The High-Tech Sector in Israel

Neil Gandal, Stefania Roccas Gandal, and Nadav Kunievsky[1]

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17.1 Introduction and Overview

Israel is recognized as one of the most innovative countries in the world. According to the Bloomberg Index of Innovation, Israel stands at number five,[2] while according to the Global Competitive Index, Israel ranks third in the innovation category.[3] The country is now recognized around the world for its excellence in technology and as a center for high-tech entrepreneurship.

There are approximately 100 Israeli companies listed on the NASDAQ stock exchange.[4] Leading players in high-tech, such as Intel, IBM, Google, Motorola, Microsoft, Facebook and many others have set up research centers in Israel, hoping to harvest local talent and knowledge. In 2015 alone, there were 95 mergers and acquisitions of Israeli high-tech companies.[5] In 2017, Intel's acquisition of Israeli computer vision firm Mobileye for $15.3 billion set a financial record; Mobileye will become the global center of Intel's efforts to develop new technology for the worldwide automobile industry.

Israeli companies today play a key role in shaping the global high-tech industry – from semiconductors to the end user applications. Israel is a world leader in Information and Communications Technology (ICT), which is the largest component of High-Tech in Israel. In

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[2] "The Bloomberg Innovation Index", www.bloomberg.com/graphics/2015-innovative-countries/ (accessed 17/12/2016)

[3] "Global Competitiveness Report 2015-2016 - Reports - World Economic Forum", http://reports.weforum.org/global-competitiveness-report-2015-2016/economies/#economy=ISR (accessed 17/12/2016)

[4] "Companies in Israel – Nasdaq.com", www.nasdaq.com/screening/companies-by-region.aspx?region=Middle+East&country=Israel (accessed 17/12/2016)

[5] IVC Research Centre (2016.)

particular, Israel is the world leader in information security, which is one of the largest and fastest growing sub-sectors of ICT.

In 2000, near the peak of the worldwide high-tech boom (or "dotcom" bubble,) there were already more than 2000 high-tech firms in Israel. By 2015, there were more than 4400 high-tech firms in the Israeli Information and Communication Technology sector alone! [6] Most of the high-tech companies are concentrated in the so-called "Silicon Wadi[7]," in the coastal plain in Israel. Additional companies are located in Haifa and Jerusalem. In 2015, Israeli firms raised a staggering $4.43 Billion in venture capital, much of it from abroad.[8] Clearly, venture capital abounds in Israel.

The degree to which Israel stands out - even when compared to other nations that are emerging as global R&D centers - is revealed in work by Branstetter, Glennon, and Jensen (2018). They use data on U.S. multinational affiliates to measure the productivity of R&D investment around the world. They associate U.S. affiliates abroad with the patents these affiliates generate, using the addresses of individual inventors listed on the patent documents. Then they regress these patents on affiliate-level measures of R&D spending and other control variables. They find that U.S. affiliates in Israel are approximately six times more productive than the baseline destination (outside the U.S.) in terms of turning R&D dollars into U.S. patents.

17.1.1 Road Map

An article or a chapter about high tech can be very different, depending on the type of analysis the researcher wishes to conduct. The goal of this chapter is to provide some background, summary, and trend data, as well as examine key problems facing Israeli high-tech.

The chapter proceeds as follows: In section 17.2, we provide background, summary, and trend data regarding high-tech in Israel. In this section, we provide a brief historical perspective as well as an examination of key trends over the last twenty years. At the end of the section, we focus on promising new frontiers for Israeli high-tech. We believe the patterns and empirical regularities we highlight here are likely to be applicable to other domains in information

[6] Getz and Goldberg (2016.)
[7] DeFontenay and Carmel (2004.)
[8] IVC Research (2016.)

technology (like digital health and the digital automotive revolution) where Israel has found success.

Section 17.3 addresses key problems facing the high-tech sector, in particular a shortage of skilled engineers and computer scientists. In this section, we discuss the potential sources to increase the supply of high tech professionals in Israel.

Section 17.4 provides very brief conclusions.

17.2 Background, Summary Data, and Trends

17.2.1 What is High-Tech?

Despise the widespread use of "High-Tech", the term remains relatively amorphous. Contrary to other economic activities, which are traditionally defined according to the end product (Health, Education, Real-estate, etc.), industries which are classified as High-Tech are usually defined by innovation in the production method, innovation in the final product and the share of engineers, scientists, academic scholars in the labor force. As a result, the high-tech sector includes activities associated with the manufacturing sector (pharmaceutical products, computer manufacturing, etc.) and activities associated with the services sector (computer programming etc.)[9]

Despite, the difficulty in defining innovative, and hence which firms fall under the high-tech umbrella, high-tech firms are usually firms that invest heavily in research and development, and employ R&D personnel, regardless of whether they produce a high-tech product or service. Fortunately, the Israeli Central Bureau of Statistics (CBS) defines the “boundaries” of High-Tech – and we will use their definition in our analysis.

The goal of this section (Section 17.2) is to survey the development of the Israeli high-tech sector in the past 30 years, as well as to explore its various facets. The rest of section 17.2 proceeds as follows: We first briefly discuss the early days of Israeli innovative activities. We then describe trends in the high-tech sector. As mentioned, firms in the high-tech sector rely heavily on R&D; hence, we follow by delving deeper into the R&D sector in Israel. Next, we turn to describe government policies which helped nurture the current high-tech sector. We

[9] Hence, it is difficult to measure productivity in high-tech.

then examine Israeli "start-ups", a unique character of the Israeli high-tech sector. We close the section by discussing up-and-coming high-tech fields that play to Israel's strengths.

17.2.2 A Brief Selective History of the Foundations of High-Tech in Israel

A famous English proverb (source unknown) states, "Necessity is the mother of invention." Clearly, necessity was a driving force in innovation in Israel. Israel is primarily a desert with limited water resources, so early on the country needed to find innovative ways to make its land productive. The solution was drip irrigation. It enabled Israel to turn arid land into a productive industry. In 1965, the company Netafim was founded on Kibbutz Hatzerim and Israel's irrigation technology took off both locally and all over the world. Today, Netafirm is a global company operating in more than 100 countries. Drip irrigation technology was the beginning of what became a large Israeli agricultural technology industry.

