities and academic colleges since the wave of Jewish immigration from the former Soviet Union in the 1990s prompted the establishment of numerous tertiary institutions to absorb the additional demand (CHE, 2014). However, the Arab and ultra-orthodox minorities still attend university in insufficient numbers. The *Sixth Higher Education Plan* places emphasis on encouraging minority groups to enrol in higher education. Two years after the *Mahar* programme was implemented in late 2012 for the ultra-orthodox population, student enrolment had grown by 1 400. Twelve new programmes for ultra-orthodox students have since been established, three of them on university campuses. Meanwhile, the Pluralism and Equal Opportunity in Higher Education programme addresses the barriers to integration of the Arab minority in the higher education system. Its scope ranges from providing secondary-school guidance through preparation for academic studies to offering students comprehensive support in their first year of study, a stage normally characterized by a high drop-out rate. The programme renews the *Ma'of* fund supporting outstanding young Arab faculty members. Since the introduction of this programme in 1995, the *Ma'of* fund has opened tenure track opportunities for nearly 100 Arab lecturers, who act as role models for younger Arab students embarking on their own academic careers.

Living on the fruits of the past?

One of the main criticisms of the current state of the higher education system is that Israel is living on the 'fruits of the past', that is to say, on the heavy investment made in primary, secondary and tertiary education during the 1950s, 1960s and 1970s (Frenkel and Leck, 2006). Between 2007 and 2013, the number of graduates in physical sciences, biological sciences and agriculture dropped, even though the total number of university graduates progressed by 19% (to 39 654) [Figure 16.9].

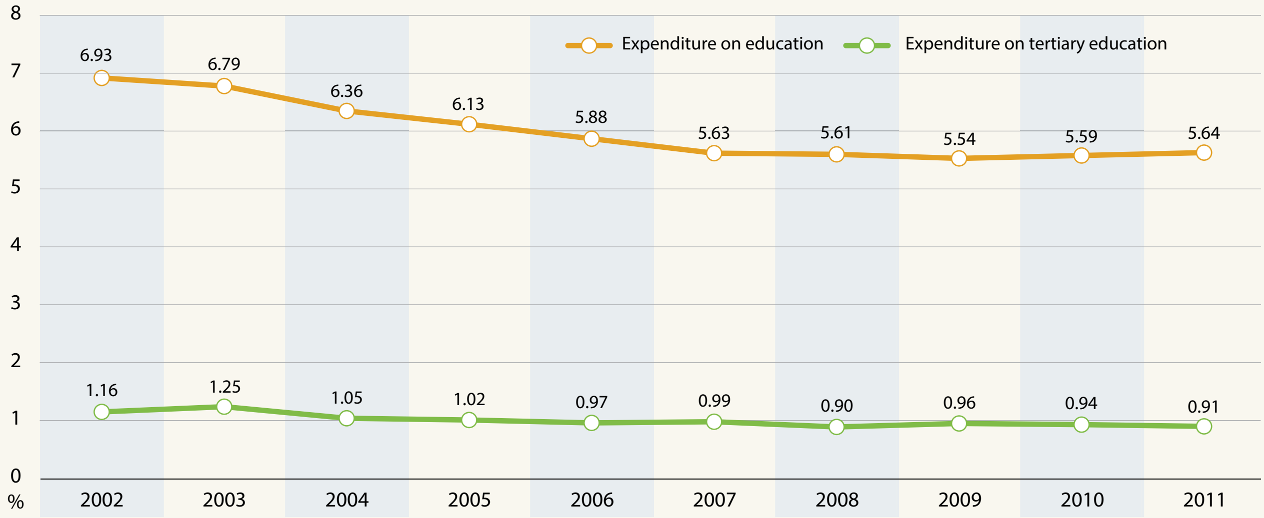
Recent data reveal that Israeli educational achievements in the core curricular subjects of mathematics and science

Figure 16.9: **University graduates in Israel, by field of study, 2006/2007 and 2012/2013**



Source: Central Bureau of Statistics

Figure 16.10: **Education spending in Israel as a share of GDP, 2002–2011 (%)**



Source: UNESCO Institute for Statistics, April 2015

are low in comparison to other OECD countries, as revealed by the exam results of Israeli 15-year olds in the OECD's Programme for International Student Assessment. Public spending on primary education has also fallen below the OECD average. The public education budget accounted for 6.9% of GDP in 2002 but only 5.6% in 2011. The share of this budget going to tertiary education has remained stable at 16–18% but, as a share of GDP, has passed under the bar of 1% (Figure 16.10). There is concern at the deteriorating quality of teachers at all levels of education and the lack of stringent demands on students to strive for excellence.

Research universities: the backbone of higher education

Seven research universities around the country form the 'backbone' of Israel's higher education system: the Hebrew University of Jerusalem, Technion – Israel Institute of Technology, Tel- Aviv University, Weizmann Institute of Science, Bar-Ilan University, University of Haifa and Ben Gurion University of the Negev.

The first six ranked among the world's top 500 universities[4] in 2014 in the Shanghai Ranking[5]. These six also ranked in the top 200 World Universities in Computer Science[6] for the same year. Three Israeli research universities rank among the top 75 in mathematics and four among the top 200 in physics and chemistry.

Over the 2007–2014 period, Israeli projects benefiting from the European Research Council's Starting Grants (see Box 9.1) recorded a success rate of 17.6% for 142 funded projects, placing Israel second after Switzerland. During the years 2008–2013, Israel ranked ninth for the European Research Council's Advanced Grants (85 funded projects), reflecting a 13.6% success rate. Since 2009, two Israeli academics have won the Nobel Prize: Professor Ada E. Yonath in 2009 for her studies on the structure and function of the ribosome and Professor Dan Shechtman in 2011 for his discovery of quasicrystals in 1984. This brings the total number of Israelis who have won the Nobel Prize in one of the sciences to eight.

The volume of publications is stagnating

The number of Israeli publications has stagnated over the past decade. Consequently, the number of Israeli publications per million inhabitants has also declined: between 2008 and 2013, it dropped from 1 488 to 1 431; this trend reflects a relative constancy in scholarly output in the face of relatively high population growth (1.1% in 2014) for a developed country and near-zero growth in the number of FTE researchers in universities.

Israeli publications have a high citation rate and a high share of papers count among the 10% most-cited (Figure 16.11). Also of note is that the share of papers with foreign co-authors is almost twice the OECD average, which is typical of small countries with developed science systems. Israeli scientists collaborate mostly with the USA and EU but there has been strong growth in recent years in collaboration with China, India, the Republic of Korea and Singapore.

Between 2005 and 2014, Israeli scientific output was particularly high in life sciences (Figure 16.11). Israeli universities do particularly well in computer science but publications in this field tend to appear mostly in conference proceedings, which are not included in the Web of Science.

4. The Hebrew University of Jerusalem and the Technion figured among the top 100, Tel Aviv University and the Weizmann Institute among the top 200.

