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Inside the Israeli Innovation System: its origins, development and evolution

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by

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ABSTRACT

This dissertation examines the origins and evolution of the Israeli Innovation System, which propelled the development of the country's economy, focusing on how it is responding to the new challenges of green energy. The research is interdisciplinary, involving documentary historical and policy research, in-depth interviewing, and analysis within the Systems of Innovation theoretical framework. The findings indicate that the main reasons for the successes of the system have been the commitment of government through policies and programs; the technological developments by elite military units; a military and business culture that embraces risk and entrepreneurship; the role of its universities in applied R&D; and the Russian Jewish immigration that brought a wealth of human capital. The findings also show that although the Israeli Innovation System has been very successful for the last 20 years, 'innovation' in the system itself is now required if its success is to continue. The main weaknesses of the Israeli innovation system include its narrow focus on research and development (R&D), and the practice of exporting new technologies instead of developing them into domestic industries. The conclusion is that culture and public policy are equally important in technology transfer and innovation, possibly making it difficult for other countries to copy the Israeli Innovation System.

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List of Symbols, Abbreviations and Nomenclature

Symbol	Definition
CTO	Chief Technology Officer
GTEP	Grand Technion Energy Program
IIA	Israel Innovation Authority
IT	Information Technology
MNC	Multinational Company
NIS	National Innovation System
OECD	Organization for Economic Cooperation and Development
OCS	Office of the Chief Scientist
R&D	Research and Development
T3	Technion Technology Transfer Office
TTO	Transfer of Technology Office
US	United States

Epigraph

"Israel has sun, endless sun, an independent resource to develop Israel's economy in a sustainable way" (Interviewee G2)

CHAPTER 1: INTRODUCTION

1.1 ORIGINS OF THE ISRAELI NATIONAL INNOVATION SYSTEM

Even before the foundation of the State of Israel in 1948 there were Jewish people living and thriving in what was then Palestine, to which Levi-Faur (1998) and Breznitz (2007b) refer as a home of ancient people with a strong national identity. As Teubal (2013) describes, Israel's vision involved "the overarching national goal" (p.47) of developing a knowledge economy and society with a strong Science, Technology and Higher Education (STHE) focus, starting in the 1920s, under the British Mandate before the state was founded and until 2000.

During the British Mandate, from 1918 to 1948, the Israeli Innovation System was born through the establishment of its three well known universities; and research and development (R&D) was focused on applied research. The country's "Heroic Period" took place from 1948 to 1973, when Israel's economy was centralized and controlled by the government, led by Bureaucratic Champions, and achieving outstanding economic growth. This was also a period with a high regard towards Science and Technology (S&T), when more universities were founded, and applied and commercial R&D was conducted mainly by academia and the defense sectors. Breznitz (2007b),[1] and Levi-Faur (1998) [2] point out that in the 1950s and 1960s, as a democratic country and with the capability of achieving outstanding economic growth, Israel was an example to other developing countries.

Government policies implemented during this period set the stage for the economic development of the country in the 1990s and 2000s. Key events included the establishment of the Office of the Chief Scientist (OCS) in the late 1960s, and with it a shift to industrial R&D support. Breznitz (2007b) explains that this period also saw the

[1] In both, his article and his book, Breznitz (2007a; 2007b) compares Israel's, Ireland's and Taiwan's economies and industries and how they were shaped, based on their unique bureaucratic structures and cultures; the development of the IT industry and the co-evolution of government-industry relations, which is very different in the three countries. I only examine his analysis of the Israeli IT software industry and business model.

[2] In his article, Levi-Faur (1998) analyzes and compares the economic development of Israel, Taiwan and South Korea. I only examine his analysis on Israel.

opening of R&D centres in Israel by several Israeli senior R&D managers of American Multinational Companies (MNCs) such as INTEL in 1974; and Senor and Singer (2009) indicate the creation of Transfer of Technology Offices (TTOs) in Israeli universities, the first such institutions in the world (p.211).

Israel then experienced the period called by Teubal (1993) the "Paradox" of the 1970s and 1980s. This is a phase when Israel had an abundance of skills, created the high-tech industry, and while it could have achieved further economic growth, due to poor government performance the country experienced instead economic stagnation. During this period the Israeli government implemented liberalization policies - opening up the market to competition; also, the population grew significantly and so did industrial R&D. Several OCS grant programs were established, such as the Bilateral R&D Foundation (BIRD) that is still active today. There was also strong military-civilian transfer flow through scientists and engineers who may have also participated in Israel's high-tech developments in the 1990s.

The period of the 1990s and 2000s brought significant growth in human capital due to a large wave of highly educated immigrants from the former Soviet Union. In order to absorb these immigrants, the OCS implemented several more R&D programs which focused mostly on IT and biotechnology, such as the Public Technological Incubators, and also those in the cleantech and renewable sectors supporting intensive commercial R&D. This period also saw the creation of the second largest Venture Capital (VC) industry in the world after the United States, following the Silicon Valley VC model. Together, these policies and the Israeli culture had a strong role in shaping the entrepreneurial character of Israelis. As Avidor (2011) explains, some cultural traits were shaped by military training as well such as out-of the-box thinking and improvisation, flexibility, and reacting and adapting quickly to changes. Nevertheless, some of these could also become a challenge in the global competitive market. The 1990s also saw cuts in university funding, which were privatized in 1995, with the possibility of a decline in education and research.

In 2010, several large offshore gas reservoirs were discovered in Israel, as well as large onshore shale oil reservoirs. Before these discoveries Israel had been a country with few natural resources, practically with no fossil fuel. It is believed that due to these recent

gas discoveries Israel will soon become an exporter. This discovery presents significant new opportunities and challenges for the Israeli Innovation System which until now has revolved mainly around information technology (IT) and biotechnology.

This dissertation examines the development of the Israeli National Innovation System from its historical origins to the present. By looking at the green energy sector – alternative and renewable energy, it explores how the System is evolving with this new technological and industrial challenge, and possibly with others as well. If, as Teubal (2013) suggests, the Israeli case is of significance, especially in the creation of its VC industry, not only for developing countries, but also for developed industrialized economies, the Israeli experience is of potential importance for Canada.

1.2 DEVELOPMENT OF QUESTIONS

Chorev and Anderson (2006) and Senor and Singer (2009) describe Israel as a young nation (61 years since its independence) that has achieved the economic status of a developed country mainly due to its high technical and unique entrepreneurial culture. After reading Senor and Singer's (2009) book *Start-up Nation* I became interested in finding out more about Israel's scientific and technological innovations which propelled the country into its strong economic growth. In their book, Senor and Singer (2009) look mainly at high-tech start-ups, and as they indicate, their book "is part exploration, part argument and part storytelling...a mosaic like approach" (p. ix). However, the authors describe mostly Israel's innovation activities in terms of successes, not weaknesses or challenges by being mainly a Start-up Nation. Missing from their analysis as well is reference to any coherent body of scientific literature on innovation.

Differently from *Start-Up Nation*, my dissertation is centered in the National Innovation Systems literature (NIS) which stems from the Neo-Schumpeterian view of economic growth through technical change (Freeman, 2004). The theory is based on the concept that innovation is the result of how the production, flow and application of knowledge is organized by public and private institutions, particularly regarding interactions between universities, industry and government institutions. My research investigates these interactions in Israel using a combination of documentary research and

in-depth interviews with significant individuals in the development of Israeli technology transfer policies, initiatives and institutions. By using green energy as a case I investigate how the Israeli National System is responding to new technologies like green energy, and its impact, from strongly established technologies, such as IT and biotechnology.

The Organization for Economic Cooperation and Development, in the the Oslo Manual (OECD/Eurostat, 2005), defines innovation as “the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations” (p.29). However, the OECD (OECDiLibrary, 2013) further expanded its definition of innovation to include ongoing or abandoned product or process innovations. Marketing includes sources such as “suppliers of equipment, materials, components or software, clients or customers, competitors or other enterprises in the same sector and consultant, commercial labs or private R&D institutes” (p.29). Institutions include universities, government and public research institutions. Collaboration involves cooperation in innovation projects with “other firms or organizations” (p.29), suppliers and customers.

In the National Innovation Systems (NIS) literature, Freeman (2004) and Utterback (1974) indicate that such activities are the main force of economic growth, industrial productivity and international competitiveness. However, the ways in which this takes place are very complex and often indirect.

Bozeman (2000) found that transfer of technology happens mainly through indirect processes which take many years to be measured such as through the movement of scientists and engineers, creating spillovers from university innovations. Cohen et al. (2002), Feller et al. (2002) and Freeman (2004) also recognize that although research and development (R&D), government subsidies, patents and commercialization of technologies should result in economic development, these factors are not strong enough on their own to drive an economy, and that there is no linear pathway from such efforts to economic growth.

However, if current claims and Israeli academic findings are correct, the Israeli case would seem to challenge these observations. For example, the Israeli government has had

a strong and successful role through its funding programs, mainly under the Office of the Chief Scientist (OCS); and as Teubal (1983) argues, by locating it under the Ministry of Commerce and Industry (today the Ministry of Economy and Industry), mostly in support of industry. Teubal (2013) further provides an example of a successful government support program indicating that Israel had a huge economic success mainly through its VC industry. According to Senor and Singer (2009), Israel also produces a high number of patents. For example, between 1980 and 2000 Israel registered 7,625 patents (p.209). The authors also state that Israeli university's Transfer of Technology Offices (TTOs) are very successful in their licensing efforts. For example, Yeda, the TTO from the Weizmann Institute, from 2001 to 2004, earned about US$200 million in royalties; and by 2006 Yeda had the highest income in royalties among global academic institutions (p.211). Yissum, the TTO of the Hebrew University, has granted over 450 technology licenses with earnings on sales of over US $1 billion worldwide per year (p.211), and as Kalman, (2008) adds, mainly from drug royalties for Alzheimer's and cancer.

Israel's public and private research institutions also appear to be creating new firms that contribute substantially to the country's gross domestic product (GDP). For example, Prof. Peretz Lavie (Personal communication, July 16, 2014), indicated that in 2014 Israel had 6,500 startups, a higher number than Germany, France, and the UK. Senor and Singer (2009) state as well that there are more Israeli companies on the NASDAQ than from all of Europe together (p.11), second in number only to the United States (US). In addition, until now the OCS has supported only Research and Development (R&D), creating Israel's vast economic growth.

Freeman (2004) argues that each country has its own technological infrastructure which has different effects on international competitiveness; and technological leadership gives absolute international advantage to a country as well. In addition, Archibugi and Pianta (1992) and Patel and Pavitt (1994) discuss that many countries develop and maintain specialized technological capabilities that are reproduced in their R&D patterns, in their patenting and scientific publications, and therefore develop specific capabilities within their national innovation systems. In this way, Breznitz (2005) and de Fontenay and Carmel (2004) explain that military graduates from Israeli high-tech elite units have had a strong role in the development of the civilian information technology (IT) industry,

which the military has also encouraged. Therefore, IT became Israel's technological strength, turning it into an international leader in this sector.

However, although Israel is producing important innovation in areas such as IT and biotechnology, there are significant knowledge gaps as to how Israeli innovation system is responding to new technological and commercial challenges, for example green energy. Senor and Singer (2009) discuss Israel's successes, but they do not provide a critical scholarly perspective on the performance of the Innovation System or on how it may evolve.

This dissertation fills some of these gaps by looking at some historical events and current evolution of the Israeli Innovation System from the perspective and experiences of significant key players involved in its formation and evolution, a subject broadly covered by the National Innovation Systems (NIS) literature. With this objective, the dissertation poses two broad research questions:

1. How has the Israeli Innovation System evolved since its inception in 1948 and what events shaped it?
2. How is this system responding to the new technological area of green energy?