Similarly, the defense needs of the new state required innovation in military technologies. From the very beginning, military R&D was a necessity. In 1948, Israel founded the Science Corps, which was responsible for the development of arms and electronic appliances for the Israeli Defense Forces (IDF.) Ten years later, the IDF Science Corps were reorganized as Rafael - the Authority for the Development of Armaments. Rafael is still known today for high-quality weaponry and other elite technologies used by the IDF. The defense technology developed in Israel runs the gamut from antimissile systems to cybersecurity. Many of the military innovations led to breakthroughs in products for non-military use.

The French Government's arms embargo on Israel in 1967 forced Israel to start developing its own advanced weapons. It also incentivized the Israeli government to invest heavily in these developments. It did not take long for Israel to become an innovative and creative player in advanced weaponry. One of the embargo's effects was the subsequent decision of the Israeli government to develop new weapons systems.[10] The development of these systems helped the local labor force to specialize in creating and developing chips and advance sensors. As these weapons programs were scaled back (in favor of partial reliance on weapons systems from the U.S.), highly skilled engineering talent was released into Israel's civilian economy and many top engineers found civilian applications for the skills they acquired in the military.

[10] www.calcalist.co.il/articles/0,7340,L-3720135,00.html

In addition to investing in military and agricultural technologies, the government invested in universities, that from the beginning, made cutting-edge contributions in basic research in a wide range of fields. Hebrew University and the Israel Institute of Technology (the Technion) were established in 1925, more than twenty years before Israel came into existence. The Weizmann Institute for Science was also founded before Israel achieved its independence.

Knowledge from the universities quickly spilled over to the private sector. The University R&D foundations - the first of which was established in 1952 by the Technion - were primarily responsible for jumpstarting the interaction between university researchers and industry which has grown significantly over time.

Elron, the first non-governmental Israeli company in the high-tech industry, was formed in the 1962. It was the first electronics company in Israel and its early products were measurement tools for medical applications. Shortly thereafter, Elron established a new joint venture (Elbit) which created mini-computers for the IDF. New companies such as Elscint and Tadiran joined the small industry and started to specialize in communications, medical equipment and printing. One of Israel's earliest successful Telecom companies, ECI Telecom, was initially a producer of technology for military applications.

Israel's initial success in military and agricultural innovations attracted international firms. In 1964, Motorola established its first non-U.S. subsidiary in Israel. Motorola was followed by IBM (1972) and Intel (1974). Both of the tech giants established R&Ds center in Israel when highly regarded Israeli engineers in these companies moved back to Israel after years of experience in the U.S. high-tech sector. This was the beginning of "two-way" flows of top scientific and engineering talent between Israel and technology centers in the United States. This flow played an extremely important role in the subsequent development of the Israeli high-tech industry – and it continues to be important today. Flows of knowledge and venture capital from the United States have often been initiated by direct, personal connections between Israeli scientists and entrepreneurs and key investors in the U.S.

Despite the early foreign direct investments, both banks and the government were initially skeptical about whether Israeli companies would be able to become important players in the global high-tech industry. A turning point came in 1972 when Elscint had a successful initial

public offering (IPO) in the U.S. on the NASDAQ stock exchange. This drew the interest of banks, other investors, and the Israeli government.

Before the potential shown by Elscint's successful IPO could be realized, the Israeli economy needed to undergo some significant changes. From independence through the early 1980s, the Israeli economy operated under a quasi-socialist model with heavy state intervention, intrusive regulation, and widespread inefficiency in the allocation of resources across sectors and firms. Persistent macroeconomic policy errors eventually led to hyperinflation in the mid-1980s. The resulting economic crisis turned out to be an opportunity and the “centralized” model of economic activity was effectively abandoned. This enabled flows of talent and capital out of the bureaucratized organizations that had dominated the Israeli economy in prior decades.

At the same time when Israel's economy was shifting to a more market-driven model, the Soviet Union was collapsing. The unexpected and rapid unraveling of the Soviet Union provided an opportunity for hundreds of thousands of Soviet Jews to immigrate to Israel. Many of the Russian immigrants were highly skilled engineers and scientists. The flows of engineering talent out of the indigenous weapons programs described above, combined with flows of highly educated Soviet emigres, led to a significantly larger engineering labor market that could be mobilized for civilian technological development.

This pool of engineering talent emerged at an ideal time. The personal computer revolution of the 1980s and 1990s drove massive growth in the demand for increasingly sophisticated software to run on the rapidly growing installed base of smart machines. The rise of the Internet in the 1990s created demand for (increasingly wireless) communications to link computers, more sophisticated cybersecurity systems, and new internet business models. These global technological shifts created unprecedented opportunities for R&D-intensive firms that did not require large fabrication facilities or other extensive manufacturing capabilities. As nations like Japan struggled in the Internet era, Israel's emerging high-tech industry benefitted from the new software technologies that played to its strengths.

Foreign firms realized the potential in Israel in information technology, and began to increase investments. During the 1980’s, more large international technology companies followed in the footsteps of the early pioneers, Motorola, IBM, and Intel, forming R&D centers in Israel in order to harvest local talent. During the 1990’s, this flow became a flood, as Israel was

inundated with foreign investments made by leading players in the global high tech industry. The increasing number of R&D centers and general growth in venture capital led to the formation of hundreds of startups.

Currently, most major high-tech firms in the world have R&D centers in Israel. Intel itself has four R&D facilities, as well as two manufacturing centers in Israel, and employs more than 7,000 people in Israel. Google opened two R&D centers in Israel, and Facebook established its first R&D venture outside the US in Israel. Strongly connected networks that originate in the IDF continue to infuse the Israeli high-tech industry with high quality and well-connected engineers and computer scientists.[11] In part because of its defense needs, Israel has a comparative advantage in ICT/information security. It is considered by many to be the top country for innovation and R&D in this field. Many local firms (like Checkpoint) are world leaders. The digitalization of "health services and "automotive mobility" are upcoming fields that also play to Israel's strengths.