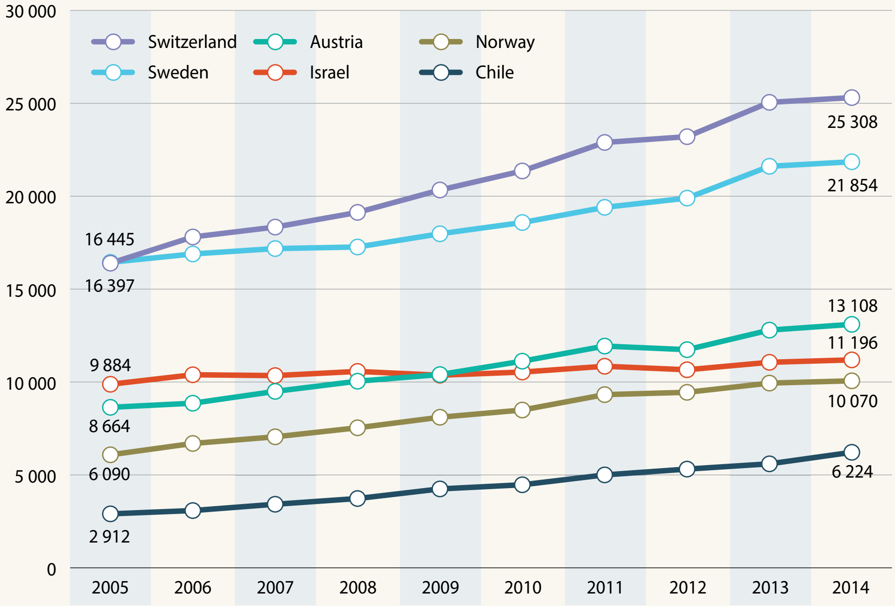
5. Shanghai Academic Ranking of World Universities, 2014

6. The Technion and Tel Aviv University ranked among the top 20, the Hebrew University and Weizmann Institute among the top 75.

Figure 16.11: **Scientific publication trends in Israel, 2005–2014**

Israeli publications have grown slowly since 2005

Countries of a similar economic size are given for comparison



1.15

Average citation rate for Israeli scientific publications 2008–2012; the OECD average is 1.08

11.9%

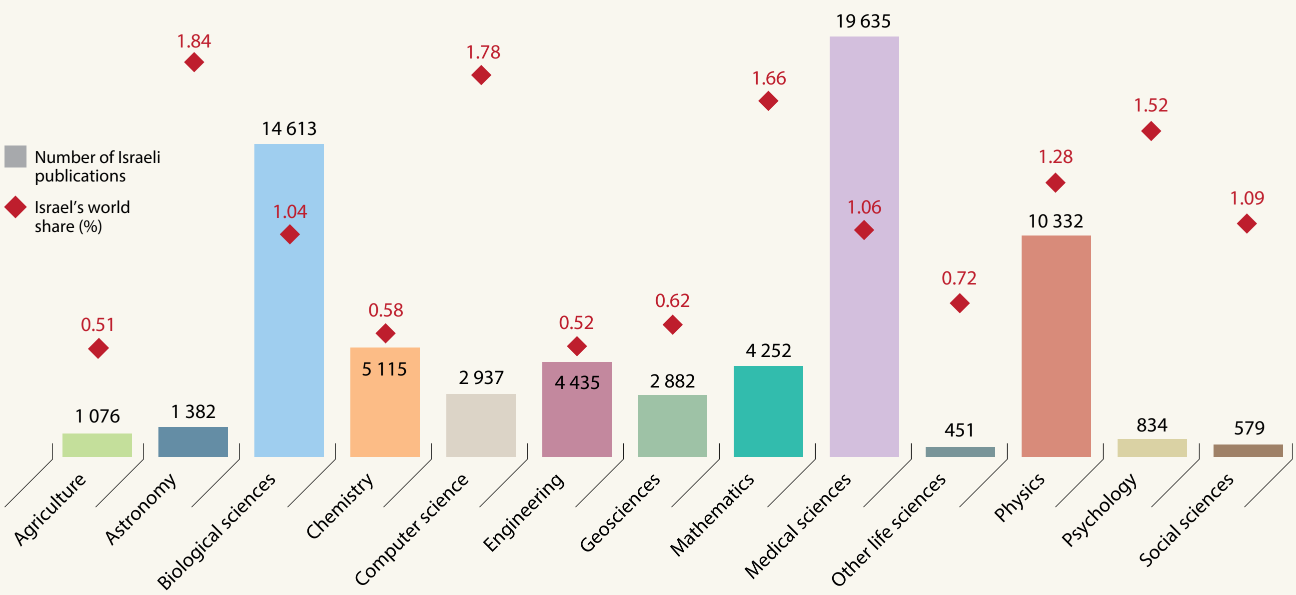
Share of Israeli papers among 10% most cited papers 2008–2012; OECD average is 11.1%

49.3%

Share of Israeli papers with foreign co-authors 2008–2014; the OECD average is 29.4%

Israel specializes in life sciences and physics

Cumulative totals by field, 2008–2014



Note: A further 6 745 papers are unclassified. Israel accounts for 0.1% of the global population.

Israeli scientists collaborate mostly with the USA and EU countries

Main foreign partners, 2008–2014 (number of papers)

	1st collaborator	2nd collaborator	3rd collaborator	4th collaborator	5th collaborator
Israel	USA (19 506)	Germany (7 219)	UK (4 895)	France (4 422)	Italy (4 082)

Source: Thomson Reuters' Web of Science, Science Citation Index Expanded, data treatment by Science–Metrix

Four priority research areas which will impact daily life
The Israeli Science Foundation is the main source of research funding in Israel and receives administrative support from the Academy of Sciences and Humanities. The foundation provides competitive grants in three areas: exact sciences and technology; life sciences and medicine; and humanities and social sciences. Complementary funding is provided by binational foundations, such as the USA–Israel Binational Science Foundation (est. 1972) and the German–Israeli Foundation for Scientific Research and Development (est. 1986).

The Ministry of Science, Technology and Space funds thematic research centres and is responsible for international scientific co-operation. The Ministry's National Infrastructure Programme aims to create a critical mass of knowledge in national priority fields and to nurture the younger generation of scientists. Investment in the programme mainly takes the form of research grants, scholarships and knowledge centres. Over 80% of the ministry's budget is channelled towards research in academic institutions and research institutes, as well as towards revamping scientific infrastructure by upgrading existing research facilities and establishing new ones.

In 2012, the ministry resolved to invest NIS 120 million over three years in four designated priority areas for research: brain science; supercomputing and cybersecurity (Box 16.2); oceanography; and alternative transportation fuels. An expert panel headed by the Chief Scientist in the Ministry of Science, Technology and Space chose these four broad disciplines in the belief that they would would be likely to exert the greatest practical impact on Israeli life in the near future.