1.3 INTERDISCIPLINARY APPROACH AND METHODS

This thesis is done under the Interdisciplinary Graduate Program (IGP) by examining a question that is not addressed under one perspective only. It looks at the historical policy changes that took place since Israel's inception in 1948 and before, and up to November 2014, with some present date updates. It addresses the leading role Israel has played in IT and how Israel's National Innovation System (NIS) is being applied to the new innovation area of green energy, and if it is working the same way or differently than in the IT industry. The main format of my interviews is based on the case study method, incorporating some premises from grounded theory methodology. My research involves three sources of information which reflect the interdisciplinary aspect of my research:

1) Documentary review based on the Israeli academic literature and institutional sources, including policy issues.
2) In-depth interviews.
3) Academic literature on Systems of Innovation theory and the business literature related to green energy.

1.3.1 Case Study method

My research involves a large empirical case study of the Israeli Innovation System, developed from both, historical sources, mainly policy, and from in-depth interviews with key individuals who have played a direct role in the shaping of this system or who have direct experience on how it functions. The case study includes the Israeli Innovation System as a whole, and the specific example of green energy.

Eisenhardt (1989) discusses that "Case study is a research strategy that focuses on understanding the dynamics present within single settings. Case studies can involve single or multiple cases and numerous levels of analysis within a single study" (p.534). She proposes that case studies usually include different sources for collecting data such as interviews and documentary and literature review which offers a stronger and better validation of hypotheses; and flexible data collection methods to allow researchers to analyze emerging themes. She also suggests that "mixed methods" allows the triangulation or comparison of data in order to look at information from different perspectives, while comparing it with similar and conflicting literature. Findings similar to the existing literature result in stronger legitimacy; while identifying phenomena not captured by the literature or being in conflict with what the literature proposes, results in new insights. My research uses several sources of information through a combination of theoretical literature, historical evidence based on documentary research, and in-depth interviews.

Eisenhardt (1989) further discusses that case studies are based on inductive reasoning, which also involves formulating tentative hypotheses and arriving at general conclusions, stating that inductive reasoning is open-ended and exploratory. In this way,

my research was guided by *ten tentative hypotheses* derived from the literature review on the political, industrial and social developments in Israel. These are as follows:

1) The Israeli National System of Innovation has been shaped by a strong national identity and ideology, and by its culture.
2) The development of green energy in Israel is driven more by economic and safety concerns than by environmental concerns.
3) Israeli success in meeting the R&D risks and challenges in green energy depend on both domestic and international collaborations.
4) Although Israel is a world leader in the productivity and intensity of its basic research in science and technology, it lags behind in its ability to transfer technology and commercialize it.

1.3.2 Grounded Theory method

The interdisciplinary approach used in this thesis is also based broadly in 'grounded theory', which refers to the use of qualitative methodology with the objective of building theory from data based on inductive reasoning (Strauss and Corbin, 1990; Glaser and Strauss 1967). Glaser (1992) states that "qualitative methods can be used to uncover the nature of people's actions and experiences and perspectives" *(*p.12), which cannot be detected by most other research methods. He also proposes that "Qualitative research and analysis give the intricate, most relevant, and problematic details of the phenomenon…." (p.12). Yin (1992) states further that the goal of grounded theory is to identify new categories obtained from empirical research, using qualitative and other analysis methods.

Strauss and Corbin (1990) define qualitative research as "any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification" (p.17). Corbin and Strauss (2008) define qualitative analysis as a "process of examining and interpreting data in order to elicit meaning, gain understanding, and develop empirical knowledge" (p.1). They further point out that the existing literature can be a source for making comparisons; for demonstrating where the phenomena identified correspond or not to existing knowledge in the literature. Moreover, the authors propose

that the researcher use common sense instead of worrying about the right or wrong way of conducting the analysis (p.327).

Glaser and Strauss (1967) explain that grounded theory is founded on comparative analysis rather than on specific processes (p.1), using the logic of comparison; while the researcher should also generate an explanation of the facts discovered (p.4). Glaser (1992) discusses that grounded theory produces conceptual categories or themes, and properties which are a conceptual characteristic of categories or themes, and are uncovered through the ongoing comparative analysis. According to Glaser and Strauss (1967), core categories or themes have "the most explanatory power" (p.70).

1.3.3 Review of historical and policy documentation

The first phase of developing my case study of the Israeli Innovation System involved collecting relevant historical and policy documentation, obtained from thorough review of published academic studies. Some materials were obtained through correspondence with individuals in universities, companies and governments departments, and other documents were available on-line. This process continued throughout the project. In many cases, interviewees identified or provided additional documentation.

As suggested by Burgelman (2011), the documentary review encompassed content analysis based on a longitudinal investigation founded on historical methods. He argues that historians consider every specific consequence to result from several historical causes. The longitudinal analysis only briefly examined the developments in Israel between the British Mandate in 1918 and more in–depth since statehood in 1948 (the innovation system was shaped primarily in the post statehood period). As proposed by Corbin and Strauss (2008), the main objective of the documentary research was to understand how past processes that took place in Israel created the present context of its innovation system; what were the processes that influenced the development of Israel's innovation system; why Israel reacted in certain ways and chose certain processes; what happened and how it happened, and what were the outcomes.

Based on the documentary research, 10 hypotheses were originally developed as guidelines for formulating the interview questions. These were reduced eventually to the *four hypotheses* described above, and developed as core categories or themes under Chapters Five to Eight.

1.3.4 Interviews

The documentary research was followed by interviews, most of which were conducted during my field trip to Israel. As the objective was to tell the story of the Israeli system and its development through the eyes of significant individuals, the in-depth interview method was chosen. In-depth or open-ended questions allow interviewees to talk without limitation of time, while the researcher listens to their stories; and more direct questions are asked afterwards for clarification and further information (Glaser and Strauss 1967; Corbin and Strauss 2008). The objective of the interviews was not to obtain facts and figures, but to, as Chorev and Anderson (2006) propose, identify the "how" and the "why" of the innovation system in Israel, as experienced and perceived by these respondents.

I first identified the key players to be interviewed through my Israeli academic and institutional literature research, and referrals. I sent introductory emails in September and October 2014 requesting an interview with a brief description of my research (Appendices 2 and 3), scheduling my interview meetings across Israel before my trip. In November 2014, I conducted in-depth interviews with key players in government, academia and industry involved in transfer of technology and the green energy sector, to get a greater understanding of how the innovation and transfer of technology is applied.

As Eisenhardt (1989) points out, in-depth interviews are carried out in order to understand the case "in as much depth" (p. 539) as possible. Thus, some of the interviewees were directly involved in the system as such whereas others had experience of critical contributing factors. For example, one interviewee was not involved in green energy or transfer of technology, but provided extensive information on the military and Israeli culture according to his own experience.

I conducted a total of 34 interviews. Two interviews were conducted in Calgary, before my field trip to Israel, since one interviewee now lives in Calgary and a second one came to Calgary for business. The rest of the interviews were conducted in Israel in November 2014. Thirty-three interviews were conducted face-to-face and one over the telephone in Hebrew that I translated into English. All other interviews were conducted in English with Hebrew words inserted by the interviewees also translated into English. The interviewees signed a consent form where I requested permission to audio-record the interviews. One interviewee requested not to be recorded and I took notes during the interview. I specifically requested of all interviewees that the information provided be only to what the interviewees would themselves be comfortable disclosing in public.

To guide the interviews and keep them on track, I developed unstructured interview questions based on my 10 hypotheses. I used guiding questions since the interviewees are significant and close to the shaping of the Israeli innovation system. There were no standard questions. Some questions were general and others more specific to the organizations interviewed. This interviewing format was selected in order to give the interviewees the flexibility to answer, to provide as much information as possible, and to fully express their views and perspective on the subject. Interview questions also addressed contradictory issues in the Systems of Innovation theory, in the Israeli academic and business management literature, and Israeli institutional review. As the interviews progressed I learned new concepts that were not addressed by the Israeli academic literature or that were different from those concepts presented in the Systems of Innovation literature. Also when new information was provided by the interviewees, I added new questions to the following interviews, as proposed by Eisenhardt (1989).

A small number of interviews were followed up with telephone calls or by e-mail to clarify some issues. The audio-recorded interviews were transcribed back in Calgary, and analyzed and classified according to the hypotheses themes. After I returned to Calgary, four interviewees requested not to be included in my thesis research. Accordingly the data they provided was not used.

Since the interviewees are high-level key people directly involved in transfer of technology and/or in green energy as well; are familiar with these situations in Israel and therefore provided inside views of the country's NIS, some of them gave a large number of details that are difficult to verify. However, the objective of the interviews was not to receive accurate numbers and dates, but to get their opinions and views. The interview chapters, Chapters Five to Eight, present the view of the interviewees only; the way they saw things happening and what they believed to be important; while the footnotes expand on the information provided by the interviews.

Moreover, Glaser and Strauss (1967) state that although the objective of grounded theory is to develop theory, the authors add that grounded theory can also be presented as propositions, using conceptual categories and their properties (p.31). In either case the accurate description, verification and evidence of interviews are not crucial (p.30), since people in different positions can provide different information about the same facts (p.67). As well, different groups of interviewees have different perspectives of the categories or themes, and these cannot be verified as accurate evidence (pp.65-66).

The Israeli organizations interviewed represented government, municipality, academia, incubators, venture capital firms, incubated companies (startups) and private industry. The position titles included CEO, Director, Executive Director, Professor, Manager, Chairman, Senior Research Fellow, General Counsel and Partner. The interviewees are coded as follows: 'A' for Academia, including scientists, researchers, and transfer of technology office; 'G' for Government, including programs within the Office of the Chief Scientist and the Municipalities of Eilat and Eilot in southern Israel; 'P' for Private Industry, including private companies, startups, incubators and venture capital firms.

I also attended two presentations in Calgary. One presentation was delivered by Professor Peretz Lavie, President of the Israel Institute of Technology (Technion) at the Calgary Jewish Centre on July 16, 2014, who talked about the Technion's and Israel's high-tech achievements and where I took notes. The second presentation I attended was

that of Udi Gat, Mayor of Eilot and the Arava Region in Southern Israel,[3] and Chairman of the Eilat-Eilot Renewable Energy Administration, also at the Calgary Jewish Centre on August 6, 2014 (mentioned in this dissertation as 'personal communication'). Mayor Gat addressed the technological advances in green energy - renewable and alternative, in Israel and especially in the Eilat and Eilot Region (Appendix 4, maps of Israel and its southern region). The presentation was audio-recorded with permission from the speaker and the event organizer.

1.3.5 Analysis

The analysis of my research is at a macro level, as suggested by Corbin and Strauss (2008), examining the Israeli policies and their impact, and their cultural and historical conditions (p.230). All interviews were transcribed and the content of each interview analyzed. The analysis was based on a comparative examination of similarities and differences in the data, which uncovered properties that were organized and synthesized under each category or theme. The next step of my analysis was to compare the interview findings with the Israeli documents –Israeli and business literature, and the Systems of Innovation Theory, based on the four hypotheses developed early in my research, and then developed into core categories or themes. Each category or theme is presented as a separate chapter, as suggested by Glaser (1992, p.15). The author argues as well that consulting the literature also has "a level of groundedness" (p.23), especially when the investigator suggests future research.

By linking the interviews to the documentary research and comparing and discussing the similar and contradicting concepts, the interviews gave me new and deeper

[3] According to the Kol Emeth (2017) Website, The Central Arava region of southern Israel is one of the most remote parts of the country. It is located in the Negev Desert along the Jordanian border between the Dead Sea and Red Sea, about 80 miles from the nearest cities of Be'er Sheva and Eilat. Established in 1978, the Central Arava Regional Council is comprised of seven communities. Although the region is becoming a popular tourist destination for hikers, the primary source of income for residents is agriculture. Roughly 500 farming families in the Central Arava produce 60% of Israel's fresh vegetable exports and 10% of its cut flower exports, despite an average yearly rainfall of about one inch. The area under the Council's jurisdiction is more than 370,000 acres-approximately 6% of Israel's total land mass-but is inhabited by just 3,200 people scattered throughout an arid desert environment with sharp climate changes, extreme topographical conditions, and limited resources," (para.1).

insights on the Israeli Innovation System and how it is applied to the green energy sector, which is a process addressed by Eisenhardt (1989). The comparison of the findings with the Systems of Innovation theories has also provided me with an understanding of the strengths and limitations of these theories.