17.2.3 The High Sector – Trends from 1990 to Today

Following the Israeli CBS, we divide the high-tech sector into its two main components – manufacturing and services. For High-Tech manufacturing, we use the CBS definition of "High-Tech manufacturing activities". This includes the manufacture of pharmaceutical products, office and accounting machinery and computers, electronic components, electronic and communication equipment, industrial equipment for control and supervision, and medical/scientific equipment. For High-Tech services, we use the CBS definition of Information and Communication Technology (ICT), which consists mostly of services activities, and includes all of the high-tech services in Israel.[12] This category includes all software services: data processing, computer programming, telecommunication services, and cybersecurity.

In 2012, the CBS adopted the OECD definition for ICT. The main differences between the new definition of ICT and the definition previously used in CBS publications are the removal of (1)

[11] Ellis, Drori, and Shapira (2013) argue that the development of high-tech in Israel was in part driven by successful Israeli "serial entrepreneurs," i.e., those who established more than one start-up each. They follow Israeli "serial entrepreneurs.

[12] www.cbs.gov.il/www/publications/hitech/hi_class_heb.pdf. For the iCBS high-tech definition, see www.cbs.gov.il/shnaton67/st12_00.pdf

research and development[13] and (2) the manufacture of industrial equipment for control and supervision, as well as (3) the addition of ICT wholesale. The key change was the removal of R&D since the manufacture of industrial equipment for control and supervision and the wholesale categories are relatively small. These changes make it hard to track continuous trends in the ICT sector from 1990 and 2015. To avoid comparing apples and oranges, we focus on the changes before 2012 and then discuss the ICT sector today.

The ICT service sector experienced significant growth during the 90s and the early 2000s. Between 1990 and 2001, the ICT services sector's real GDP rose by 500 percent. At the same time, the ICT manufacturing sector grew by 135 percent. Because of the extremely fast growth rate in services, the service sector part of ICT grew from less than 40 percent in 1990 to 70 percent by 2001.

The rapid growth during this period earned the sector the title "the growth engine of Israel." For comparison, during the same (1990–2001) period, the Israeli business sector grew by 34 percent. Without the ICT sector services and the high-tech manufacturing sectors, the growth rate would have been 26 percent. This illustrates the critical importance of the high-tech sector to Israel economy, which, short on labor and natural resources, relies heavily on innovation as its growth engine. Although the focus is primarily on services, manufacturing industries with "high technological intensity" have grown much faster than manufacturing industries with "low technological intensity." After 2001, and the burst of "dot-com" bubble, the growth rate of the ICT sector slowed and during the 2001-2012, the sector grew at an average rate of approximately 5.5 percent both in services and manufacturing.

The greater importance of services over time also can be seen in venture capital investment. Semiconductor venture capital investment accounted for approximately 19 percent of the venture capital invested in Israel in 2007, but only 4 percent of the venture capital in 2015. Software venture capital on the other hand accounted for 49 percent of the venture capital invested in Israel in 2007 and shot up to 69 percent in 2015.

This rapid growth in Israeli high-Tech sector during the 90's and first decade of 21st century in Israel was a part of a global trend of growth in High-Tech industries in general and in the ICT

[13] R&D which directly relates to ICT is still part of the ICT sector.

sector in particular. In some sense, Israel was lucky to ride this wave. The increase in supply of skilled workers in Israel, primarily from immigration from the former Soviet Union (FSU,) coincided with a huge increase in demand worldwide for ICT products and services.

Between 1990 and 2000, immigrants from FSU totaled a million people. Many of the immigrants from the FSU were highly educated and highly skilled, with a large number having advanced degrees and technical training. This influx of immigrants increased Israel population by a fifth and reinforced its general educational level. Among the immigrants, there were approximately 100,000 scientists and engineers. With the influx of these skilled workers, Israel had the highest number of engineers per capita in the world, by far —140 per 10,000 employees.[14] This was twice the per-capita level of the United States and Japan, the second and third ranked countries in this category. This massive increase in skilled labor helped to answer rising demand for workers in the ICT sector.

Another boost to the sector in those years, came from the increase in investments during the 90s. During this period, according to Lach et al. (2008,) the share of ICT investment (as a percentage of GDP) nearly doubled. While Israel started the 1990s with a relatively low level of investment in the ICT sector, by the end of the decade it had eclipsed many other Western economies.

During the 1990's, investment was primarily provided by public funds. A report for the Ministry of Economics and Industry found that between 1990 and 2007, every million NIS subsidized by the government in R&D, resulted in an addition of 1.28 million NIS to R&D[15]. This large support by the Israeli government led to even larger investments by the business sector in R&D and helped "jump-start" the High-Tech sector in Israel.

17.2.4 Employment, Productivity and Wages

By 2013, the share of high tech[16] jobs reached 9 percent of the total number of jobs in the Israeli economy. Using OECD data, we can compare the share of the ICT sector to other OECD countries. This Comparison shows that the share of ICT jobs in the economy is relatively large

[14] Getz and Goldberg (2016.)
[15] Applied Economics (2008.)
[16] High-tech jobs refer positions in the ICT sector and in the High-Tech manufacturing sector.

in Israel, accounting for nearly 5 percent of employment as of 2015. This is larger than other OCED countries, where the average was 3.7 percent.[17]

The average wage in the sector is one of the highest in Israel and in 2015 was approximately 20,000 NIS, while the overall average wage in Israel was less than 10,000 NIS. The difference in wages between the high-tech sector and other sectors in the economy has increased in recent years. The rise in wages in high-tech contributes to Israel's high level of income inequality (As of 2015, Israel was #7 among OECD countries in the (Gini) inequality index.[18])

The wage gap between high-tech and other sectors is unlikely to diminish because productivity in the high-tech sector is relatively high compared to other sectors. One of the reasons for the high productivity is the skilled workforce.

Another reason for the high level of productivity in the sector stems from high-tech firms in Israel selling their products and services in international markets. Various studies have highlighted the connection between international trade and productivity (Melitz, 2003.) Gallo (2011) examines the effect of trade on productivity in Israel and finds that Israeli firms that rely more on exports are much more productive. Gallo (2011) also points out that although the exporting firms have high levels of productivity before they start exporting, these firms become even more productive after they start exporting, implying that exporting might increase the level of productivity.