A rise in funding for space research
In 2012, the Ministry of Science, Technology and Space substantially increased its investment in the civil space programme administered by the Israel Space Agency (ISA). ISA's planned budget came to NIS 180 million for three years: NIS 65 million was allocated to fostering university–industry co-operation and NIS 90 million to joint international projects. In 2013, ISA signed contracts for a cumulative value

Box 16.2: Israel launches cyber security initiative

In 2013, hackers presumably used a cyber virus to shut down a major tunnel system in Israel for eight hours, causing massive traffic jams. Cyber attacks are a growing threat in Israel and worldwide.

In November 2010, the Israeli prime minister entrusted a task force with responsibility for formulating national plans to place Israel among the top five countries in the world for cyber security.

Less than a year later, on 7 August 2011, the government approved the establishment of the National Cyber Bureau to promote the Israeli cyber defence industry. The bureau is based in the Prime Minister's Office. The National Cyber Bureau allocated NIS 180 million (*circa* US$ 50 million) over 2012–2014 to encourage cyber research and dual military–civilian R&D; the funding is also being used to develop human capital, including through the creation of cyber security centres at Israeli universities that are funded jointly by the National Cyber Bureau and the universities themselves.

In January 2014, the prime minister launched CyberSpark, Israel's cyber innovation park, as part of plans to turn Israel into a global cyber hub. Located in the city of Beer-Sheva to foster economic development in southern Israel, CyberSpark is a geographical cluster of leading cyber companies, multinational corporations and universities, involving Ben Gurion University of the Negev, technology defence units, specialized educational platforms and the national Cyber Event Readiness Team.

About half of the firms in CyberSpark are Israeli, mostly small to medium-sized. Multinational companies operating in CyberSpark include EMC2, IBM, Lockheed Martin and Deutsche Telekom. PayPal recently acquired the Israeli start-up CyActive and has since announced plans to set up its second Israeli R&D centre in CyberSpark, with a focus on cyber security. This acquisition is just one of the many Israeli cybersecurity start-ups acquired by multinational companies in the past few years. Major acquisitions of Israeli start-ups in 2014 include Intellinx, purchased by Bottomline Technologies, and Cyvera, purchased by Palo Alto Networks.

The National Cyber Bureau recently estimated that the number of Israeli cyber defence companies had doubled in the past five years to about 300 by 2014. Israeli companies account for an estimated 10% of global sales, which currently total an estimated US$ 60 billion.

Total R&D spending on cyber defence in Israel quadrupled between 2010 and 2014 from US$ 50 million to US$ 200 million, bringing Israel's spending to about 15% of global R&D spending on cyber defence in 2014.

Cyber security technologies are exported by Israel in accordance with the Wassenaar Arrangement, a multilateral agreement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies.

Source: National Cyber Bureau; CyberSpark; Ministry of the Economy; Ziv (2015)
See: www.cyberspark.org.il

of NIS 88 million. The rest of the budget will be utilized in the coming years.

The aim of the national space programme is to enhance Israel's comparative advantage and place it among the world's top five countries in the field of space research and exploration. Israel plans to use its expertise in miniaturization and digitization to capture 3–5% of the US $ 250 billion global space market and generate US$ 5 billion in sales within ten years.

Over the next five years, ISA will be focusing on:

- joining the European Space Agency as a full or associate member;
- initiating and promoting two micro-research satellites;
- developing in-house knowledge, in order to increase the manufacturing capabilities of space systems and subsystems in Israel.

The ministry is also promoting collaboration with other leading countries in the field of space, including the USA, France, India, Italy, Japan and the Russian Federation, through co-operative ventures with the business sector.

Making science more approachable

Another objective of the ministry has been to bring the general public closer to science, particularly those living on Israel's periphery and the younger generation, by making science more approachable. This is done via science museums and annual events run by universities and science institutions, such as Researchers' Night.

Another tool used by the ministry has been the establishment of eight R&D centres since the 1980s on the country's geographical and social peripheries to spur local development and deepen community engagement in S&T. These centres have been established with the specific aim of drawing young, leading scientists to these parts of the country, along with raising the level of local education and fostering economic development. These R&D centres focus on finding solutions to local challenges.

A wealth of new funding programmes

The main ongoing programmes managed by the Office of the Chief Scientist within the Ministry of the Economy are: the Research and Development Fund; Magnet Tracks (est. 1994, Table 16.3); Tnufa (est. 2001) and the Incubator Programme (est.1991). Since 2010, the Office has initiated several new programmes (OCS, 2015):

- *Grand Challenges Israel (since 2014)*: an Israeli contribution to the Grand Challenges in Global Health programme, which is dedicated to tackling global health and food security challenges in developing countries; Grand Challenges Israel is offering grants of up to NIS 500 000 at the proof of concept/feasibility study stage.
- *R&D in the field of space technology (2012)*: encourages R&D to find technological solutions in various fields.
- *Technological Entrepreneurship Incubators (2014)*: encourages entrepreneurial technology and supports start-up technology companies.
- *Magnet – Kamin programme (2014)* provides direct support for applied research in academia that has potential for commercial application.
- *Cyber – Kidma programme (2014):* promotes Israel's cybersecurity industry.
- *Cleantech – Renewable Energy Technology Centre (2012)*: supports R&D through projects involving private–public partnerships in the field of renewable energy.
- *Life Sciences Fund (2010)***:** finances the projects of Israeli companies, with emphasis on biopharmaceuticals; established together with the Ministry of Finance and the private sector.
- *Biotechnology – Tzatam programme* (2011): provides equipment to support R&D in life sciences. The Chief Scientist supports industrial organizations and the PBC provides research institutions with assistance.
- *Investment in high-tech industries (2011)*: encourages financial institutions to invest in knowledge-based industries, through a collaboration between the Office of the Chief Scientist and the Ministry of Finance.

Another source of public research funding is the Forum for National Research and Development Infrastructure (*Telem*). This voluntary partnership involves the Office of the Chief Scientist of the Ministry of the Economy and the Ministry of Science, Technology and Space, the Planning and Budgeting Committee and the Ministry of Finance. *Telem* projects focus on establishing infrastructure for R&D in areas that are of common interest to most Telem partners. These projects are financed by the *Telem* members' own resources.

Regular evaluations of policy instruments

The country's various policy instruments are evaluated by the Council for Higher Education, the National Council for Research and Development, the Office of the Chief Scientist, the Academy of Sciences and Humanities and the Ministry of Finance.

In recent years, the Magnet[7] administration in the Office of the Chief Scientist has initiated several evaluations of its own policy instruments, most of which have been carried out by independent research institutions. One such evaluation was carried out in 2010 by the Samuel Neaman Institute; it concerned the *Nofar* programme within the Magnet directorate.