With regards to qualitative research, instead of the terms validity and reliability, as proposed by Eisenhardt (1989), Glaser and Strauss (1967) and Corbin and Strauss (2008) use the term credibility, where findings are considered to be 'trustworthy and believable' (pp. 301-302), reflecting experiences of interviewees with a "phenomenon, but at the same time the explanation is only one of many possible 'plausible' interpretations possible from data" (p.302). In this way I can say that my analysis findings are trustworthy and believable (not truth), and reflect the experiences of the interviewees; and my analysis and discussion are one of several possible reasonable interpretations from the data. Therefore, according to Corbin and Strauss (2008), the philosophic debate on 'truth', 'validity' and 'reliability' is superfluous, as stated by Postmodernism, while it is useful because it explains and describes things (p. 301).

1.3.6 Limitation of the Case Study and Grounded Theory Methods

Glaser and Strauss (1967) state that the limitation of the grounded theory method is that it cannot know if all the data obtained from interviews is true, but rather presents the view of people interviewed. Limitation of the interviews that I conducted is that these reflect the experience and perspectives of the significant interviewees and cannot be verified. But as Corbin and Strauss (2008) state, these are trustworthy and believable.

1.4 KEY FINDINGS AND CONTRIBUTIONS

The dissertation makes contributions to knowledge in the following areas:

1) Role of Israeli culture, education, and Jewish values
2) Government support
3) Role of universities
4) Defense and private industries

5) Response of the Israeli Innovation System to the new technological area of green energy
6) Weakness of the Israeli Innovation System
7) Contribution to the Systems of Innovation literature

1) Culture, education and Jewish values

The Israeli academic literature mentions that the State of Israel was founded on a 'National Ideology' based on developing a knowledge based economy in support of Science and Technology; on intellectual capital founded on Jewish values of education. However, according to more recent studies and to my research, the goal of Transfer of Technology Offices in Universities (TTOs), Venture Capital firms (VCs) and businesses do not include the contribution and benefits to the country's economy, while their main focus is on markets and profits. Differently however, this 'National Ideology' seems to exist in southern Israel, where there is intense development of renewable energy technologies for both, domestic implementation and global exporting notwithstanding the country's discovery of fossil fuel fields.

My research identified that Israelis consider themselves to be a culturally more open society than Americans. Because of this, they establish close networks that facilitate the informal and indirect transfer of knowledge and technology. As well, Israeli society and its government tend to be action oriented, also by being aware of the System's deficiencies and correcting them on an ongoing basis.

In addition, according to the Israeli and institutional literature, the country's culture became more individualistic as its economy was liberalized. However, according to my findings, the Israeli culture is still very socialist, especially when it comes to dealing with the government. Moreover, Israeli society may have the lowest military and business hierarchical distances, where individuals question orders from their superiors and challenge the status quo in the workplace. In this sense, it may be that Israel has a different cultural model that does not fall within Geert Hofstede's collectivist, individualistic, and hierarchical distances model, from where the literature has adopted these concepts (as cited in Lindstrom, n.d). Israeli culture could be a combination of both,

collectivist due to military service and cohesiveness in its values and a sense of purpose; to remnants of its socialist non-distant past, and individualist in its entrepreneurial spirit.

2) Government support

The focus of Israel's high quality universities was, and is today largely on applied research with intensive commercial purposes. We see this focus on commercialization goals also in the Office of the Chief Scientist (OCS) programs. For example, although pointed out in the Israeli documentary review that the Israeli culture has a high tolerance for failure, this tolerance has a limit and the government does not fund companies that have been funded several times without arriving to the commercialization phase.

Nonetheless, the strong support and commitment of the Israeli government and its bureaucratic champions, throughout the decades, prepared the country for its economic development in the 1990s and 2000s. According to the Israeli literature (Getz and Segal, 2008; Avidor, 2011), the Israeli government has supported mainly industrial R&D for 20 years, while expecting commercialization in order to create manufacturing, employment, export, and spillovers. Nevertheless, very little of these have taken place in Israel, possibly resulting in a shortage of large Israeli companies, a shortage of engineers, a double economy, and possible future crises. Even so, Israel has been successful in transferring most of its technologies overseas and achieving an accumulation of knowledge within the country.

3) Role of Universities

The Israeli literature (Meseri and Maital, 2001) discusses that Israeli universities have a low performance in transfer of technology since they conduct a large amount of basic research, suggesting that further research of all institutions is necessary to better understand these dynamics. Thirteen years later, my investigation adds that Israeli universities conduct a large amount of applied research, producing core technologies, such as in green energy, that are suitable for large industries and are mainly licensed to large foreign MNCs, instead of the transfer of the technology taking place in Israel since the country does not have many large Israeli companies. My research also identified the

strong networking between TTOs and researchers with a large number of entrepreneurs; a point identified in the NIS literature but not by the Israeli literature.

4) Defense and private industries

Similarly to the US but also unique to Israel, its military sector had a strong role in developing the civilian Israeli high-tech industry (Senor and Singer, 2009; Breznitz, 2005; de Fontenay and Carmel, 2004), and which has also been transferred to and applied in the biotechnology sector. However, this trend may be changing since today about five percent of Israeli entrepreneurs come from the military.

The Israeli literature (Breznitz, 2007b) indicates that few VCs invest in incubated startups. However, according to my research, the reason may be that since Israeli VCs are early stage, they would not have many investments in incubated technologies. Nevertheless, startups prefer large companies and VCs as investors, than incubators, due to higher financing and success rates; and under the umbrella of a VC they probably follow a more direct commercialization path as well. Also, the large number of VCs in Israel, second to the US, probably results in a high number of startups achieving the commercialization stage.

5) How is the Israeli Innovation System responding to the new technological area of green energy?

The Israeli government had set a goal for the country to have five percent renewable energy by 2014, in order to reduce green house emissions, and ten percent by 2020. However, by the end of 2014 the Israeli government had not achieved its five percent goal. While the government supports mainly R&D in green energy, it had been setting barriers to the implementation of renewable energy. Notwithstanding this, there are companies that have built solar fields in southern Israel, a region that plans to be fully renewable energy by 2025, becoming the Silicon Valley/Sun Valley of Renewable Energy.

Different reasons were identified on the low implementation of renewable energy. However, in the past the government has placed barriers as well to all large industrial technologies such as the building of water desalination plants in the country, which

eventually became a large industry with headquarters in Israel, and with overseas offices and projects. On the other hand, IT and green energy technology seem to fall within the same frame or category of R&D only and their overseas development, whatever the reasons provided.

Nonetheless, the defense industry is investing in renewable energy for military use, diversifying into the civilian sector, and collaborating with universities. These collaborations may have a positive impact on the development of green energy in Israel in the near future.

Regarding the impact of Israel's large gas discoveries on the development of green energy, these could have had an influence on the slowing down of the five percent renewable implementation by 2014, and possibly on 10 percent goal set by 2020. Alternatively, another not negative impact identified was the country's need for different sources of clean energy. Nevertheless recently, in 2017, the Israeli government has decided to speed up the installation of solar energy fields through the Ministry of Energy.

Somewhat differently from the business literature that proposes to develop green technologies in developing markets (Day and Schoemaker, 2011), Israelis are already exporting their technologies to both, developing markets and also to developed markets such as the US, Spain, and are planning to enter the Canadian market as well. My research also shows that Israel's power supply and national security are the main reasons for the country to reduce its dependence on foreign oil and on dealing with energy crises, while the desire to improve the environment ranks second.

6) Weakness of the Israeli Innovation System

In addition to some weaknesses mentioned above, since the Israeli government supports mainly R&D, most startups run out of money and close. Most startups that do survive are acquired by foreign MNCs or have foreign MNCs as investors, and generally the technologies are developed overseas. Different views were identified regarding this issue, the strongest being that the government must invest in startups after their incubation stage and take most of their development risk, with no equity in the companies, as it presently does with its other programs, and to help grow companies and their technologies with headquarters in Israel.

In response, the Israeli government is taking action and is starting, in 2017, to address some of these weaknesses. Therefore, while the Israeli Innovation System has been very successful for the last 20 years, it is now starting to innovate itself.

7) Contribution to the Systems of Innovation literature

I am drawing attention to the relative lack of coverage by the NIS literature of what goes on inside a country, of how things work, such as its human dynamics. There is a gap in the Systems of Innovation theory regarding this important component. Also, although the NIS is not specific about all countries, there may be other democratic countries, such as Israel, that could be studied.

The Israeli case seems to differ from rich countries such as Britain and the United States (US), as described by the NIS literature in several aspects. For example, Israel has little manufacturing, economies of scale or the resulting accumulation of capital. Israel had little natural resources until recently, and nonetheless the nation achieved economic growth based only on its intellectual or mental capital, without manufacturing, through institutional change, and strong foreign direct investment. Differently as well from the US and Britain, Israel has a social component of compulsory military service that shapes its culture; which favours risk, questions military orders, is daring and challenges the status quo, and therefore embraces change. In addition, Israel is home to Jews who arrived "home" from many countries, but they consider themselves to be "one people," a trait that is different from other countries established through immigration such as the US and Canada. It is also a country in transition from a socialist to a capitalist society, facing bureaucratic hurdles influencing its national innovation system, as it had in the past and is still taking place today.

Also differently from the NIS literature (McDonald, 2002; Smith, 2000; Cohen et al., 2002; Feller et al., 2002; Freeman, 2004), direct or linear innovation can create a country's economic development under special circumstances, as it happened in Israel, through 20 years of government support and commitment through R&D only; by implementing strong patenting laws; through profitable university licensing and creation of startups, and with successful results. Nevertheless, R&D only can create economic development up to a certain point, when the further development of technologies and

growth of companies is needed to maintain a country's economic development and stability.

Differently as well from the NIS literature (Hospers, 2005) that suggests policy makers should not chase after successful programs in other countries, Israel actually established a very successful VC industry by adopting the VC model from the Silicon Valley and adapting it to Israeli culture and its institutions. Furthermore, the Systems of Innovation literature does not distinguish between successful and unsuccessful entrepreneurs**,** but rather sees entrepreneurship as a driver of economic growth. However, only entrepreneurs who successfully grow technologies into companies create the economic growth of a country, and only they should be admired.

Nonetheless**,** indirect technology transfer processes are also needed, as addressed earlier, such as having strong networks and an ongoing flow of knowledge through the constant movement of scientists and engineers across the country's institutions, which are also a unique characteristic of the Israeli Innovation System. My research also provided a description of the human side of technology transfer as it takes place in the Israel Institute of Technology (Technion), where it happens both ways, through technology push and market pull, from academia to industry and vice-versa.

1.5 THESIS ORGANIZATION

The dissertation Chapters are organized as follows:

Chapter 2: Looks at the Systems of Innovation theories and the National Innovation Systems (NIS) literature, arguing that regions and/or nations develop their own NIS; addresses the important role of government support; of basic and applied research, and of technology transfer within innovation systems. Presents the important role entrepreneurs play according to Schumpeter's theory; the neo-Schumpeterian movement coming out of Schumpeter's work; and the significance of technical innovation for economic growth.

Chapter 3: Examines Israel's national and political processes and strategies that lead to Israel's unique events creating the present context of its innovation system. For example,

why Israel reacted in certain ways and chose certain processes, such as establishing its academic and government research institutions even before the 1920s, and the Office of the Chief Scientist (OCS) in the late 1960s. In this way, by having the right infrastructure in place, Israel was able to become an innovative and developed country in the 1990s.