The sector's high level of productivity raises the question whether there are positive spillovers to other sectors in the Israeli economy. These spillovers may occur through multiple channels. For example, it is possible that workers who are working in high-tech would use the knowledge they gain and use it when they move into other sectors. Another channel might be that innovative products developed in high-tech would be used in other sectors to improve their productivity.

Unfortunately, this does not seem to be the case in Israel. Regen and Brand (2015) show that between 1995-2009, the productivity gap in high-tech between leading OECD countries and Israel fell. In all other sectors, the gaps have stayed the same, or worsened.

[17] From OECD data, see https://data.oecd.org/ict/ict-employment.htm#indicator-chart.
[18] www.oecd.org/social/income-distribution-database.htm - accessed 20/10/2017

One possible reason for the low spillovers between the sectors might be is that Israeli high-tech is mainly focused on creating new knowledge and selling it abroad and not in developing the final product. As a result, there is not much interaction between traditional local firms and high-tech firms in Israel. Brand and Regev (2015) also show that mobility of workers between sectors declined between 1996 and 2011, implying that workers are less likely to spread the knowledge acquired in the High-Tech sector to other sectors.

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17.2.5 Investment in Research and Development (R&D)

Israel invests a large amount of capital in R&D. In 2014, the national expenditure on civilian R&D stood at 12.4 Billion USD,[19] and constituted 4.3 percent of GDP, which is the highest rate per capita in the world. This reflects a rise of 235 percent in R&D expenditure since 1990.

In Israel, in 2014, the private/business sector accounted for 84 percent of the civilian expenditure on R&D. A further 13 percent of the expenditure took place in institutes of higher education (primarily universities.) Private non-profit organizations and the government conducted the remaining 3 percent of R&D expenditure.[20] The share of R&D expenditure by the business sector is higher than any other OECD country.[21]

The share of R&D performed by the business sector significantly increased during the 1991-2013 period. During this period, research and development shifted from the government/public

[19] CBS Annual report, table 26.1, www.cbs.gov.il/reader/shnaton/templ_shnaton.html?num_tab=st26_01&CYear=2016.
[20] CBS Annual report, table 26.1, www.cbs.gov.il/reader/shnaton/templ_shnaton.html?num_tab=st26_01&CYear=2016.
[21] OECD (2016), Main Science and Technology Indicators, Volume 2016 Issue 1, OECD Publishing, Paris.

sector to the private sector. The changes over time are dramatic. Currently the government conducts a very small share, while the share of R&D conducted by institutes of higher education has declined by about 50 percent in the period from 1991-2013.

The main source of financing for Civilian R&D in Israel now comes from abroad.[22] In 2013, investment from abroad made up nearly 50 percent of Civilian R&D, while the local business sector financed another 37 percent. The government financed 12 percent, while higher education institutions and non-profit organizations financed the remaining 2 percent. Note that through the period the private sector financing has replaced the large share of government finance.

The very large share of R&D financing from abroad is unique to Israel. Financing from abroad soared during the 1991-2012 period. Israel receives a higher percent of foreign R&D "venture capital" than any other OECD member country and large numbers of multinational firms have R&D centers in Israel.[23]

17.2.6 Government Support and Incentives

The importance placed on R&D in Israel can be traced back to one of the initial meetings of the Israeli Parliament, the Knesset, in 1948. In that meeting, Israel's first Prime Minister, David Ben Gurion, made the following statement:

> "*We cannot match other nations in strength, wealth, size or material but we are also not inferior to any other nation in our intellectual and moral abilities… we must take scientific research, be it basic or applied, to its highest peak*[24]

In the spirit of Ben Gurion's words, Israel invests heavily in innovation, R&D and scientific research through different channels. We discuss the main government/public channels for investment in R&D below.

A key institution in Israel's support of R&D is the Innovation Authority[25], which operates under the Ministry of Economics. In 2015, The Innovation Authority (IA) replaced the Office of the Chief Scientist (OCS). The IA is responsible for all governmental support to R&D and

[22] CBS Annual Report, table 26.2, www.cbs.gov.il/reader/shnaton/templ_shnaton.html?num_tab=st26_02&CYear=2016
[23] OECD (2016.)
[24] Lemarchand, G. A., Leck, E., and A. Tash (2016).
[25] The Innovation Authority, www.economy.gov.il/RnD/pages/default.aspx (Hebrew)

entrepreneurship. It supports hundreds of projects in different ways, from pre-seed initiatives to start-up companies.

The IA provides matching grants for commercial R&D Projects. Grants from the IA are especially important for startup firms. In the past decade, IA/OCS grants have declined both in scale and in their share of the state budget. This is in large part because the private venture capital industry has attracted so much capital in recent years. The government is still important, however, for targeted projects (i.e., support for integrating Israeli Arabs into high-tech.)

Legislation has also been enacted in support of R&D and high-tech. In 1984, Israel legislated the establishment of the Law for the Encouragement of Industrial Research and Development (the R&D law). The goal was to create new jobs and to absorb skilled workers and increase growth while exploiting the technological infrastructure and the existing human resources in the state. The law offers funds for R&D initiatives and export-targeted products that meet certain criteria of eligibility. Funds are supplied through the IA.[26]

Another important channel in which the government affects R&D in Israel is investment in military R&D. In 1982, MAFAT, the Administration for the Development of Weapons and Technological Infrastructure, was established under the Ministry of Defense and the Israeli Defense Force, replacing the former R&D department in the Ministry of Defense. MAFAT controls all defense R&D programs in Israel and coordinates between the Ministry of Defense, the Israeli Defense Force, Israel Military Industries, Israel Aerospace Industries, Rafael Advanced Defense Systems, the Institute for Biological Research, and the Space Agency. Tabansky and Ben-Israel (2015)estimate that Israel's expenditures on defense R&D is between 1 percent and 1.5 percent of GDP. This is in addition to the 4.3 percent of GDP spent on civilian R&D.

Higher education, of course, plays a key role as well and the government provides much of the funding for Israel's top Universities. Nearly 50 percent of Israelis[27] between the ages 25-64 have completed some higher education. This rate is one of the highest among OECD countries. In addition to supplying the high-tech industry with highly skilled and educated workers, 13

[26] www.economy.gov.il/RnD/InnovationStrategy/Pages/GovernmentSupport.aspx
[27] From the OECD data, https://data.oecd.org/eduatt/adult-education-level.htm

percent of R&D expenditure takes place in the universities and other research institutions funded by the government.[28]

17.2.7 Venture Capital

The rise in private sector financing of civilian R&D in Israel was due in part to the creation of a robust venture capital industry. Although it was not always the case, Israel now has a very sophisticated and mature venture capital industry.