7. Magnet is the acronym, in Hebrew, for Generic Pre-Competitive R&D.

Table 16.3: **Grants by the Israeli Office of the Chief Scientist, by R&D programme, 2008–2013, NIS**

Programme (year of creation)	2008	2009	2010	2011	2012	2013
Research and Development Fund (1984)	1 009.0	1 245.0	1 134.0	1 027.0	1 070.0	1 021.0
Magnet (1994)	159.0	199.0	159.0	187.0	134.0	138.0
Users Association (1995)	3.2	2.7	0.8	3.2	0.7	1.6
Magneton (2000)	31.1	30.8	32.9	26.8	28.0	23.8
R&D in Large Companies (2001)	71.0	82.0	75.0	63.0	55.0	59.0
Nofar (2002)	5.0	7.8	6.9	7.6	6.9	6.2
Traditional Industries Support (2005)	44.9	79.5	198.3	150.0	131.0	80.8
R&D Centres (2010)	4.6	14.8	10.9	7.6	8.6	8.2
Cleantech (2012)	65.4	95.4	100.7	81.9	84.4	105.6

Source: Office of the Chief Scientist, 2015

Nofar tries to bridge basic and applied research, before the commercial potential of a project has caught the eye of industry. The main recommendation was for *Nofar* to extend programme funding to emerging technological domains beyond biotechnology and nanotechnology (Getz *et al.*, 2010). The Office of the Chief Scientist accepted this recommendation and, consequently, decided to fund projects in the fields of medical devices, water and energy technology and multidisciplinary research.

An additional evaluation was carried out in 2008 by Applied Economics, an economic and management research-based consultancy, on the contribution of the high-tech sector to economic productivity in Israel. It found that the output per worker in companies that received support from the Office of the Chief Scientist was 19% higher than in 'twin' companies that had not received this support (Lach *et al.*, 2008). The same year, a committee headed by Israel Makov examined the Office of the Chief Scientist's support for R&D in large companies. The committee found economic justification for providing incentives for these companies (Makov, 2014).

Universities apply for 10% of Israeli patents

Since the 1990s, the traditional dual mission of universities of teaching and research has broadened to include a third mission: engagement with society and industry. This evolution has been a corollary of the rise of the electronics industry and information technology services, along with a surge in the number of R&D personnel following the wave of immigration from the former Soviet Union.

Israel has no specific legislation regulating the transfer of knowledge from the academic sector to the general public and industry. Nevertheless, the Israeli government influences policy formulation by universities and technology transfer by providing incentives and subsidies through programmes such as Magnet and Magneton (Table 16.3), as well as through regulation.

There were attempts in 2004 and 2005 to introduce bills encouraging the transfer of knowledge and technology for the public benefit but, as these attempts failed, each university has since defined its own policy (Elkin-Koren, 2007).

All Israeli research universities have technology transfer offices. Recent research conducted by the Samuel Neaman Institute has revealed that, in the past decade, the universities' share of patent applications constituted 10–12% of the total inventive activity of Israeli applicants (Getz *et al.*, 2013). This is one of the highest shares in the world and is largely due to the intensive activity of the universities' technology transfer offices.

The Weizmann Institute's technology transfer office, Yeda, has been ranked the third-most profitable[8] in the world (Weinreb, 2013). Through exemplary university–industry collaboration, the Weizmann Institute of Science and Teva Pharmaceutical Industries have discovered and developed the Copaxone drug for the treatment of multiple sclerosis. Copaxone is Teva's biggest-selling drug, with US$ 1.68 billion in sales in the first half of 2011 (Habib-Valdhorn, 2011). Since the drug's approval by the US Food and Drug Administration (FDA) in 1996, it is estimated that the Weizmann Institute of Science has earned nearly US$ 2 billion in royalties from the commercialization of its intellectual property. An additional revolutionary drug for the treatment of Parkinson's disease, Azilect, was developed by scientists from the Technion – Israel Institute of Technology. The drug was commercialized by the Technion Technology Transfer Office and the manufacturing license was given to Teva Pharmaceutical Industries. In 2014, the US Food and Drug Administration approved the Azilect label for treatment at all stages of

8. About 10–20% of the Weizmann Institute's annual budget of US$ 470 million comes from its commercialization company Yeda, which has a number of bestseller products. Yeda's annual income has been estimated at US$ 50–100 million (Weinreb, 2013).

Parkinson's disease. This means that the drug may be used alone, or in combination with other drugs, to treat Parkinson's disease.

Sustainability more visible in STI policy

In recent years, sustainability and environmental considerations have been increasingly taken into account in the formulation of general STI policies. Both internal and external forces are responsible for this trend. Among key internal drivers are the shortage of available land for development and the need for problem-solving to cope with population[9] growth. Among the external drivers are international and regional environmental agreements signed by Israel, such as the *Kyoto Protocol* to rein in climate change (1997) and the *Barcelona Convention for Protection against Pollution in the Mediterranean Sea* (1976), which set new environmental standards and benchmarks (Golovaty, 2006; UNESCO, forthcoming). It is the Ministry of Environmental Protection which is responsible for formulating an integrated nationwide policy to protect the environment.

Sustainability and environmental policies are being promoted through various legislative tools, including the Green Growth Act (2009) and Greenhouse Gas Emissions Reduction Act (2010), as well as through economic and R&D incentives. The government is targeting both the public and private sectors, with a focus on mitigating environmental hazards and maximizing efficiency by developing novel technologies in such fields as renewable energy or water treatment. A scheme has been initiated jointly by the Water Authority and the Ministry of Economics to match the investment cost of applying innovative water technologies; the government contributes 70%, the entrepreneur 15% and the local water utility a further 15%. Israel has one of the world's greatest capacities for desalination and the highest rate of water recycling. It has also developed a wide range of water-efficient technologies for agriculture. Some 85% of Israeli households use solar energy to heat water, equal to 4% of Israel's energy capacity. In 2014, Israel topped the rankings of the Global Cleantech Innovation Index, with 300 domestic companies active in this sector. In parallel, Israel is developing a non-renewable source of energy, natural gas, to ensure greater energy independence (Box 16.3).

9. Since peaking at 2.5% in 2007 after a wave of immigration, the annual population growth rate has dropped to a more sustainable rate of 1.1% (2014).

Targets for more sustainable development

Since 2008, the government has fixed a number of quantifiable targets for the country's sustainable development:

- a 20% reduction in electricity consumption by 2020 (government decision of September 2008);
- 10% of electricity to be generated from renewable sources by 2020, including a 5% milestone in 2014, which has not been met (government decision of January 2009);
- a 20% reduction in greenhouse gas emissions by 2020 over and above the target to 2020 for the 'business as usual' scenario (government decision of November 2010);
- A national plan for green growth is to be established covering the period 2012–2020 (government decision of October 2011).

Box 16.3: Natural gas: a chance to develop technologies and markets

Since 1999, large reserves of natural gas have been discovered off Israel's coast. This fossil fuel has become the primary fuel for electricity generation in Israel and is gradually replacing oil and coal. In 2010, 37% of electricity in Israel was generated from natural gas, leading to savings of US$ 1.4 billion for the economy. In 2015, this rate is expected to surpass 55%.

In addition, the usage of natural gas in industry – both as a source of energy and as a raw material – is rapidly expanding, alongside the requisite infrastructure. This is giving companies a competitive advantage by reducing their energy costs and lowering national emissions.