Chapter 4: Analyzes the country's institutional strategies and how these work – government, academia, private and defense industries, and the military. It looks at how the different institutions collaborate in the area of R&D and transfer of technology; how these strategies are applied to the development of green energy; and the significant role of Israeli culture in the country's innovation system.

Chapter 5: Describes the important role culture plays in the Israeli Innovation System. Israel is a country of immigrants and of 'one people,' with an emotional connection to the Land. The different Israeli cultural characteristics are presented which contributed to the high-tech entrepreneurial spirit of its people, many of them resulting from the compulsory military service. It presents the country's entrepreneurial weaknesses as well.

Chapter 6: Examines the informal and formal R&D collaboration between Israel's institutions – government, academia, industry and the military, funded by government. The collaboration of Israeli universities mainly with European research institutions, and addresses their patenting policies. It looks as well at the investment role of the defense industry in renewable energy and its diversification into the private industry.

Chapter 7: Addresses how transfer of technology takes place in Israel's Innovation System, from academia to industry; industry to industry; and military to industry. It looks at its strengths and weaknesses, such as government implementation barriers and presents proposed solutions. The chapter also explores the institutions' green energy programs, including those of its two top universities and how these work.

Chapter 8: Explores Israel's reasons for developing and implementing green energy; its impact on Israel's economy; and the impact of the country's large gas discoveries on its green energy developments and implementation of renewable energy.

Chapter 9: Discusses the main findings of the interviews regarding Israel's Innovation System, and compares them with the Israeli academic literature and institutional sources, and with Systems of Innovation theories, and business management literature related to green energy.

Chapter 10: The Conclusion Chapter answers the two research questions and provides an overview of lessons learned. The outcomes of my research clarify whether Israel's Innovation System indicates a new practice in technology transfer and whether it can be adopted by other countries; or whether this success is a sole product of Israel's industrial history and culture. It summarizes the key findings, the research limitations and recommendations for future investigation.

CHAPTER 2: LITERATURE REVIEW
SYSTEMS OF INNOVATION THEORY

2.1 INTRODUCTION

Systems of Innovation theory focuses on the institutional connections that may facilitate or otherwise intervene in the production, transmission and application of knowledge (Freeman, 2004; Lundvall, 1992).

> "A national system encompasses elements and relationships, either located within or rooted inside the borders of a national state" (Lundvall, 1992, p. 2)

Systems of innovation theories have evolved into the understanding that when firms innovate, these are not their independent decisions, but rather the result of their interactions with their environment at different levels. These comprise interactions with firms, including customers and suppliers with whom they cooperate, learn and create technologies; institutions, infrastructures, access to scientific knowledge; and interact with their social and cultural environments, among others, which are specific to a region or nation (Smith, 2000).

In addition, many countries develop and maintain specialized technological capabilities that are reproduced in their research and development (R&D) patterns, in their patenting and scientific publications, and therefore develop specific capabilities within their national innovation systems (Archibugi and Pianta, 1992; Patel and Pavitt, 1994). In this regard, government involvement policies are important in establishing the national structure for economic development (Hirst and Thompson, 1996).

This chapter starts by describing the work of Joseph Schumpeter on the role of entrepreneurs as drivers of innovation and economic growth. It then examines the contributions of the neo-Schumpeterian movement within the evolutionary school of economics, whose members adopted Schumpeter's core concepts of innovation and expanded them significantly, such as the concept of technical change as the major drive of economic growth.

The chapter then looks at the Systems of Innovation Theory and National Innovation Systems; their historical origins in Britain and the United States; the different

views on technology push, and market pull or both; and addresses the importance of government intervention in supporting specific industry sectors. Next, it examines the current thinking about the roles of basic research, technology transfer and industrial research and development (R&D) in the innovation system. It then discusses the importance of technological leadership, and it concludes by contextualizing the discussion on the field of green energy technology.

2.2 BASIC THEORY OF INNOVATION

2.2.1 Joseph Schumpeter (1883-1950)

Ruttan (1959) explains that Schumpeter focused on the important role of innovation which is the essential function of the entrepreneur or innovator, and which creates economic growth, development and, as Fagergerg (2013) adds, social change. As Freeman (1994) and Fagerberg (2013) indicate, Schumpeter proposed that there are two kinds of innovation agents: entrepreneurs, who are outstanding individuals, and a larger group of imitators. In his early writings, Schumpeter views individual entrepreneurs as the drivers of innovation, and in his later work he also examines the role of large firms as innovators as well.

Andersen (1992b) points out that Schumpeter criticized Walras` neoclassical ‘general equilibrium model’ (Walras, 1874-77/1954) which proposed that economic change is caused by external factors where the economy is in constant equilibrium with nature, bringing production back into equilibrium. Instead, Schumpeter (1937, 1942) posits that the capitalist economy is in constant evolution, disrupting the equilibrium in the economy from within, while equilibrium seldom happens.

Schumpeter (1934, 1939, 1942, 1947) introduced the concept of ongoing ‘creative destruction’ taking place through the constant evolution of economic systems in capitalist societies, where old economic structures are destroyed and new ones are created resulting in economic development. He proposes that this process happens since innovation in some industries tends to happen in clusters and during certain periods of time or ‘long waves,’ when economic growth and booms take place followed by economic busts. Schumpeter (1939) also proposed that innovations usually concentrate in specific sectors,

creating a diffusion process and generating additional innovations. As Bergek et al. (2008) further discuss, clusters of innovation take place when particular technologies, their knowledge, products and support services (such as suppliers and financial organizations) are usually concentrated within a specific geographical area and have an international focus, for example the Silicon Valley in California.

Schumpeter (1940) classified innovations according to five categories or types: 1) new products, 2) new production processes, 3) new supply sources, 4) new marketing methods and 5) new business organizations. This definition remains until today as the one selected by the Organization for Economic Cooperation and Development (OECDiLibrary, 2013). Freeman (1994) and Edquist (2005) further posit that because of this concept, Schumpeter's views have been regarded widely as supportive of the 'entrepreneurial technology-push' or linear model of innovation. However, his followers have always criticized this model and have developed interactive models of innovation comprising social, political and organizational institutions, among others.

As well, Ruttan (1959) discusses that Schumpeter was only interested in the effects of innovation on economic development and growth and he did not address the actual process of innovation. Freeman (1994) and Fagerberg (2013) point out that Schumpeter's followers have adopted his core concepts and taken his work further by studying the processes of invention, innovation and diffusion and their causes and impacts, as these take place inside the firm, between firms and industries, and between countries.

2.2.2 The Neo-Schumpeterians

Freeman (1994) and Fagerberg (2013) explain that Neo-Schumpeterians refer to Schumpeter's work as 'evolutionary' by describing capitalism as an economic system that experiences ongoing evolution due to the technological and organizational innovations it goes through constantly. This evolution, as described by Freeman (1994), is seen to occur in long waves that follow on from radical innovations such as steam power, electrical power and information technology. These radical innovations spurred many subsequent incremental changes through long periods of adaptation, thus driving growth.

Furthermore, Rosenberg (1982) explains that neo-Schumpeterians have expanded Schumpeter's five categories or types of innovations to 1) encompass innovation and diffusion within and between firms, industries and countries, 2) firm behaviour, 3) international trade; as Fagerberg (2013) adds, 4) organizational and services innovation, and as Freeman (1994) adds, 5) a wide range of products, processes and services. Fagerberg, (2013) argues that neo-Schumpeterians have also expanded Schumpeter's view of innovation as focused largely on 'tangibles', i.e. manufactured products, and on radical innovations which happen less often and only in a few industries, for example high-tech firms that focus on R&D. In addition, Neo-Schumpeterians also study the smaller and more frequent innovations that take place across industries, as well as the more intangible ones such as organizational and service innovation; innovation in 'low-tech' industries and in developing countries. This research indicates that innovation has become an important factor for policymakers.

According to Nelson and Winter **(**1977), neo-Schumpeterians consider technical change as the most important dynamic component in capitalist economies, and technical progress as the most significant factor in economic growth. Dosi (1988), Utterback (1979) and Lundvall (1992) further discuss that technical change takes place due to the firm's accumulation of knowledge, including tacit knowledge and skills formation, resulting from formal training and learning by doing. A study done by Grant and Gregory (1997) showed as well, that the transfer of tacit knowledge has a positive impact in the manufacturing industry. Bozeman (2000) describes that skills, know-how, tacit knowledge and knowledge acquired through experience are embodied in scientific and technical human capital; and as the production of scientific and technical knowledge is a social activity many of the skills involved are more social, such as networks between scientists and firms, and more tacit than intellectual.

Cooke (1998) further indicates that most neo-Schumpeterians have abandoned the general equilibrium theory and instead follow the evolutionary approach developed by Nelson and Winter (1974), viewing innovation, uncertainty, and change as taking place within the economic system and assuming that economic equilibrium hardly ever occurs.

Neo-Schumpeterians examined Schumpeter's notion of uncertainty when making innovation decisions, adopting 'bounded rationality,' as hypothesized by Simon (1978),

Simon et al. (1992) and other behavioural economists, such as Dosi and Egidi (1991), who examined situations where entrepreneurs, both individuals and firms, do not have a clear and defined vision of R&D outcomes. These studies indicate that entrepreneurs do not make the best decisions based on precise information or on 'rational expectations'. Instead, innovation involves a high degree of risk taking.

2.3 SYSTEMS OF INNOVATION

As Fagerberg (2013) describes, the Systems of Innovation theory is concerned with the emergence and diffusion of innovations, the factors that influenced these processes (such as policy), and their social and economic outcomes. This field of study originated after World War II with scholars mainly from the United States (US) and the United Kingdom (UK), such as Richard Nelson and Christopher Freeman, who began examining the importance of innovation in creating economic and social change.

The Organization for Economic Cooperation and Development (OECDiLibrary, 2013) further expanded its definition of innovation to include ongoing or abandoned product or process innovations. Marketing includes sources such as "suppliers of equipment, materials, components or software, clients or customers, competitors or other enterprises in the same sector and consultant, commercial labs or private R&D institutes" (p.29). Institutions include universities, government and public research institutions. Collaboration involves cooperation in innovation projects with "other firms or organizations" (p.29), suppliers and customers.

Edquist (2005) indicates that innovation systems are formed through the participation of many private and public sources creating patterns of interactions or networks, which become somewhat stable. Lundvall (1992) and Nelson (1993) explain that national systems of innovation include institutional connections - "systemic interdependencies" within a country, the relationship between firms – inter-firm networks, the different links between users and producers, and as Andersen (1992a) states, government institutions and policies.

2.3.1 National Innovation Systems (NIS)

Fagergerg (2008, 2013) mentions that the "national innovation system" (NIS) concept was first addressed in the literature by Freeman (1987) in his study of the 'national innovation system' of Japan, who was also the first to use this term, followed by Lundvall (1992) and Nelson (1993). However, as Freeman (1995) points out, Friedrich List was the first to come up with the concept of National Innovation System in his book "The National System of Political Economy" (1841).

List (1841) first proposed that nations should propel industrialization and economic growth through "mental capital", meaning intellectual work such as science and technology. He explains that the economic development of a nation depends on the accumulation of all its "discoveries, inventions (and) improvements…." (p.113), throughout its history, its previous generations, and on the ownership of those achievements. As Freeman (1995, 2002) indicates, these ideas laid the foundation for subsequent strategies to link industries with educational and scientific institutions.

List's (1841) concern was that Germany's economic performance should surpass that of Britain, arguing that government policies should protect new industries; encourage and boost industrialization and economic development; and industry should interact with institutions of science and technology in order to develop and implement new technologies. List's concepts, which encouraged the development of a top worldwide technical education and training in Germany indeed surpassed Britain's economic development in the late ninetenth century. As Prais (1981) indicates, these theories are until today the basis for Germany's high skills and productivity of its workforce. Freeman (2002) indicates that List's book predicted many issues on the future national innovation system's literature of the twentieth century. For example, that industry should be connected to science and universities (education institutions). As Freeman (1995) explains, List was also impressed with the successful economic development in the US which had surpassed that of Britain, achieved through education, and its waves of immigrants which helped the country's national innovation system to overcome those of European countries.