During the mid-1990s, government money (80 Million USD) created 10 "Yozma" (initiative) funds, which were privately managed. An additional 20 million USD were directly managed by a government-owned fund. A further 150 Million USD came from financial institutions and corporations from abroad and from Israel. This "seed money" was invested in nearly 200 startups.[29] Yozma was created, in part, because of an increase in the supply of high-tech personnel in Israel. As discussed, the increase in supply was due to two key events: (1) In the late 1980s, the Israeli military industries laid-off many engineers and scientists and (2) The massive immigration of more than one million Jews from the former Soviet Union in the early 1990s included a non-trivial number of engineers and scientists.

Between 2013-2015, venture capital raised by Israeli starts-ups and other entities nearly doubled. According to Israel Venture Capital (IVC), Israeli firms and startups raised about $2.3 billion in 2013. In 2015, as noted, Israel's high-tech sector attracted a staggering $4.43 billion in investment, much of it from abroad.[30]

17.2.8 Start Ups

A key aspect of Israeli innovation is its start-up industry. There are more startups per capita in Israel than in any other country in the world,[31] and many of these startups are in the ICT field. Most of the financing for startups comes from "venture capital."

17.2.9 Foreign R&D Centers

[28] Additional government support includes bi-national programs for Israeli R&D, such as Binational Industrial Research and Development Foundation (BIRD), the Canada-Israel Industrial R&D foundation (CIIRDF), the Binational (US-Israel) Science Foundation (BSF) and many others, providing additional funding.
[29] Avnimelech and Teubal (2006.)
[30] IVC Research (2016.) For more on the development of the venture capital industry, see Avnimelech and Teubal (2006.)
[31] Senor and Singer (2009) and the sources cited within.

The impressive growth of the High-Tech sector and especially the development of the Israeli ICT sector, was accompanied by a large increase in the number of foreign R&D. Leading companies such as Google, Apple, Intel and Facebook all have R&D centers in Israel, and they are part of 307 such companies in 2007. According to a report by Dun and Bradstreet[32], these international R&D companies, which total 5.4 percent of Israeli R&D companies, are responsible for 63 percent of the total business R&D expenditure, in 2015. Today most of the internationally held R&D centers are focused in IT & Enterprise software and Medical devices and come from the US.

Since the 1960s, 380 foreign R&D centers were opened in Israel.[33] The first R&D centers were relatively small, with 7-10 employees. During the 90s, as part of the globalization and the information revolution, more companies started to open R&D centers around the world, and especially in Israel.[34]. Two main factors typically drive global expansions in foreign R&D. The first is lower costs overseas. The second is the use of foreign R&D as enhancer of innovation and the use of foreign knowledge as unique inputs for international corporations. Wages in high-tech Israel are competitive with the US. Hence, improved innovation rather than lower costs is the primary reason for the increase in the number and size of foreign R&D centers in Israel.

Benefits from foreign R&D centers flow to Israel as well. Sokolinski et al (2016) show that employment in international firms increases the productivity levels of Israeli workers, especially when the workers are employed in larger multinational firms. Additionally, a report for the Innovation Authority[35] examined the effect of foreign firms on the local industry and found that an increase in R&D expenditures of foreign firms is positively correlated with the expansion of local firms, implying that there might spillovers. The report notes that a relatively large number of workers who worked in foreign firms become entrepreneurs and started their own companies, suggesting an additional channel of potential knowledge spillover.

Although multinational R&D centers show great advantages, some fear that they might have some negative effects on local firms. The main issue is that these multinational companies

[32] www.iati.co.il/files/files/R&D%20Centers%20of%20Int.%20Corporates%20in%20Israel.pdf
[33] See Slonim (2013.)
[34] http://unctad.org/en/Docs/wir2005_en.pdf
[35] Applied Economics (2008)

increase the demand for local engineers and raise wages, therefore, making it harder for local firms to compete in international markets. The same Ministry of Economics report from 2014 also found that wage increases in foreign centers correlates with wage increases in local firms. Further, a large portion of the workers who were working in foreign firms, had previously worked in Israeli firms, implying that foreign and local firms compete for the same labor force.

17.2.10 New Frontiers in Israeli High-Tech: Automotive Industry + Digital Health

Before closing this section, we very briefly discuss other emerging high-tech sectors (I) Automotive industry and (II) Health IT + Digital Health. These relatively new sectors require skills similar to those needed in ICT. Hence, Israel is well positioned to be an important player in these fields.

There were two large acquisitions of Israeli firms in the automotive sector recently. The huge acquisition of the Israeli firm "Mobileye" in 2017 by the semiconductor giant Intel for a staggering 15.3 Billion USD was the largest acquisition in Israeli high-tech ever. The goal for Intel is to team up with BMW to produce autonomous (driverless) vehicles. This acquisition followed the 2013 acquisition of Waze by Google for 1.3 Billion USD. Other firms are increasing investments in Israel as well. GM recently (2016) announced the doubling of its workforce at its Israeli research center.[36]

In general, technological changes in the automotive industry mean that consumers will be increasingly "consuming mobility" rather than purchasing automobiles. The digitalization of mobility (for "object recognition" and advanced driver systems for example) play to the strengths of Israel's tightly networked high-tech workforce, namely ICT.[37]

The Israel life sciences industry has seen rapid growth in recent years.[38] Two especially promising sub-sectors of the Life Sciences Industry in Israel are Health IT and Digital Health. Like the "digitalization of mobility" in the automobile industry, there have been significant advances in the digitation of health in recent years. These two sub-sectors are thus very similar

[36] "General Motors to double size of Israel R&D center," Globes, Tali Tsipori, 19 April, 2016, available at www.globes.co.il/en/article-in-the-future-we-might-team-up-with-apple-or-google-1001118610.
[37] See Bernhard, Leutiger, and Ernst (2016.)
[38] Israel's Life Sciences Industry, Israel Advanced Technology Industries (IATI) 2015 Summary Report, by Karin Mayer Rubinstein and Benny Zeevi, available from the IATI website at www.iati.co.il/. IATI is "Israel's largest umbrella organization for the High-Tech and Life Sciences Industry."

to the ICT industry and draw upon the skilled ICT workforce in Israel. Unlike clinical trials that require significant upfront investments, Health IT and Digital Health, similar to ICT in general, require relatively modest amounts of investment.