Since early 2013, almost the entire natural gas consumption of Israel has been supplied by the Tamar field, an Israeli–American private partnership. The estimated reserves amount to about 1 000 BCM, securing Israel's energy needs for many decades to come and making Israel a potentially major regional exporter of natural gas. In 2014, initial export agreements were signed with the Palestinian Authority, Jordan and Egypt; there are also plans to export natural gas to Turkey and the EU via Greece.

In 2011, the government asked the Academy of Sciences and Humanities to convene a panel of experts to consider the full range of implications of the most recent discoveries of natural gas. The panel recommended encouraging research into fossil fuels, training engineers and focusing research efforts on the impact of gas production on the Mediterranean Sea's ecosystem. The Mediterranean Sea Research Centre of Israel was established in 2012 with an initial budget of NIS 70 million; new study programmes have since been launched at the centre to train engineers and other professionals for the oil and gas industry.

Meanwhile, the Office of the Chief Scientist, among others, plans to use Israel's fledgling natural gas industry as a stepping stone to building capacity in advanced technology and opening up opportunities for Israeli innovation targeting the global oil and gas markets.

Source: IEC (2014); EIA (2013)

In order to reach these targets, the government has introduced a national programme to reduce greenhouse gas emissions. Its total budget for the period 2011–2020 amounts to NIS 2.2 billion (US$ 0.55 billion); in 2011–2012, NIS 539 million (US$ 135 million) was allocated to the following measures:

- Reduction of residential consumption of electricity;
- Support for emissions reduction projects in the industrial, commercial and public sectors;
- Support for innovative, environment-friendly Israeli technologies (NIS 40 million);
- Promotion of green construction, green building codes and related training;
- Introduction of educational programmes on energy efficiency and emissions reduction; and
- Promotion of energy efficiency regulation and energy surveys.

In May 2013, the programme became a casualty of national budget cuts and was suspended for three years. It is scheduled to resume in 2016 for a period of eight years. In its first three years of operation, the project generated NIS 830 million (US$ 207 million) in economic benefits:

- A reduction of 442 000 tons of greenhouse gases per year, with an annualized economic benefit of NIS 70 million;
- A reduction in electricity generation of 235 million kWh per year, with an annualized economic benefit of NIS 515 million; and
- A reduction in pollutant emissions and consequential health problems valued at NIS 244 million.

In 2010, the government launched a voluntary greenhouse gas emissions registry. As of 2014, the registry contained over 50 reporting organizations, which account for about 68% of Israel's greenhouse gas emissions. The registry respects international guidelines.

TRENDS IN PRIVATE SECTOR R&D

An attractive destination for multinational companies

Israel's high-tech industries are a spin-off of the explosive development of computer science and technology in the 1980s in such places as Silicon Valley and Massachusetts Route 128 in the USA, which ushered in the current high-tech era. Up until that point, Israel's economy had been essentially based on agriculture, mining and secondary sectors such as diamond polishing and manufacturing in textiles, fertilizers and plastics. The key factor which enabled ICT-based high-tech industries to take root and flourish in Israel was the massive investment by the defence and aerospace industries, which spawned new technologies and know-how. This formed the basis for Israel's unique high-tech industries in medical devices, electronics, telecommunications, computer software and hardware etc. (Trajtenberg, 2005). The massive Russian immigration of the 1990s reinforced this phenomenon, doubling the number of engineers and scientists in Israel overnight.

Today, Israel has the world's most R&D-intensive business sector; in 2013, it alone performed 3.49% of GDP. Competitive grants and tax incentives are the two main policy instruments supporting business R&D. Thanks to government incentives and the availability of highly trained human capital, Israel has become an attractive location for the R&D centres of leading multinationals. The country's STI ecosystem relies on both foreign multinationals and large corporate R&D investors, as well as on start-ups (OECD, 2014).

According to the Israel Venture Capital Database, 264 foreign R&D centres are currently active in Israel. Many of these centres are owned by large multinational firms that have acquired Israeli companies, technology and know-how and transformed them through mergers and acquisitions into their own local research facilities. The activity of some R&D centres even spans more than three decades, such as those of Intel, Applied Materials, Motorola and IBM.

In 2011, foreign R&D centres employed 33 700 workers through local subsidiaries, two-thirds of whom (23 700) worked in R&D (CBS, 2014). The same year, these R&D centres spent a total of NIS 14.17 billion on R&D across the full spectrum of industry, up from 17% over the previous year.

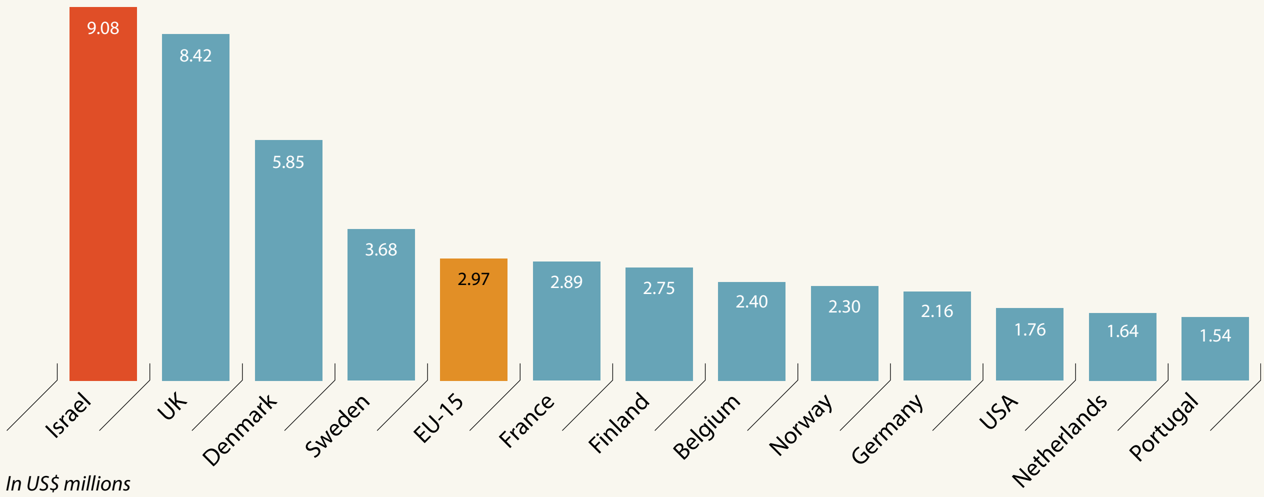
A vibrant venture capital market

Israel's thriving start-up industry is complemented by a vibrant venture capital market, which attracted US$ 2 346 million in 2013 (IVC Research Centre, 2014). Over the past decade, the venture capital industry has played a fundamental role in the development of Israel's high-tech sector. By 2013, Israeli companies had raised more venture capital as a share of GDP than companies in any other country (Figure 16.12). Today, Israel is considered one of the biggest centres for venture capital in the world outside the USA.