Lundvall (1992), Nelson (1993) and Edquist (1997b) propose that each country has its own national innovation system and technologies which reflect their unique

institutional characteristics, and the institutional interactions within this system can create national economic growth. Furthermore, Lundvall (1988) argues that within a national innovation system, the interactions among institutions (industry, government, universities) involve learning processes between producers and users. This technology transfer process takes place not only between firms and consumers, but also between universities and industries, where universities are the producers of basic research and industries are their users. Alternatively, university applied researchers also learn what are the needs of industry.

Malecki (1981a,b), Malecki and Tootle (1996) add that technology transfer builds knowledge within geographical areas, in scientific and technical institutions, creating economic growth. In this way each country has its own particular national innovation system based on its history, which influences its economic development. As Nelson and Rosenberg (1993) further suggest, within the boundaries of national innovation systems firms design and produce new products and new manufacturing processes.

Abramovitz (1986) argues that national innovation systems boost national economic growth creating large economic gaps among countries. ‘Social capability’ is the capacity of a country to make institutional changes that facilitate and advance technical change creating different growth rates among countries. In this way, the national innovation systems theory disapproves of the accumulation of capital theory which posits that accumulation of capital and increase in labour force are the drivers of economic growth. Nelson (1981) adds that instead, the national innovation systems approach looks at the quality and not only at the quantity of capital accumulation; at the skills of entrepreneurs and the labour force, among others. Similarly, in his research, Pavitt (1993) found that in order for developing countries to attain economic growth through innovation, they do need competence and education in basic science within their innovation systems.

Fagerberg et al. (2008) discuss that the development of national innovation systems should be examined as historical and co-evolutionary processes, where the innovation of a country is shaped by its resources, which in turn affect its public research infrastructure, policies and institutions. According to Freeman (1994), a difficult question faced by neo-Schumpeterians is regarding the contribution of national innovation systems to global innovation throughout history.

2.3.2 Origins of National Innovation Systems

This section examines the history of the national innovation systems of Britain and the United States – how both innovation systems were formed, since it will be interesting to compare these descriptions with Israel's history of its national innovation system. As Freeman (2002) explains, in order for national innovation systems to succeed, these must be in synchronicity with their social sub-systems such as "science, technology, economy, politics and culture" (p.193). Furthermore, according to Edquist (1997a,b), this is a situation that Britain first experienced during its exceptional economic growth in the eighteenth and nineteenth centuries. Lundvall (1992) indicates that differently from other European countries, Britain's economic growth in the eighteenth century is attributable to the development of its capitalist industry. This was a trajectory that had started during the period of the Renaissance (fourteenth to seventeenth centuries), due to the nation's cultural connection with science, technology invention, and its industrial processes, which created the industrial revolution; and to its government policies that integrated science, technology, culture and entrepreneurship, which became the features of the British national innovation system. These characteristics were later transferred to Europe and the New World.

Lundvall (1992) discusses that some other features of the British national system were the strong ties between scientists and entrepreneurs; the ability of inventors to raise funds and collaborate with entrepreneurs; government support for science, becoming a national institution; its popularization in the nation's clubs; and an economic policy in support of industrialization. An example of the differences in support for science, as Jacob (1988) indicates, between Britain and other European countries, was the admiration and respect towards Newton in Britain versus the imprisonment of Galileo in Italy.

According to Freeman (2002), during this time as well, investment in Britain's industry, such as transport, which opened its cross country trade and international markets, became more important than owning land, when the country's 'created advantages' became more important than its 'natural advantages'. Freeman (2002) proposes that for both, Britain and the United States, it was their radical innovations that created the countries' huge economic growths, as well as their economies of scale achieved through factory manufacturing and ongoing improvement of machinery;

resulting in accumulation of capital and a lead position to their manufacturing firms over others in Europe. However, as Foray (1991) describes, the diffusion of innovation only took place in some parts of Britain, where there was an easier access to global markets, and only in some industries, creating localized industry clusters that catered to international markets. Moreover, Mass and Lazonick (1990) argue that in this way sub-national innovation systems were created, with a labour force that acquired cumulative and specialized skills. Freeman (2002) adds that these sub-national innovation systems or 'industrial districts' contributed to the success of Britain's industrial revolution. Britain's national and sub-national innovation systems complemented each other due to national support through its government and technological institutions, including access to capital markets, legal protection of property and its accumulation of, and access to engineers and scientific knowledge.

Supple (1963) explains that in addition, Britain and the US had abundant natural resources, advanced technological agricultural systems versus other European countries that had feudal institutions keeping their agriculture underdeveloped. Britain also had achieved access to large international markets through its sea ports; a stable political system that welcomed social change through a parliament and limited Monarchy, incorporating science and religion; a scientific heritage and an ideology that supported business and innovation, all of which facilitated its national economic change, and as Freeman (2002) adds, together with a strong and dominant navy. Abramovitz and David (1994) propose that additional advantages of the US included a large domestic market which facilitated economies of scale; formation of skilled labour, and creation of large firms with the intention of generating and exploiting huge markets, among others. Freeman (2002) argues that while fore-runners enjoy economies of scale and strong market positions, forging-ahead, as the US did, is considered a 'miracle' by dominating, in the late 1990s, the software industry and becoming a military super-power as well.

2.3.3 Catching-up through national innovation systems

Freeman (2002) explains that Western European countries caught-up with innovation and economic growth between 1950 and 1975, achieved through institutional and technical change, and by investments of European firms in the US and of American

firms in Europe. However, catching-up for countries that are late-comers to achieve economic development through radical innovations will be difficult in the late twentieth century, since they will not have the opportunity to create radical innovations in new industries but instead will become imitators.

According to Gershenkron (1963), in some situations late-comers could catch-up and achieve a higher growth than developed countries have, with the social capability to attain institutional and technical change in their national innovation system and with the right international connections. In addition, Freeman (2002) indicates, geographical and cultural proximity to leading innovation countries has a positive effect on the rate of new-comers catching-up and forging-ahead, as it happened with Britain's European neighbours.

Gerschenkron (1963) also points out that in order to innovate, countries need huge investments for very large plants, and therefore need to innovate their financial systems. Alternatively, Perez and Soete (1988) explain that not all industries must have economies of scale, such as drugs and semi-conductors.

Regarding multinational companies (MNCs), Bell and Pavitt (1993) indicate that developing countries with foreign corporations with large plant installations, with their foreign technologies and assistance, will not build technological capability and will remain underdeveloped. Alternatively, Freeman (1994) explains that within national innovation systems, MNCs play an important role in diffusing and establishing global standards in technology developments through their international R&D and production centres with the goal of achieving economies of scale in R&D, production and marketing; and as Lundvall (1992) adds, while attaining diffusion of their tacit knowledge as well.

Nevertheless, Freeman (2002) contemplates the future of innovation in the twenty first century as being oriented mainly towards information and communication technologies (ICT) moving from a strong manufacturing industry towards the dominance of the service sectors, while agriculture continuing to be important. Manufacturing will continue to be located outside of the industrialized nations and therefore further reducing employment in this industry. In the twenty first century the innovation focus will be on managing global networks with main activities in research, design and development of software and hardware mainly in the home country as long as MNCs have the right

scientific, technological, financial and communication support. However, these new innovation structures and developments are also widening the social inequality gaps within their national social systems.

Freeman (2002) points out to the importance of the right technological investments, as the Asian Tigers did, by focusing since the 1970s on R&D, training and technology development in the electronics and telecommunication industries. Later on, in the 1980s and 1990s, networks in the electronics industry and its sectors were formed in East Asia, together with government protective policies of specific industries and with subsidies to particular firms, while promoting R&D and exports. Initially the Asian Tigers caught-up with hardware design and production, and later on, in the 1990s, with software design, production and marketing, and with successful commercialization. Freeman (2002) also mentions the importance of graduate education of engineers and of training, which are strengths of those countries as well; and he further distinguishes between active and passive national innovation systems, classifying learning to produce, by importing and improving technologies, as ‘active;’ and learning to innovate as ‘passive.’

Nelson and Winter (1982) propose that innovation must be studied at the firm and industry levels, and have confirmed and formalized Schumpeter's view that ‘innovation-based competition’ propels the development of capitalist societies. Expanding from Schumpeter’s concept of the less important role of innovations’ ‘imitators,’ Nelson and Winter (1977), Dosi (1988), and Dosi et al. (1990) examine the diffusion of innovations and technical change at the firm and industry levels; and how these processes differ among the different types of firms and industries or sectors, with innovation procedures that are also diverse. Moreover, as Mansfield (1989) discusses, the rates of diffusion also vary according to product, technological system and country; and as Nelson and Winter, (1977) and Dosi (1988) add, these differences should be applied in the implementation of policies as well. Nevertheless, as Freeman (1994) indicates, research shows that the country with the first innovation does not always achieve the fastest diffusion or highest productivity growth.

2.4 INNOVATION AT THE FIRM AND INDUSTRY LEVELS

Nelson and Winter (1977) view innovation and diffusion at the firm and industry levels as the most important drivers of economic development and standards of living.

2.4.1 External direct and indirect sources of innovation

Innovation at the firm level takes place by accumulation of knowledge which in turn happens through the continuous interactive processes with external and internal sources, which can be direct or indirect. External direct sources of innovation include technology licensing and the creation of firms.

External indirect sources of innovation, which are more successful, include formal collaboration, supported by government policy, between firms and universities to produce generic technologies. Nelson (1992) describes technology as "generic knowledge…that… provides understanding of how things work…." (p.350). Nelson (1987) further describes generic knowledge as codified and accessible to all firms and industries and especially to those in applied scientific fields like electrical engineering and materials science, which are technology related. Freeman (1994) adds that such successful examples have resulted in the transfer of technologies mainly in information and communication technology (ICT), biotechnology, and new materials which had a rapid diffusion in the 1970s and 1980s. However, Faulkner and Senker (1995) discuss that in order for this to happen, individuals and firms must have access not only to codified knowledge but also to tacit knowledge and personal interactions. As Brooks (1994) adds, a large amount of knowledge needed for technological innovation is tacit or ingrained in people, and is not codified or written down. Rosenberg (1990) and Pavitt (1998) state that having tacit knowledge means that people know more than they can say, acquiring this knowledge through years of formal training and in learning by doing.

Freeman (1994) suggests that other external indirect sources of innovation comprise hiring of graduate students; informal networking between firms, with users of products and systems; with suppliers, and with university scientists. According to Salter and Martin (2001) and Bozeman (2000), university students become involved in technology transfer through graduate and postgraduate positions with industry, bringing codified and

tacit knowledge with them. Freeman (1994), Salter and Martin (2001) and Cohen et al, (2002) propose that tacit knowledge also takes place through spillovers, when it is codified in scientific publications and through conferences, indirectly creating technical development and economic growth. Zvi Griliches (1998) defines Spillover as the knowledge capacity that remains unused in one firm or organization that can spill over into use in some other setting.

As well, Feldman and Florida (1994) and Saxenian (1994) point out that spillovers can be geographical or regional since these happen within clusters of specialized knowledge where scientists and technologists share and transfer knowledge; according to Feldman and Florida (1994) patents usually cite papers published by local public institutions. Salter and Martin (2001) explain that in this manner tacit knowledge is codified and becomes the collective property of the region. Thus a nation should have good basic research and development (R&D) capabilities in order to absorb the knowledge produced by other societies and to maintain technological and economic development.

Regarding internal indirect sources of innovation, Nelson and Winter (1982) propose that to a large extent, detailed knowledge within a firm's routines (manufacturing processes) and its R&D labs (product innovations) is tacit. Therefore, since tacit knowledge can be acquired through the work experience within a firm, Freeman (1994) and Cohen and Levinthal (1987, 1990) indicate that firms must learn from their own R&D, production and marketing in order to be successful, as these generate new knowledge, contribute to a firm's accumulation of knowledge and to its absorptive capacity.