As noted in the IATI (2015) report, the health IT market is potentially huge, since (due to regulation among other reasons) healthcare organizations traditionally used little IT. This, of course, has changed in recent years, and the Israeli ICT strengths mean that Israel is extremely well-positioned in Health IT. Not surprisingly, there has been a large increase in the number of Israeli firms in Health IT. As the IATI (2015) report notes, half of the nearly 300 Israeli companies active in 2015 were formed during the 2011-2014 period.

17.3 The Future of High-Tech in Israel

In recent years, the growth rate of the ICT sector has slowed down considerably. Between 2011 and 2015, the real growth rate of the ICT Sector (under the new definition of the CBS), was approximately 3 percent per year.

17.3.1 Shortage of Skilled Workers

Until recently, the high-tech industry benefitted from (1) academics and employees of the public sector (including the military industries) moving into the private sector and (2) the immigration of tens of thousands of Jewish engineers from the former Soviet Union. These sources have been all but exhausted. Further, the success itself of high-tech in Israel has led to an increase in venture capital funding and an associated demand from firms for skilled labor. The demand currently exceeds the supply of skilled labor. Hence, a critical question is will the high-tech sector in Israel be able to continue its remarkable success going forward.

Despite the success of Israeli high-tech, there has been stagnation in the High-Tech sector in Israel during the last few years. Between 1998 and 2012, the tech industry grew on average more than double the rate of Israel's GDP. In recent years, the tech sector has expanded at a slower rate than the overall economy. This slowdown is often blamed on a growing shortage of skilled workers. According to sources quoted by the Economist magazine,[39] there is a

[39] "The "Startup Nation" is running out of steam, the Economist, 9 July 2016. "High-tech boom may be over, Israel's chief scientist warns," Shoshana Salomon, the Times of Israel, 30 June 2016.

significant lack of engineers and computer scientists in Israel. Three main causes for the lack of supply of skilled personnel in the high-tech sector are: (1) a decreasing stream of graduates (2) lower quality of engineers and computer scientists who study at non-University institutions and (3) inefficient use of the existing workforce.

According to the report, the first reason is due to the relatively low number of "mathematical oriented" high-school graduates. According to the reports, and to voices within the industry,[40] the second reason is that the quality of a non-trivial percentage of students who graduate with degrees in relevant fields from "colleges" is not sufficiently high to meet the market needs.[41]

Other voices argue that there is no real shortage in skilled workforce. Specifically, Bentel and Peled (2016) argue there is no shortage in the number of STEM (Science, Technology, Engineering and Mathematics) graduates. They point out that currently, each year, there are 10,000 bachelor students who major in STEM subjects, and an additional 4000 who graduate from advanced STEM degrees. According to Bentel and Peled, these numbers correspond to approximately 10 percent of the skilled labor force in the high-tech sector, and are enough to compensate for the natural retirement from the sector. They also argue that during the last 15 years in the high-tech sector, there was no substantial real increase in wages, implying, again, that there is no shortage in skilled labor force.

The inefficient usage of existing workforce is primarily due to norm in which engineers and computer scientists often leave technical fields at relatively young ages. However, this has changed in recent years – and it is not unusual for high-tech workers to continue working into their 50s and even 60s.

17.3.2 Future Labor Supply

Israeli Arabs and the Ultra-Orthodox are currently underrepresented in high-tech. Here we examine a very important trend: the entry of Israeli Arabs and the Ultra-Orthodox into the Israeli high-tech sector. A non-trivial increase in future supply of high-tech workers may come from sectors of the population underrepresented today in high-tech: Israeli-Arabs and the Ultra-

[40] www.ynet.co.il/articles/0,7340,L-4865128,00.html

[41] Perhaps more than other fields, there is a large variation in the productivity of programmers. Indeed, research shows that there are "order-of-magnitude" differences among programmers." This mean that high quality makes a big difference. See https://softwareengineering.stackexchange.com/questions/179616/a-good-programmer-can-be-as-10x-times-more-productive-than-a-mediocre-one.

Orthodox. These sectors together make up around 30 percent of the population, but less than 4 percent of high-tech workers. Currently, out of the current estimate of 250,000-300,000 high-tech employees, only about 6,000 (4000 women and 2000 men) are Ultra-Orthodox,[42] while there are approximately 2700 Israeli Arab high-tech professionals.[43]

There is a quiet "high-tech" movement in the Israeli Arab sector. In the case of Israeli Arabs, only 350 worked in high-tech in 2008. Hence, the increase is 670 percent since 2008. While the actual numbers may be small, the percentage changes are large. Additionally, there is a significant increase in the number of Arab students in high-tech disciplines.

More Israeli Arab students are studying at Universities in Israel than ever before. In the 1989-1990 academic year, there were 46,519 BA and BS students in "Universities" in Israel (Tel Aviv University, Hebrew University, Bar-Ilan, Ben Gurion, the Technion, the Weizman Institute and the University of Haifa.) Only 2,950 or 6.3 percent of the students were Israeli Arabs.[44]

Twenty-five years later, the picture is very different. Overall, the undergraduate student population at top Universities increased by 52 percent from 1989-1990 to 2014-2015 when it reached 70,785 students. The Arab student population increased by 296 percent during the same time period. The percent of Arab students studying for either BA or BS degrees in the top Universities increased to 16.5 percent (11,672 out of 70,785) in the 2014-2015 academic year.

The change is even more dramatic when we examine the changes between 1999-2000 and 2014-2015. During that fifteen year period, the overall number of BA/BS students studying in Israeli Universities actually decreased by 5 percent.[45] During that period, on the other hand, the number of BA and BS Arab students in Israeli Universities increased by 84 percent.