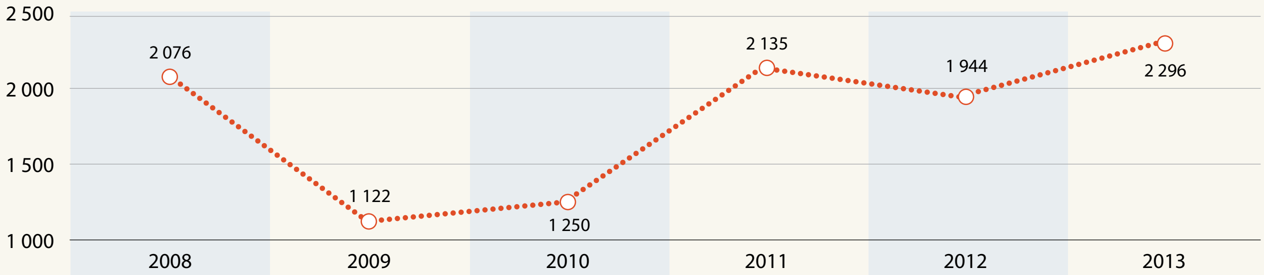
Several factors have contributed to this growth. These include tax exemptions on Israeli venture capital, funds established in conjunction with large international banks and financial companies and the involvement of major organizations desirous to capitalize on the strengths of Israeli high-tech companies (BDO Israel, 2014). These organizations include some of the world's largest multinational companies, including Apple, Cisco, Google, IBM, Intel, Microsoft, Oracle Siemens and Samsung (Breznitz and Zehavi, 2007; IVC Research Centre, 2014). In recent years, the share of venture capital invested in the growth stages of enterprises has flourished at the expense of early stage investments.

Figure 16.12: **Venture capital raised by Israeli funds, 2013**

Per thousand units of GDP



In US$ millions



Source: Eurostat, OECD (2014); Israeli Venture Capital Research Centre

Foreigners: nearly 80% of applications to Israel Patent Office

Intellectual property rights in Israel protect copyright and performers' rights, trademarks, geographical indicators, patents, industrial designs, topographies of integrated circuits, plant breeds and undisclosed business secrets. Both contemporary Israeli legislation and case law are influenced by laws and practices in modern countries, particularly Anglo-American law, the emerging body of EU law and proposals by international organizations (OECD, 2011).

Israel has made a concerted effort to improve the economy's ability to benefit from an enhanced system of intellectual property rights. This includes increasing the resources of the Israel Patent Office, upgrading enforcement activities and implementing programmes to bring ideas funded by government research to the market (OECD, 2011).

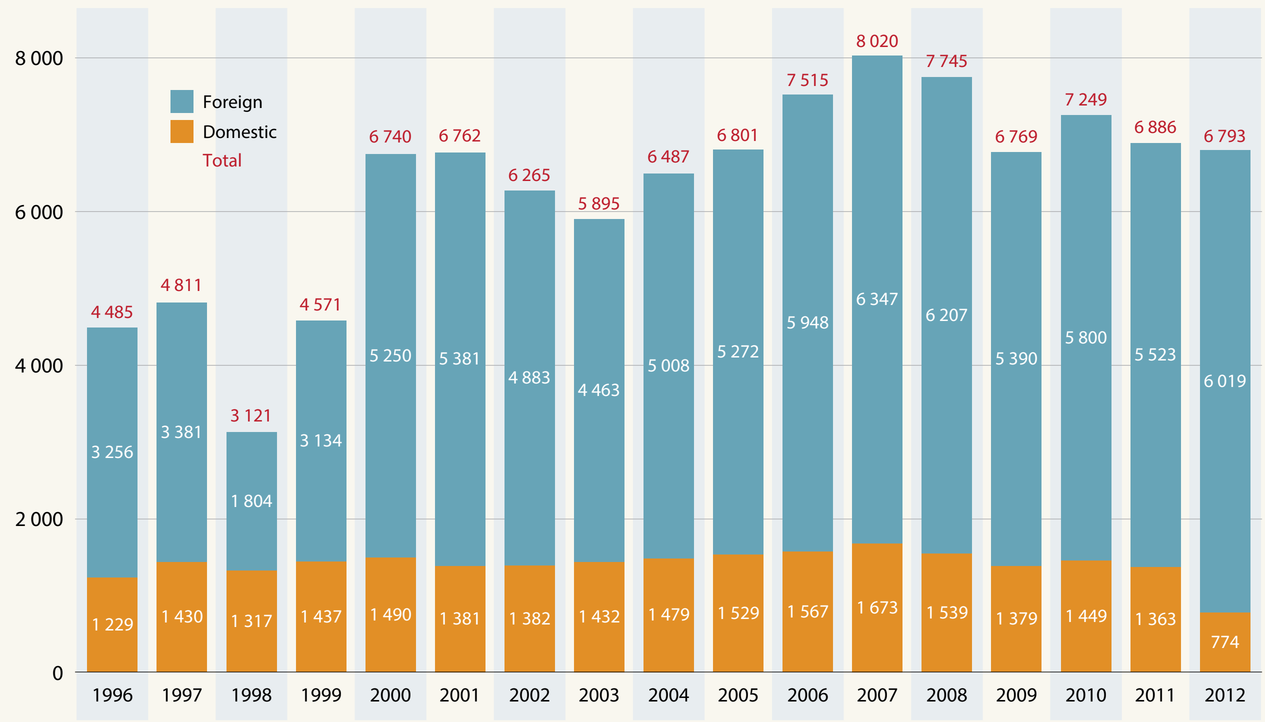
Foreigners account for nearly 80% of the patent applications filed with the Israel Patent Office since 2002 (Figure 16.13). A sizeable share of foreign applicants seeking protection from the Israel Patent Office are pharmaceutical companies such as F. Hoffmann-La Roche, Janssen, Novartis, Merck, Bayer-Schering, Sanofi-Aventis and Pfizer, which happen to be the main business competitors of Israel's own Teva Pharmaceutical Industries.

Israel ranks tenth for the number of patent applications filed with the United States Patent and Trademark Office (USPTO) by country of residence of the first-named inventor (Figure 16.14). Israeli inventors file far more applications with USPTO (5 436 in 2011) than with the European Patent Office (EPO). Moreover, the number of Israeli filings with EPO dropped from 1 400 to 1 063 between 2006 and 2011.

This preference for USPTO is largely due to the fact that foreign R&D centres implanted in Israel are primarily owned by US firms such as IBM, Intel, Sandisk, Microsoft, Applied Materials, Qualcomm, Motorola, Google or Hewlett–Packard. The inventions of these companies are attributed to Israel as the inventor of the patent but not as the owner (applicant or assignee).

The loss of intellectual property into the hands of multinationals occurs mainly through the recruitment of the best Israeli talent by the local R&D centres of multinational firms. Although the Israeli economy benefits from the activity of the multinationals' subsidiaries through job creation and other means, the advantages are relatively small compared to the potential economic gains that might have been achieved, had this intellectual property been utilized to support and foster the expansion of mature Israeli companies of a considerable size (Getz *et al.*, 2014; UNESCO, 2012).