Goto (1982) explains that knowledge accumulation within the firm also takes place through ongoing improvements of products and processes across the firm's departments, with an internal structure of vertical and horizontal integration, such as that of successful Japanese firms. As explained by Burns and Stalker (1961), firms must have good internal coupling and communication between design, development (R&D), production and marketing, and R&D should happen within the production chain. Studies of US manufacturing firms found that many failures were caused by a lack of communication among these departments. Due to this problem, as Mowery (1983) points out, some US

firms, instead of contracting to research institutes, prefer to have their own R&D in house. Freeman (1994) adds that contracting for R&D and licensing are complementary to the ones in house and also need further development and improvements to be used efficiently. Utterback (1979) and Lundvall (1992), and Rosenberg (1990) and Pavitt (1998) point out that all these create skills within firms by acquiring technological tacit knowledge.

2.4.2 Firm Size

Freeman (1994) explains that in the 1970s and 1980s neo-Schumpeterians were also studying the role of firms' size in technological innovation. According to Schumpeter, a small number of large firms dominated the innovation market share. However, Pavitt's (1984) later research found that the contribution of small firms to invention and innovation is considerable and increasing; it is clustered in a few industrial sectors, such as the software industry which can be used by other sectors as well. Alternatively, large firms produce most of the innovations across industries. Also, as Utterback and Suárez, (1993) add, during the early stages of new generic technologies, and mainly in biotechnology, the main contributors are new small firms. However, since the costs to conduct R&D and develop these technologies are high, it is during these stages that small companies and their technologies are acquired.

2.4.3 Incremental and radical innovations

Innovation at the firm and industry levels, as Freeman (1994) indicates, can be incremental or radical, and with many contributions from adaptations within and outside of the country. Moreover, according to Nelson and Winter (1977), the difference in industrial sectors also results in radical or incremental innovations.

Dosi (1984) argues as well, that radical innovations vary among industries and tend to be clustered in certain industries such as electronics, chemicals and nuclear power and result from changes in basic processes and from R&D departments, which in turn need new manufacturing processes and markets. Freeman (1994) adds that the fastest growing industries are those with the highest R&D intensity. Furthermore, radical innovations, are

more completely recorded than incremental innovations, and are often described in technical journals and patents.

However, Hughes (1992) and Carlsson and Stankiewicz, (1991) propose that most firms make incremental innovations and adopt new products and processes made by others. Incremental innovations are usually achieved by 'user' firms, such as instrumentation. Furthermore, most innovations are not created as isolated products, but are rather generated as part of a technology system, such as electronic products.

Notwithstanding the innovation processes described above, Arthur (1989) posits that technological systems can become locked-in to less than optimal solutions due to several situations such as standardization and the role of supporting institutions such as government. As Perez (1983) further adds, there will always be some standardization at national and international levels due to economies of scale (for example in computers and their applications), due to consumer choices and others which 'lock-out' better innovations. Before a new technological paradigm is adopted and achieves stability, there is a period of adjustment at different levels such as dealing with structural changes, training and implementing regulations, among others. In this sense, neo-Schumpeterians consider institutional changes as the drivers of development and growth.

2.4.4 Innovation by the public sector

Not all innovation is based on profit or on market competition. Nelson and Winter (1977) explain that the motivation of the public sector to innovate is not for profit or to compete with other firms; the market is not the selection environment, and for example, Staw and Epstein (2000) mention, the incentive can be for prestige. Nonetheless, Lander (2010) suggests that public sector institutions in Western countries are innovators; employ about 20 percent of the population and account for 15 percent of gross national product (GNP). Windrum and García-Goni (2008) and Djellal and Gallouj (2005) propose that public innovation tends to rely on science and technology, for example universities, public research labs and hospitals. However, according to Nelson and Winter (1977) their motivations to innovate are difficult to define and understand, and as Lander, (2010) adds, therefore the focus of innovation systems tends to be on the firm institution, which is clearer and capitalist, and thus easier to describe. As mentioned earlier, neo-

Schumpeterians have taken Schumpeter's core concepts of technology-push and developed interactive models of technology-push and market-pull innovation.

2.5 TECHNOLOGY-PUSH AND MARKET-PULL CONCEPTS

Rothwell (1994) explains that the technology-push concept of innovation views R&D as producing successful new products. The market-pull model of innovation looks at the market as directing R&D, which assumes a role of reacting and responding to the innovation process. Mowery and Rosenberg (1979) define Market-pull as "…a systematic relationship between prices, quantities, devolving (feeding back) from consumer preferences and incomes… and not…(a)… shapeless and elusive notion of needs" (p.140). The authors define technology-push as focusing on solving a problem and therefore "influencing the direction of innovation" (p.110).

Rothwell (1994) looks at various generation (G) innovation processes adopted by manufacturing firms after WWII, starting with innovation perceived as technology-push between 1950 and1960, and first generation innovation process or 1G; as market-pull from 1960 to1970, or 2G; as the coupling model from 1970 to mid 1980s, or 3G; as the integration and parallel development or 4G model from early 1980s to early 1990s, as it was implemented by Japan; and the 5G model, which developed from the 4G model, but with increased technological speed and efficiency.

2.5.1 Technology-push innovation

According to Rothwell (1994), the technology-push or 1G concept of innovation assumes that more R&D "results in more new products" (p.8); and it perceives the commercialization of technology as a linear process, from scientific discovery or invention, to technological development by firms, and to market commercialization, where major inventions emerge from the "cumulative synthesis" of many small inventions. According to Ruttan (1959) this means that all new things - science, invention and innovation are in reality a process of innovation.

Furthermore, the study done by Mowery and Rosenberg (1979) found that the world's most radical and important innovations were not responsive to market-needs but

rather created their own market, for example the computer, laser and nuclear power, and this includes the military and space industries which do not exist either within a traditional market.

2.5.2 Market-pull innovation

As Rothwell (1994) states, in the market pull or need pull model of innovation, or 2G, the market directs R&D which only has a reactive role in the innovation process. Being reactive could result in companies neglecting long-term R&D programs, and instead adapting existing products through technological increments, in order to respond to “changing use requirements” (p.9). Being reactive would also risk the ability of firms to “adapt to any radical market or technological changes that occurred” (p.9).

On the other hand, based on a large number of retrospective case studies, Utterback (1974) examined and compared the factors that limit and determine the effectiveness of a firm to innovate. He found that the strongest drivers of innovation are based on market pull. For example 60 to 80 percent of major innovations in many fields have been in response to market demand.

Utterback (1974) further suggests that governments should implement market pull strategies, such as contracting smaller firms which rely on government contracts in their early business stages; stimulating venture capital for companies to enter the markets; providing strong patent protection; and stimulating informal communications within the technical community. Alternatively, Utterback found that technology–push strategies to stimulate R&D spending, such as tax incentives, were less important.

2.5.3 The coupling model of innovation

Rothwell (1994) calls the 3G or the “coupling model” (p.9) of innovation, the interaction process between technological capabilities and market needs; a sequential process where each stage is interdependent and complex and with feedback loops; and a model that applies best to all industries.

A study done by Mowery and Rosenberg (1979) found that innovation is an uncertain and random process; there are factors that go beyond market-pull and

technology-push such as internal motivations and influences on the innovation process or changes in production technology resulting in production increase and/or lower costs and/or new products. Nevertheless, Mowery and Rosenberg (1979) and Dosi (1982) explain that both demand and supply are interrelated forces that influence the innovation process. Most innovations depend on both, on scientific and technical knowledge since innovation is not a linear sequence with a clear and defined starting point. Instead, innovations must experience changes and modifications during their development in order to be commercially successful while both, basic and applied research, have an important function in the innovation process.

Rothwell (1994) argues that this coupling model of innovation or 3G, is based on innovation and acceptance of risk; strong marketing and customer focus; commitment to human capital development; corporate flexibility and responsiveness to change; and on a culture that accepts innovation and entrepreneurship, and which is used by most industry sectors.

2.5.4 The integration and parallel development models of innovation

In the 4G and 5G models, Rothwell (1994) explains that the innovation process goes a step further through vertical integration with suppliers and customers; horizontally through internal integration across in-house departments; and through strategic networking with external organizations in order to achieve the parallel development of products. This is achieved by working on the projects simultaneously - in parallel, instead of sequentially, in series. Imai et al. (1985) discuss that this approach to the development and design of new products was used very successfully by Japanese manufacturers achieving high production efficiency.

In addition to adopting the parallel processes, Rothwell explains that in the 5G innovation model the firm adopts high-technology such as real-time information sharing across its whole innovation system, and in its designing and manufacturing operations. As well, innovation takes place within flatter, more flexible, responsive and adaptable companies. Those companies that master the 5G process “will be the leading-edge innovators of tomorrow” (p.28).

Rothwell (1994) further discusses that there is a balance between technology push and market pull as an incentive for innovation, and this could differ during the industry-cycle. There is a stronger initial radical technology-push and then a stronger market-pull role once new uses and users are identified; meaning that the technology moves from radical to incremental, and it is important to match technological capabilities to the market needs in order to achieve success.

2.5.5 Internal characteristics of the firm

Funk (2003) argues that the internal characteristics or qualities of the firm comprise resources and employee talent or human capital, which creates more wealth for business and the economy than physical and financial assets, such as a company's market value, for instance "Net cash flow, return on investment, or earnings per share" (p.66). Utterback's (1974) research found that most entrepreneurs had masters' degrees and 40 percent of the innovative ideas were originated by people with PhDs.

Utterback (1974) further explains that obstacles to innovation are highly structured organizations, while matrix organizations with small project teams with half of technical personnel working in their functional departments, were more likely to achieve technical success on schedule and according to budget. Furthermore, Abernathy and Clark (1985) argue that a company achieves a competitive advantage when it attains a position through one or more of its products' features, such as "performance, reliability…initial cost" (p.5), that are superior to those of its competitors and valued by its customers. However, these products' features and the firm's position themselves are not the company's main source of advantage. Instead, a firm's position reflects the internal reality of a company, for example its human skills such as management and teamwork; and relationships, including with customers. From these competitive factors firms build their products to enter the market. Furthermore, entrepreneurship happens in a managerial climate with organizational structures that are not bureaucratic or rigid and which can implement a new innovation strategy.

2.5.6 External environmental characteristics of firms

Utterback (1974) found that the external environmental characteristics of firms are strong drivers of innovation and these include: a firm's economic, social and political environments, such as access to government programs, incentives, and regulations, which are the main factors for its potential to innovate; as well as "the state of development of technology, and information about technology" (p.621). Hirst and Thompson (1996) indicate that government's policies are important in establishing the national structure for the economic development of a country.

2.6 GOVERNMENT SUPPORT POLICIES

According to Smith (2000), the reasons for government policy intervention stems from Arrow's (1962) market failure analysis which posits that competitive markets provide a deficient and inadequate level of knowledge and therefore also create continuous low performance or 'systemic failure.' Consequently public subsidies are needed for knowledge creation and for implementation of intellectual property rights as well. However, Smith (2000) states that this approach is related to the linear model of innovation that supports R&D subsidies.

Differently, in his review of Systems of Innovation Theories, Hospers (2005) discusses that in order for a country to be open for growth, government intervention with subsidies and protective measurements should be targeted to specific sectors of the economy for special treatment. Government interventions, such as subsidies and protective measurements to help domestic industries, should be adapted to the particular circumstances of time and space based on a "case-by-case and context based approach" (p.33). For example, Mowery and Rosenberg (1979) suggest that government must implement environmental R&D policies through incentives and information to foster the development of alternative energy technologies, since industry may not have the knowledge to develop this technology and since there may not be a market demand. The authors indicate that there is an urgent need for environmental R&D to develop green energy technologies which government must support and shape through resources and

incentives, since private firms will not develop this sector. The government must intervene and shape this market as it shaped the medicine, aircraft, agriculture and atomic energy sectors. The semiconductor sector is another successful example resulting from government policy support rather than from market demand.