More importantly for the future of high-tech in Israel, there has been a large percentage increase in Israeli Arab students in Engineering and other technical disciplines in Universities. During the 15-year period from 1999-2000 to 2014-2015, Arab students in engineering (which includes

[42] Raz and Tzruya (2017.)
[43] The estimate is from the Tsofen High Technology Center in Nazareth.
[44] All data on University students is from the Council of Higher Education.
[45] The decline is due, in part, to the large increase in students studying in colleges.

all sub-disciplines plus architecture) increased by 86 percent, while non-Arab students in engineering increased by 22 percent. In the case of Mathematics and Science, Arab undergraduate students increased by 114 percent, while non-Arab undergraduate students decreased by 14 percent.

When we look at more detailed data (which is only available from 2011-2012 to 2015-2016,) we find that the number of Arab students in Electrical Engineering increased by 81 percent, which represents an actual increase of 300 students (from 372 to 672), while non-Arab students in Electrical Engineering increased from 4,528 to 5,572 (a 23 percent increase.) In the case of Mathematics and Computer Science, Arab undergraduate students in Universities increased by 62 percent from 670 to 1084 over the same period, while Jewish undergraduates increased from 4,279 to 5,329 (or 25 percent.)

In the case of colleges, the total number of students studying engineering increased from 14,649 in 2007-2008 to 19,552 in 2014-2015 (The delineated data do not go back further than that.) Of the engineering students in colleges, 5.1 percent or 747 were Arabs in 2007-2008, while in 2014-2015, 1,401 or 8.6 percent of the engineering students in colleges were Arabs.

Gains in employment have also been significant in recent years. As noted, in 2008, there were only 350 Arab engineers and computer scientists working in high-tech. By the end of 2015, the number had increased to 2700, according to the Tsofen High Technology Center in Nazareth, which works to integrate Arabs into Israel's high-tech sector.

The number of high-tech firms based in Nazareth has grown from (essentially) zero in 2006 to more than 70 today. One particularly bright success story is Galil Software, which is based in Nazareth. Galil Software, which was founded in 2007. Galil Software currently employs about 150 high-tech personnel. The management team as well as the workers includes both Jews and Arabs.

17.3.3 The Ultra-Orthodox sector in high-tech

By the end of 2015, the Ultra-Orthodox community numbered approximately 950,000 people, meaning one in every nine Israelis is Ultra-Orthodox (11% of the population). Some 18% of the total population of children and youth (ages 0–19) are Ultra-Orthodox, and they make up

8% of the working-age population (20–46). The annual growth rate of the Ultra-Orthodox population is 4% as opposed to 1% among non-Ultra-Orthodox Jews. The share of Ultra-Orthodox as a percentage of Israel's total population is predicted to be 14% in 2024; 19% in 2039, and 27% in 2059.[46]

While it is hard to pin down precisely, in 2000, the participation rate of Ultra-Orthodox women in the work force was 48%-49%, while the participation rate of Ultra-Orthodox men was 38%-43%. In 2015, the numbers increased to 75%-77% and 50%-53% respectively. Although a change in measurement methodology makes it difficult to make exact comparisons before and after 2011, the trend is clear: Many more Ultra-Orthodox women are working and there has been little change in the percentage of Orthodox men in the work force.[47]

Only 10% of Ultra-Orthodox students earn a high school matriculation certificate, compared with 70% of their non-Ultra-Orthodox peers. Only 2% of Ultra-Orthodox men earn a matriculation certificates; in contrast, roughly 17% of Ultra-Orthodox women earn a matriculation certificate.

In a Central Bureau of Statistics (CBS) survey, in 2013-2014, 19% of the Ultra-Orthodox population reported that it was pursuing, or had pursued, an academic degree. This is an increase over 2007-2008, when the overall figure was 15%.

The share of women engaged in academic study (23%) was much greater than that of men (15%).[48] In terms of actual numbers, over 6,000 ultra-Orthodox students were enrolled in colleges and academic institutions where they were acquiring a profession.

Some higher educational institutions (for example, the Open University) provide science and engineering curriculum for Ultra-Orthodox women and men (in separate programs.) Overall, there has been a 45 percent increase in the number of Ultra-Orthodox students in the past 5 years.[49]

[46] Malach et al (2016.)
[47] Moshe (2016.)
[48] Malach et al (2016.)
[49] Globes, 13 January 2016, available at www.globes.co.il/news/article.aspx?did=1001094800.

The main path, however, to employment in high-tech for the Ultra-orthodox women is not via Universities and colleges. The most popular option for Ultra-Orthodox women is a two-year extension of high school that grants a technical diploma as a "Practical" Software Engineer, i.e., a computer programmer.

Based on current estimates,[50] there about 600 Ultra-Orthodox women graduating each year with at least two years of higher education in high-tech (primarily software programming) via the two-year extension of high school. About ten companies tap into this Ultra-Orthodox trained workforce, and offer the mainstream Israeli high-tech companies an outsourcing option, which is an alternative to an offshore model for high-quality/low-cost labor.

Some companies provide separate working environments for Ultra-Orthodox women: The "separate" offices are located within proximity to Ultra-Orthodox neighborhoods; there are children-friendly working hours, suitable eating facilities, maternity rooms etc. The pioneer in this model of employment is Matrix, a leading IT company in Israel, which employs about 8000 professionals. In 2004, Matrix opened a site tailored for Ultra-Orthodox women. Today they employ about 800 women in this model.[51]

Another company is Rachip, which employed more than 100 Ultra-Orthodox women in 2016. I-ROX and SW outsourcing services employs about 100 women software engineers, takes pride in having the "best orthodox female programmers from Israel's leading educational institutions."[52]

Barriers to entry still exist, especially for Ultra-Orthodox men. In general, there is a very big educational gap between Ultra-Orthodox men and women. While all Ultra-Orthodox women study Mathematics and English, these subjects are not part of the curriculum for Ultra-Orthodox men.