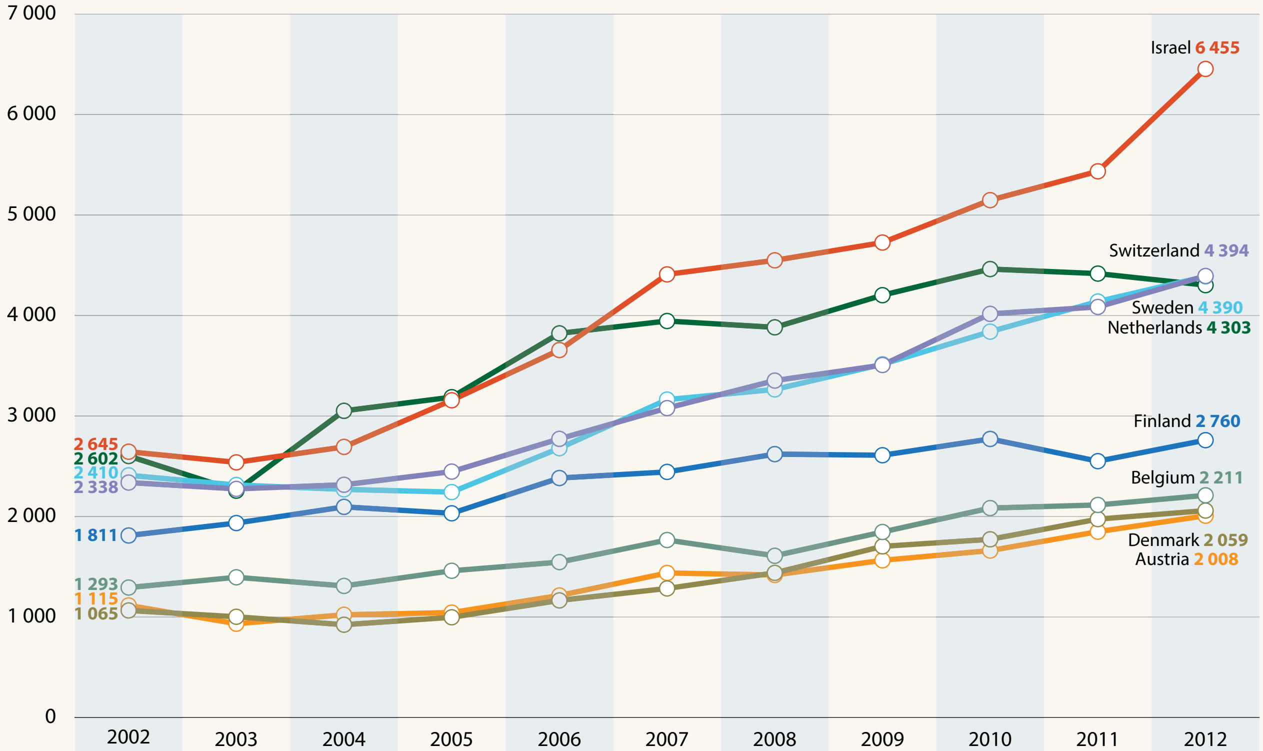
Figure 16.13: **Domestic and foreign patent applications to the Israel Patent Office, 1996–2012**



Source: Israel Patent Office

Figure 16.14: **Israeli patent applications filed with USPTO, 2002–2012**

By inventor's country of residence, other countries with a similar population size are given for comparison



Note: The top two countries registered 268 782 (USA) and 88 686 (Japan) patents respectively in 2012. Israel ranked tenth worldwide.

Source: USPTO

Chapter 16

TRENDS IN SCIENTIFIC CO-OPERATION

Broad collaboration around the world

Israel collaborates in STI with a wide range of countries, regions and international organizations. The Israel Academy of Sciences and Humanities has official agreements with 38 institutions (mostly national academies) in 35 European countries, as well as with countries in North and South America, the Indian subcontinent and Southeast Asia.

Israel has been associated with the EU's framework programmes on research and innovation since 1996. Between 2007 and 2013, Israeli public and private institutions contributed their scientific expertise to over 1 500 projects.

Israel also participates in other EU programmes, such as those of the European Research Council or European Biology Laboratory. Israel joined the European Organization for Nuclear Research (CERN) in 2014, after having participated in its activities since 1991 and becoming an associated member in 2011. Israel has been a Scientific Associate of the European Synchrotron Radiation Facility since 1999; the agreement was renewed in 2013 for a fourth term of five years and notably raised Israel's contribution from 0.5% to 1.5% of ESRF's budget. Israel is also one of the ten founding members of the European Molecular Biology Laboratory, which dates from 1974.

In 2012, the Weizmann Institute of Science, together with Tel Aviv University, was chosen as one of the seven core centres of the new Integrated Structural Biology Infrastructure (Instruct), joining prestigious institutions in France and Germany, Italy and the UK. Israel has been selected as one of the seven nodes of the European Strategy Forum of Research Infrastructure, which is establishing about 40 such nodes in total, seven of them in biomedical sciences. The aim of the biomedical Instruct is to provide pan-European users with access to state-of-the-art equipment, technologies and personnel in cellular structural biology, to enable Europe to maintain a competitive edge in this vital research area.

Israel is also one of the nodes of Elixir, which orchestrates the collection, quality control and archiving of large amounts of biological data produced by life science experiments in Europe. Some of these datasets are highly specialized and were previously only available to researchers within the country in which they were generated.

The USA is one of Israel's closest partners in STI. Some collaborative projects are funded through binational funds such as the Binational Industrial Research and Development (BIRD) foundation, which awarded US$ 37 million in grant payments for binational R&D projects from 2010 to 2014, according to its 2014 annual report. Other examples are the Binational Agricultural Research and Development fund, the US–Israel Science and Technology Foundation and the US–Israel Binational Science foundation. The Israeli Industry Centre for R&D, which falls under the Ministry of the Economy, implements bilateral co-operation agreements with various US federated states. The most recent agreements were concluded in 2011 with the State of Massachusetts in life sciences and clean technology and with the State of New York in energy, ICTs and nanotechnology.

Israel's long-lasting collaboration with Germany continues to grow. For example, the annual budget of the German–Israel Foundation for R&D (GIF) increased by € 4.8 million per year between 2010 and 2012 and by € 5 million per year from 2014 to 2016. In the past two years, GIF has distributed about € 12 million per year through the grants it provides to the regular programme and the young scientists programme.

The Israeli Industry Centre for R&D supports co-operative projects through other binational funds, such as the Canada–Israel Industrial Research and Development Foundation, the Korean–Israel Industrial Research and Development Foundation and the Singapore–Israel Industrial Research and Development Foundation.

In 2006, the Israeli and Indian ministers of agriculture signed a long-term agreement for co-operation and training. This was followed two years later by a US$ 50 million shared agricultural fund, focusing on dairy, farming technology and micro-irrigation. In 2011, Israel and India signed a co-operation agreement on urban water systems. In May 2013, the two countries signed an agreement for the establishment of 28 centres of excellence in agriculture. The first 10 centres of excellence specialize in mangoes, pomegranates and citrus fruits. They have been operational since March 2014 and are already offering farmers free training sessions in efficient agricultural techniques such as vertical farming, drip irrigation and soil solarization.