Also, Hospers (2005) discusses that economic change should happen from the bottom-up, from a country's existing resources that shape a country's innovation, which in turn affect its public research infrastructure and political institutions, determining a country's economic process. In this way, not only institutions shape the economic process, but the other way around as well – democracy and its political institutions are also shaped by the economy. Policy makers also tend to chase after "the latest trends" and "what worked somewhere else" (p.34). Instead, they should take into consideration the "existing economic and institutional structure of their own country" and work towards a future transition "from that specific context." (p. 34).

Moreover, as explained earlier, technological development and technology transfer build knowledge within geographical areas, in its scientific and technical institutions, and create economic growth. As Bozeman (2000), Hospers (2005) and Fagerberg et al. (2008) add, in this way each country has its own particular national innovation system based on its history which influences its economic development.

Freeman (2004) further argues that each country has its own technological infrastructure which has different effects on international competitiveness; and technological leadership gives absolute international advantage to a country as well. Countries that are technological leaders have government institutions that support the five basic strategies of innovation or 'Five Cs,' which are:

- coupling - taking inventions of new products and processes to the commercialization stage by organizing the relationships between science, technology and markets;
- creating – supporting the making of new discoveries to be commercialized;
- clustering - forming innovation groups to promote diffusion that lead to additional innovation;
- comprehending - having the ability to innovate profitably and constantly; and
- coping - believing in a long-term vision, and having tangible and intangible strategies

These strategies were successfully adopted by Germany in the later half of the nineteenth century and by Japan after the Second World War, while both countries became leaders in international trade. Freeman (2004) also indicates that developing a country's defense technology boosts national morale, political power and promotes indirect economic progress. Ruttan (2006) explains that historically, military institutions have had a major contribution in technology R&D. For example, since WWII, the United States government has invested two thirds of its R&D in military technology, becoming "a source of commercial technology development… implementing the new general-purpose technologies that have emerged from military and defense R&D and defense-related procurement" (p.3).

Cohen et al. (2002) and Feller et al. (2002) posit that the involvement and support of government institutions, through public-funded research, has been essential for technological innovation and the economic development of societies. For example, as part of the Bayh-Dole Act initiatives, the US government created programs such as the Cooperative Research and Development Agreements (CRADAs) and the Engineering Research Centers (ERCs) to foster a closer relation between university and industrial research and to encourage economic development.

2.7 BASIC OR PUBLIC RESEARCH

There are several definitions of basic research. Salter and Martin (2001) define basic research or public research as both, the desire to acquire new knowledge, which is curiosity oriented; and strategic or applied research, which is oriented towards a specific application, although it may not be clear what will be the final product or process.

The OECD Frascati Manual (2015) defines applied research as "original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective" (p.365).

Cohen et al., (2002) add that basic research includes a large amount of applied research and development, and therefore, while it generates ideas for new research and development (R&D) projects, it also contributes to the completion of existing projects. In

addition, Bozeman (2000) indicates that scientific knowledge that is curiosity oriented, used by scientists to further science is called ‘knowledge transfer;’ while scientific knowledge, that is applied or strategic, used by scientists and others in new applications is called ‘technology transfer,’ and “both originate from basic research” (p.642).

As Salter and Martin (2001) indicate, basic research produces spillovers or diffusion of tacit and codified knowledge to industrial R&D, which increase the productivity of firms and industries by adding to the existing body of knowledge. Freeman (2004) and Bozeman (2000) as well posit that transfer of technology is spread mainly through the movement of scientists and technologists, especially for spillovers from high technology university innovations.

According to Cohen and Levinthal (1990) and Rosenberg (1990), firms invest in basic research less for specific results, and more to be able to acquire general knowledge to allow them to develop “useful scientific and technological knowledge” (p.148), or to quickly react and develop further innovations after their competitors develop a major technology. Gibbons et al. (1994), Mazzucato (2013), Feller et al. (2002) and Mowery and Rosenberg (1979) explain that the nature of basic research is changing towards more collaboration and a stronger orientation to application. As Salter and Martin (2001), Feller et al. (2002) and Mansfield (1998) add, this reflects an effort to work closer with industry, and in this way the distinction between public and private knowledge becomes indistinguishable, since some government funding supports collaborative research between universities and industry.

According to Martin et al. (1996), basic research has produced significant scientific knowledge that can be used for the economic benefit of society, although most of the applications of knowledge from basic research and their economic returns or commercial values are indirect and difficult to measure due to its complexity, its incremental characteristics and long run nature of its contributions. Nevertheless, indirect economic benefits are real and have significant effects on economic growth. The authors identify the main types of benefits to economic growth from public research, and these include the following:

1. Increasing the stock of useful knowledge through publications.

2. The important benefit of university graduates to firms and industries.
3. Creating new scientific instrumentation and methodologies such as semiconductors is an output of government basic funded research. Due to the challenges presented in basic research, scientists must design new instruments to deal with particular research problems, which sometimes are adopted by industry and are almost undistinguishable from industry's capital goods (Rosenberg, 1992). These new instruments are used in industrial R&D projects such as drugs, petroleum, chemicals, aerospace, glass, electrical, and computers (Salter and Martin, 2001; Cohen et al., 2002).
4. Forming networks and stimulating social interaction exchanging ideas and conducting research collaboration between firms and public-sector scientists (Faulkner and Senker, 1995).
5. Increasing the capacity for scientific and technological problem solving through university graduates and post-graduates
6. Creating new firms, which differently from the indirect benefits to economic growth, is a direct benefit from public-funded research but of lower impact than the ones described above. Spinoff companies can be created from basic research where academic researchers develop specific projects to be commercialized. As Salter and Martin (2001) add, the most significant number of spinoffs from basic research is in the electronics equipment, but in other sectors this number is insignificant.

In addition, Bozeman (2000) and Cohen et al. (2002) found that firm size is important as well when it comes to the impact of basic research on industry, since more than half of technology transfers initiated by universities are to large firms. Large companies have more experience with federal and university R&D than small firms since access to modern technical facilities at, and information from universities is an incentive for them. Start-up companies are an exception, and mainly those in the pharmaceutical sector. The reason for this may be that start-ups in the drug industry are created from university R&D, or are spinoffs from large firms. Utterback and Suárez (1993) add that the cost of R&D to develop university technologies are high and therefore large firms often acquire start-ups and their technologies.

With regards to the transfer of knowledge and technology from universities to firms, Stankiewicz, (1994) found that academics are not good entrepreneurs and should not be involved in the commercialization process of their discoveries. For example, Bozeman's (2000) study in the United States show that university and government technology-transfer laboratories, such as the Cooperative Research and Development Agreements (CRADAs) and Engineering Research Centers (ERCs), have a small potential for creating startups, and only about 22 percent of technical projects between federal laboratories and industry interactions result in the commercialization of technology.

Differently, Fini et al. (2010) found that a significant number of academic entrepreneurship takes place directly with a wide range of industry sectors and not under intellectual property (IP) agreements. On the other hand, technology transfer offices (TTOs) tend to focus on commercializing discoveries within a small number of academic disciplines which they assume have higher possibilities of commercialization. Instead, the authors suggest that TTOs should expand their activities to include more faculties. In addition, Balconi and Laboranti (2006) and Grimpe and Hussinger (2008) suggest that R&D managers in private firms should also develop informal relationships directly with academic researchers and not only interact with universities TTOs.

2.8 RESEARCH AND DEVELOPMENT (R&D)

The OECD Frascati Manual 2015 Edition defines research and experimental development (R&D) as comprising "creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge" (p.378).

Fagerberg et al. (2008) and Cohen and Levinthal (1990) propose that research and development (R&D) allows both, the creation of new knowledge and the ability to absorb and exploit external knowledge. Cohen and Levinthal (1990) refer to the ability to adopt and adapt knowledge from external sources as *'absorptive capacity,'* and firms with higher levels of absorptive capacity are more proactive in exploiting or creating new opportunities. Similarly, Salter and Martin (2001), Hospers (2005) and Fagerberg et al. (2008) often refer to the capabilities of a country to absorb and commercially exploit new

knowledge as ‘adaptive efficiency.’ This involves interactions between government, a highly educated workforce and institutions at all levels.

Brooks (1994) proposes that science, technology and innovation are all interrelated with two-way interactions between science and technology, being this an indirect innovation process. Therefore, the same as science contributes to technology, technology also contributes to science. For example, scientists often conduct basic research on technological problems identified within industries, such as material science, in order to improve the quality and operation of semiconductors. Basic research has also followed, after radical technological R&D advances, such as the transistor, laser and computer, where “the more radical the invention, the more likely it is to stimulate wholly new areas of basic research….” (Brooks, 1994, p.483). Technological advances in the defense and health care industries have supported both, technological developments and also basic research in related disciplines. In addition, industries that are strongly focused on R&D, such as the biomedical industry, result in a strong basic research by academia and government laboratories. Technology as well has played an important role in measuring “natural phenomena” (Brooks, 1994, p.483), where for example, space technologies such as measuring the electromagnetic spectrum were followed by the interest of basic scientists. As seen earlier, research scientists have developed laboratory instruments which have mostly been improved, commercialized and sold to industry for further research. However, these improved instruments are then adopted back by scientists improving their research performance. This for instance took place with huge government investments in US defense R&D, which adopted and improved these instruments during the first two decades after WWII.

2.9 INTELLECTUAL PROPERTY (IP)

2.9.1 Patenting and licensing

> The fact is that voluntary dissemination of technology by its proprietors does occur and has been going on for well over a century, is substantial in scale and appears to have been growing since its early beginnings. The basic reason, of course is that it can be a very profitable activity (Baumol, 2003, p.437).

As Baumol (2003) explains, in the nineteenth century, there was an increase of inventions and trade in patent rights through a patent system that created a strong incentive for companies to be involved in the technology market. Macdonald (2002) describes that in 1982 the Federal Court Improvements Act was established in the US, which created the Court of Appeals for the Federal Circuit (CAFC), designed to standardize patent law across the US. The enactment of the CAFC resulted in an increase of 78 percent in patents awarded in the US between 1983 and 1995.

There are two views with regards to patents. One view is that of scholars such as Cohen et al (2002) and Macdonald (2002). Cohen et al (2002) argue that patenting and licensing as a way to encourage commercialization have had a low influence or importance on industrial R&D, and have been useful for technology transfer only on a small number of industries such as pharmaceuticals. In high-technology as well the influence of patents and licenses on technology transfer has been average. Patents produce insignificant results, since they are important only in a few industries, while they provide insignificant information to society when compared to other sources such as "venture capital, entrepreneurial spirit, firm size, R&D expenditure, education of chief executives, and so on" (p.3). On the other hand, there is the view of authors such as Baumol (2003) who considers patents as one factor among others in the production of inventions, and that are designed to promote the dissemination of technology; and Jaffe (2003), who views patents as also, one factor among many others, that probably contributes to innovation.

According to Macdonald (2002), the patent system is based on the linear model myth of innovation, starting from basic or applied research to invention, and to innovation; and on the myth that powerful technology can bring immediate prosperity to a company, industry and the economy. Macdonald (2002) discusses that innovations can happen without invention, and invention does not always produce innovation. An example of innovation without significant R&D spending and patents was the Japanese innovation success, which proved that innovation must not start with R&D and invention. Macdonald further explains that a reason for patenting in the US was to keep US technology within the country. However, in 1989 foreign companies owned 47 percent of US patents - versus 25 percent in 1947, an example being Japanese companies that patent

extensively in the US. Alternatively, Jaffe (2000) argues that there was an increase in foreign patents before the 1980s, but the US has not been a more important patenting destination for foreigners after the 1980s.