17.3.4 Skilled Workers from the Palestinian Territories

[50] Discussions with Rachip and calculations of the authors.
[51] See Matrix at www.matrix.co.il/About/Pages/givun.aspx
[52] See http://i-rox.co.il/en/excellence-model/

Another possible source of supply of skilled workers is the Palestinian territories. In part, because of its proximity to Israel, by 2013, approximately 4,500 Palestinians worked in the ICT sector, specializing primarily in software. Most of the Palestinian ICT firms are located in Ramallah. According to Globes (April 17, 2012,) the Palestinian ICT sector grew from less than one percent of GDP in 2008 to 5 percent in 2010. In 2014, according to the Economist, ICT outsourcing accounted for 10 percent of the West Bank's GDP.[53] At that time, there were more than 300 ICT firms in the West Bank. A non-trivial amount of the outsourcing work comes from Israeli subsidiaries of Cisco, Microsoft, HP, and Intel. Two relatively successful firms are Asal Technologies and Exalt Technologies, which had 120 and 80 employees respectively in 2014.[54]

17.3.5 Reasons to be concerned about the future

Despite the (I) impressive increase in the number of Israeli Arabs studying engineering and computer science and (II) the entry of Ultra-Orthodox women in the sector, it is not clear that these two trends can overcome the shortage of engineers and computer scientists in Israel. First, although the percent increase of high-tech workers from these sectors is relatively large, the absolute numbers are currently relatively small. Further, as discussed above, the increase in the number of Jewish students in computer science and engineering at Israeli Universities has been relatively modest.

17.3.6 Limit to Network Benefits

Entry into high tech is difficult for Arab students primarily because of two reasons (1) Arab Israeli engineers live on average quite a big distance from high-tech hubs in the center of the country and (2) a lack of professional network connections with Jewish Israeli engineers because they are not subject to military service. Spillovers from the military to the civilian sector are a considered prominent aspect of the high-tech industry in Israel – and those who do not serve with elite technical units are at a disadvantage.

17.3.7 Brain Drain

[53] "IT in the West Bank: Palestinian Connection," the Economist, 26 February 2014.
[54] Ibid.

An additional concern for the future of high-tech in Israel is the brain drain. Some of the benefits have spilled over to multinationals who collectively invested billions acquiring Israeli start-ups and expanding their Israel-based R&D units. Further, these acquisitions have made it relatively easy for Israeli scientists to migrate, in particular to the US. Statistics compiled by Ben David (2008) reveal the following: (I) In computer science, the number of Israelis in top-40 American Universities in the United States is equal to about one-third of computer scientists in Israeli research universities. (II) The number of Israeli physicists in top-40 American Universities is equal to 10 percent of Physicists in Israeli research universities. The numbers of Israeli at top U.S. Universities are also large for other high-tech disciplines. While the brain drain in academia does not directly translate to high-tech, a non-trivial brain drain (primarily to the Silicon Valley) has occurred in high tech as well.

17.3.8 Reasons to be optimistic about the future

17.3.8.1 Future Labor Supply

Despite the discussion above about the limit to network benefits, the government and private foundations are helping to make it easier for Israeli Arabs to enter high-tech. For example, the Nazareth Business Incubator Center was launched in 2014. The goal of this center is to enable experienced high-tech entrepreneurs to connect with Israeli Arab engineers.[55]

Several governmental ministries have produced initiatives to encourage high-tech firms to hire or retain older qualified workers and to help the integration of Arabs in high-tech. There is also targeted funding available from the Innovation Authority. One program called the "Early Stage Fund," helps minority entrepreneurs overcome the difficulties of raising venture capital in the private sector. For qualifying firms, financing can reach 85 percent (versus 50 percent for other startups.)[56]

17.3.8.2 Brain Gain

[55] Israel Seeks to Share High-tech Success with Arab Sector, March 11, 2016, by Robert Swift, The Media Line, available at www.themedialine.org/top-stories/nazareth-israels-next-high-tech-hub/.
[56] The Innovation Authority, www.economy.gov.il/RnD/pages/default.aspx

While the "brain drain" has harmed the Israeli economy in many ways, it is not a "cut and dry" issue. Recent research by Lobel (2015) suggests that a country's international connectedness has positive benefits from skilled emigration. For example, Lobel (2015) notes that skilled emigration is correlated with the amount of foreign investment in the country of departure. Further, recent numbers suggest that the drain has mitigated.

17.3.9 Closing Thoughts – Women in High-Tech

By far the best hope for increasing the supply of hi-tech workers is women. In Israel, women make up approximately 47% of the workforce and 55% of the students studying law and medicine. However, female engineers and computer scientists are relatively rare and the absolute number is declining.[57] In 2009/2010, women accounted for 31% of all applicants to Universities in Engineering. This percentage rose to nearly 33% in 2102/2013. However, this percentage fell back to 29% in 2014/2015.

While the lack of women in high-tech is a universal phenomenon,[58] it is more critical in Israel, since the country relies on "home-grown" talent much more than countries like the U.S. In order to significantly increase the supply of University trained engineers and computer scientists in Israel, an effort has to be made to encourage women to study these fields. Reversing the trend can only be done by increasing the number of female high-school students graduating with a high quality diploma and positive early exposure to the world of science and engineering. Some steps have been taken, but more are needed.

17.4 Brief Conclusion

In this chapter, we first provided historical background on high-tech in Israel. We then showed that the rapid growth of the high-Tech sector in Israel during the 90's and first decade of 21st century was a part of a global trend of growth in Information and Communications Technology (ICT.) Timing was also critical for the success in Israeli high-tech. The huge increase in the supply of skilled workers from immigration from the former Soviet Union in the 1990s

[57] See "Ahead of International Women's Day, Israel sees decline in number of women in hi-tech," by Chelsea Mosery Birnbaum, Jerusalem Post, March 7, 2017, available at www.jerusalemonline.com/high-tech/alarming-decline-in-the-number-of-women-in-israels-hi-tech-industry-27093.
[58] See for example, Ashcraft, McLain, and Eger (2016.)

coincided with a huge increase in demand worldwide for ICT products and services, an area in which Israel has a comparative advantage.

We discussed the challenges facing high-tech in Israel today. The excess demand for high-tech workers is an opportunity, but a huge concern as well. While recent increases in skilled workers from sectors that have not traditionally participated in high-tech is encouraging, it is not clear that the future supply is large enough without activist government programs. The most important step involves increasing the number of high-school students graduating with a high quality “math and science” diplomas and providing these students with “early positive exposure” to the world of science and engineering. Hopefully, the country will be up to the task.

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