In 2010, the Israeli Industry Centre for R&D established the China–Israel Industrial Research and Development Cooperation Programme. Industrial co-operation agreements have also been signed with the provinces or municipalities of Jiangsu (2008), Shanghai (2011) and Shenzhen (2011). The India–Israel Industrial Research and Development co-operation framework (i4RD) was signed in 2005.

In 2012, the Israel Science foundation and the Natural Science Foundation of China signed an agreement establishing a fund for joint research co-operation. Current schemes involving Israeli academic institutions include the Tel Aviv University–Tsinghua University initiative for the establishment of a joint technological research centre in Beijing and the Technion's planned branch in Guangdong Province for studies in the field of science and engineering. Within trilateral co-operation, Israel, Canada and China established a joint hub in agricultural technologies in China in 2013 (see Box 4.1).

Another example of trilateral co-operation is the Africa Initiative signed by Israel, Germany and Ghana in 2012. The three implementing partners are the Israeli and German agencies for international development co-operation, Mashav and GIZ, and Ghana's Ministry of Food and Agriculture. The aim is to develop a thriving citrus value chain in Ghana, in line with the ministry's policy of enhancing productivity to improve the livelihoods of farmers.

In October 2013, the Israeli Minister of Agriculture signed an agreement establishing a joint Israeli–Vietnamese fund for agricultural R&D, together with a free-trade agreement between the two countries.

Projects in the Middle East

Israel participates in the intergovernmental project for a Synchrotron Light Source for Experimental Science and Applications in the Middle East (SESAME), a 'third-generation' synchrotron light source in Allan (Jordan) which functions under the auspices of UNESCO. The current members of SESAME are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority and Turkey. The SESAME facility is expected to be fully operational by 2017 (see Box 17.3).

The Israeli Academic Centre in Cairo was initiated in 1982 by the Israel Academy of Sciences and Humanities. Funded by the Council for Higher Education, it is entrusted with the task of strengthening research ties between universities and researchers in Israel and Egypt. The centre operated successfully until 2011 when the political climate in Egypt cooled towards Israel. Since that time, the centre has operated on a smaller scale.

The Israel Academy of Sciences and Humanities and the International Continental Drilling Programme initiated a deep-drilling expedition to the Dead Sea in 2010. Researchers from six countries participated in this scientific project, which was implemented jointly by Israel, Jordan and the Palestinian Authority.

The Israeli–Palestinian Medical and Veterinary Research Collaboration is one recent example of inter-university collaboration between Israel and the Palestinian Authority. This collaborative public health project between the Hebrew University of Jerusalem's School of Veterinary Medicine and the Al Quds Public Health Society was launched in 2014 with funding from the Dutch Ministry of Foreign Affairs.

Also of note is the Israeli–Palestinian Scientific Organization (IPSO), a non-political, non-profit organization founded over a decade ago and based in Jerusalem. Among joint research projects, one in nanotechnology stands out. It involved Israeli chemist Danny Porath at the Hebrew University of Jerusalem and one of his doctoral students, Palestinian chemist Mukhles Sowwan from Al-Quds University. Their joint research project enabled Prof. Sowwan to establish the first nanotechnology laboratory at Al-Quds University. IPSO had planned to issue a call for research proposals in late 2014, having raised about half of the requisite funding, but this call appears to have been delayed.

CONCLUSION

A need to prepare for tomorrow's science-based industries

The Israeli economy is driven by industries based on electronics, computers and communication technologies, the result of over 50 years of investment in the country's defence infrastructure. Israeli defence industries have traditionally focused on electronics, avionics and related systems. The development of these systems has given Israeli high-tech industries a qualitative edge in civilian spin-offs in the software, communications and Internet sectors.

However, the next waves of high technologies are expected to emanate from other disciplines, including molecular biology, biotechnology and pharmaceuticals, nanotechnology, material sciences and chemistry, in intimate synergy with ICTs. These disciplines are rooted in the basic research laboratories of universities rather than the defence industries. This poses a dilemma. In the absence of a national policy for universities, let alone for the higher education system as a whole, it is not clear how these institutions will manage to supply the knowledge, skills and human resources needed for these new science-based industries.

There is no single 'umbrella-type' organization that co-ordinates all of STI and formulates STI policy in Israel. In order to safeguard the long-term relevance of Israeli R&D and the country's innovation capabilities, a holistic R&D framework and strategy should be implemented. This framework should involve the various actors of the STI system: the Office of the Chief Scientist in the Ministry of the Economy and other government ministries, Israel's research universities and research centres of excellence, its hospitals and academic medical centres and its corporate R&D laboratories.

The *Sixth Higher Education Plan* (2011–2015) sets out to improve the quality and competitiveness of the higher education system. It contains important recommendations, such as that of raising the number of academic staff by about 850 over the next six years and encouraging minorities to study at university in anticipation of the looming shortage of professionals in Israel. Enhancing the integration of ultra-orthodox men and Arab women in the labour force and their educational level will be vital to safeguard Israel's growth potential in the years to come.

The *Sixth Higher Education Plan* sidesteps one key issue, however. Israel's universities are neither equipped, nor sufficiently funded to be at the forefront of science and technology in the 21st century. Funding of research infrastructure is particularly worrying because, in decades past, insufficient government funding has been greatly compensated by philanthropic contributions from the American Jewish community. This contribution is expected to diminish significantly.

Long-term economic growth cannot be attained without improving the productivity of the traditional industrial and services sector. The remedy could lie in giving employers incentives to implement innovation, by encouraging them to assimilate advanced technologies, adopt organizational changes and new business models and augment the share of exports in their output.

Globalization presents both tremendous challenges and opportunities for Israel's high-tech industry. An economy centred on delivering innovation and added value could give companies a huge competitive advantage in the global market in the years to come, as multinational companies are continually seeking new ideas and unique products to serve unmet needs.

In recent years, scientific research in interdisciplinary frontier fields such as bioinformatics, synthetic biology, nanobiology, computational biology, tissue biology, biomaterials, system biology and neuroscience, has evolved rapidly in Israeli academia but not shown the same intensity in Israeli industry. These new interdisciplinary and converging fields are likely to constitute the next growth engines for the global economy. Regulatory and targeted policy measures should be formulated by the Israeli authorities to create the necessary infrastructure to absorb the fruits of academic research in these fields and integrate, convert and adapt the fruits of this research to wider economic and practical use.

KEY TARGETS FOR ISRAEL

- Raise industrial-level productivity – the value added by each employee – from PPP$ 63 996 in 2014 to PPP$ 82 247 by 2020;
- Increase the number of university faculty by 15% and the teaching staff of colleges by 25% by 2018;
- Capture a 3–5% share of the US $ 250 billion global space market with a sales volume of US$ 5 billion by 2022;
- Reduce electricity consumption by 20% between 2008 and 2020;
- Generate 10% of electricity from renewable sources by 2020.

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