Macdonald (2002) discusses that today, instead of patents turning invention to innovation companies see patents as corporate assets that do not offer more protection than the one they can afford financially in case of litigation. A differently view is offered by Baumol (2003). He explains that patents are important in the dissemination of technology and patent laws were designed to stimulate invention and dissemination of knowledge. The main role of patents is often to ensure that inventors can be compensated for the use of their technologies by others. In this way companies develop inventions created by other firms, a process that encourages invention, innovation and its dissemination.

Baumol (2003) states that some companies are better at innovating while others are better at taking a product, licensing it, and improving it. Some firms are good inventors that license or sell their inventions to firms that are successful users in that they develop the inventions into technologies and use them. Baumol (2003) further argues that while R&D is a costly investment, licensing can offer profits to companies that license their inventions, and licensing results in further development and improvement of original inventions. Thus, patent laws give the high technology sector a competitive edge. High-tech firms focus on applied research which Baumol (2003) calls the “D” of R&D. The development process of R&D is the one that can mostly contribute to productivity and growth. Corporations focusing on applied research have made important contributions to economic growth and productivity by creating products that are reliable, practical and user friendly, for example in the computer industry.

In addition, Macdonald (2002) suggests that companies use patents for profit, by negotiating licensing agreements, since royalties bring in more profits than products. Jaffe’s (2000) arguments agree with those of Macdonald’s, in that firms use patents in other ways than innovating, but he explains that for large corporations, such as the semiconductor sector, it is impossible to make products or processes without incorporating technologies from other companies through cross-licensing, and everyone needs cross-licensing agreements in order to avoid infringement suits (Jaffe, 2000).

Macdonald (2002) indicates that the patent system serves large corporations, especially the pharmaceutical industry, which uses patents for strategic reasons such as "Patent stacking, blocking…fencing and surrounding, by patent harvesting and ramping up, by portfolio and network arrangements, and other devices…." (pp.11-12), and not for innovation. On the other hand, Cohen et al. (2002) explain that patents and licenses have been especially important for pharmaceuticals, as a way to transfer their information from public research to industry, since patents more effectively protect inventions in drugs than in other manufacturing industries. Baumol (2003) views the improvement of products and processes as "an inventive act in itself" (p.436), and which contributes to productivity surpassing original inventions. He posits that if companies around the world would hoard intellectual property (IP), countries would produce "partially obsolete products" (p.436); and therefore, sharing patents results in better products (p.436) and in higher productivity.

Macdonald (2002) suggests that most small firms cannot afford to file for patents, since patenting is expensive. Differently, Jaffe (2000) indicates that the patent increase in the US is mainly due to new small firms, such as chip design companies (fab-less), sub-contracting their manufacturing, and that need to protect their technology.

Jaffe (2000) proposes that the patent policy changes were important, however there are only some conclusions on the resulting effects on technological innovation, and increase in patents since the mid 1980s. The reasons for this being that there were many changes in the innovation environment from the 1970s to the 1990s, and therefore it is difficult to differentiate between such innovation changes and the effects of the patenting policies. Due to these innovation changes taking place, while patents being only one of those changes, they may have only a partial or narrow effect on innovation. For example, since the 1990s there was an increase in award of patents mainly because of an increase in R&D expenditure, which started in the later half of the 1970s. R&D funded by the US federal government had declined in the 1970s, but in the 1990s it was 30 percent of all R&D expenditure in the country, and the university sector accounted for 60 percent of all research expenditure. Therefore, even without changes to the patent system in 1982 there would have been an increase in patents.

Jaffe (2000) concludes that there is little evidence that the rise in patenting resulted directly from the strengthening of IP protection in the 1980s, or that it had a strong impact on innovation, since the combination of environmental factors could have also resulted in more patents even without the new patenting laws. Nevertheless, the stronger patent system probably supported these incentives which may have also extended the R&D boom from the 1970s to 1990s. As Jaffe points out, the "apparent increase in research expenditure and the apparent signs of technological progress all around us should make us cautious about concluding that the policy changes had had no effect" (p.555).

2.9.2 University patenting

Bozeman (2000) explains that in 1980 the United States Congress passed the Bayh-Dole Act to encourage the commercialization of university research and to be used by industry, a trend that many other countries followed. Sampat et al. (2003) indicate that the Bayh-Dole Act of 1980 allowed universities to retain patent rights from government funding academic research, therefore encouraging university entry into patenting and licensing, and to license these patents on an exclusive and non-exclusive basis. Before the passage of the Act, universities had to negotiate on a case-by-case basis with the Institutional Patent Arrangements (IPAs) office.

Jaffe (2000) discusses that between 1970 and 1997 there was a significant increase in university patenting, and he describes some university patenting developments:

- Universities' R&D spending increased between 1970 and 1990, and so did their patents, from 30 in 1965, to more than 400 in 1997. The reason being that more universities engaged in patenting.
- However, university patenting had also increased during the 1970s and early 1980s.
- Although universities had increased their patenting in all technological areas, their patenting was concentrated mostly in the health (life) sciences technologies.
- The increase in university patenting is also related to a lower quality of its patents, since during the first five years (1980 to 1985), university patents were not cited in future patents.

- The cause of increase in university patenting was not only because of the implementation of Bayh-Dole, but also reflected an increase in industry research funding, in applied research, and in the growth of universities' TTOs. However, as Jaffe (2000) suggests, such large increases would have probably not happened without the Bayh-Dole patenting freedom. Furthermore, studies show economic benefits of technology transfer from universities to private industry, such as MIT (Shane, 1999) and Stanford (Jaffe, 2000).

Alternatively, Cohen et al. (2002) indicate that university patenting and licensing as a way to encourage commercialization has had a low influence or importance on industrial R&D, and has been useful for technology transfer only on a small number of industries such as the pharmaceutical industry. It has also been average in high-technology sectors such as communications equipment and aerospace.

Sampat et al. (2003) found in their study that university patents take longer to be granted than industry patents for applications after 1982. Some of the possible reasons for this may be the tendency of US universities to patent "more 'scientific' rather than 'technological' research results" (p.1387, footnote 16) – this is a different view from Jaffe(2000) above, who indicates an increase in applied research; or that publications and conferences are disseminated slower due to university interest in patenting and in keeping their research results secret, before filing patent applications, which could slow the innovation of academic knowledge - a fact that Macdonald (2002) also supports.

Macdonald (2002) argues that average patents never had much value with regards to innovation. For example, studies done in the US in the 1990s show that only one in 100 patents (one percent) produce royalty revenues. Furthermore, about 60 percent of US universities and 50 percent of UK universities do not have enough royalty revenues to cover the costs of their TTOs. In addition, profits from US university patents do not exceed their cost of patenting, while in the UK, universities patent in order to "improve their research credibility" (p.18).

Macdonald (2002) further points out that before the new patent regulations established in the 1980s, patents always had an important function and were counted to identify innovations and new technologies and their relations to R&D expenditure. Differently, today patents are evaluated according to their financial or royalties'

performance, similar to that of company's stock performance. As well, in the past companies also found a practical and sensible way to resolve patent problems, for example in the communications industry, where innovations are built on each other, so were patents, and companies agreed to use each others. However, today these arrangements do not take place. As well, ideas resulting from public research spilled over through academic networking and conferences, while today researchers are restricted in this sense. In this way, ideas that were public in the past today are private property.

Notwithstanding the issues above, Jaffe (2000) argues that although there have been many events that influenced an increase in inventions, there is also evidence that transfer of technology from universities to industry has resulted in economic benefits and these have been documented. TTOs have licensed university technology, at the proof or prototype stage, to companies that are investing heavily in developing new products and processes using university technology, which would have never been commercialized without exclusive licenses. In addition, the assistance of university inventors is essential during the development process, and "patent royalties play an important role in inducing this cooperation from the academics" (p.543). Jaffe (2000) concludes that although difficult to measure, patent protection extension to publicly funded research does seem to have an important impact on increasing technology transfer from academia.

2.10 GREEN TECHNOLOGY INNOVATION

An important characteristic of the 5G innovation model, mentioned earlier, is the increasing concern over the degradation of the environment and related regulations, resulting in the implementation of environmental sustainability as a corporate strategy (Rothwell, 1994).

2.10.1 Innovation in the fossil fuel industry

In a more recent study that examines the origins and processes that create technological progress in the oil and gas industry, Thurston and Stewart (2005) found that market/demand pull and technology push happen in a cultural context, meaning that

innovation is influenced by issues such as entrepreneurial spirit, access to capital, and legal protection of intellectual property. With regards to technology push, sciences and technologies created outside of the petroleum industry can generate progress within the industry. For example, innovations in information technology that have been implemented by the industry have resulted in its technological progress.

Thurston and Stewart (2005) also found that the speed of diffusion of new technologies seems to follow both, economic demand and/or technology push as it happened in the petroleum industry. However, it seems that innovations/new products have emerged when there has been abundant technology supply rather than when there has been strong demand. For example, in 1956 there was demand pull and also important innovations in electronics that happened in the late 1940s, creating a "wave of E&D (exploration and development) technology progress" (p.1113). In 1962 the petroleum industry spiked again with an immediate earlier IT innovation peak in seismic and computerized technology. Other such example of IT spending growth and innovations, during weak market demands, followed by E&D progress took place in 1972. However, alternatively, in 1984 there was a strong demand/market pull for innovation, creating an abundance of "new processes and products" (p.1113).

2.10.2 Innovating in Developing Economies

Hart and Christensen (2002) explain that green technologies can have a higher success rate when these are marketed initially in developing regions which are more open to technologies that address social environmental issues, than in the more mature saturated markets. In mature markets, companies with new technologies must deal with established competitors with wasteful, inexpensive and well-established technologies, facing very difficult obstacles to succeed. The developing market, due to its huge numbers, can also be a very attractive alternative. Hart and Christensen (2002) describe the developing regions as "the most exciting growth markets of the future" (pp.51-52).

The authors further propose that the concept of *'creative creation,'* is a step before Schumpeter's 'creative destruction.' Hospers (2005) points out that creative destruction refers to the constant evolution of the economic system through disruptive innovative activity that destroys old economic systems and creates new ones. Hart and Christensen

(2002) add that creative creation is the result of a disruptive innovation, where the new product is not as good as the ones that exist in the mainstream global markets, and therefore can be developed in developing markets. In an earlier article, Hart and Milstein (1999) posit that firms must develop technologies, products and services targeted specifically to the needs of developing markets, which they call “survival economies” (pp. 26, 29-30); technologies must be adapted to this market and not just transplanted from the more developed markets. This concept is also supported by Russo (2003), who same as Hart and Milstein (1999), indicates that there has been a fast development of alternative technologies in developing markets where there may be less resistance than in mature markets. Examples are small-scale wind, solar and hydro-generators, and other sustainable industries that are growing in off-grid locations in developing economies.

2.10.3 Institutional Champions

Institutional Entrepreneurs or Champions have also had an important role in the innovation process. Espinoza and Vredenburg (2010a) recognize the contribution of individual actors to innovation in two Latin American countries, Costa Rica and Ecuador. These are institutional entrepreneurs or champions who played a key role in the start-up of the wind power industry and the reconfiguration of the power sector in their countries. They achieved this through their reputation, political influence, and by building networks that supported the development of the renewable energy industry. As the authors propose, in order for this industry to be legitimate the legitimacy of its champions or visionary leaders must first exist.

2.10.4 Green Technology Markets

According to Day and Schoemaker (2011) the global market for green energy technologies, such as wind, solar energy and biofuels, is expected to reach $315 billion by 2018. However, the green technology market faces many uncertainties that are beyond the control of any entrepreneur and investor. The authors suggest 10 strategic lessons based on past experiences to help companies succeed in their development of green

technologies in the energy sector in order to survive long-term uncertainty and setbacks such as recessions, and to stay ahead of the competition.

These lessons examine mainly the human side of innovation rather than the technology itself. Day and Schoemaker (2011) suggest that 80 percent of green technology companies disappeared in the last bubble burst after the euphoria of 2005-2007. This means that most companies lose their market war since they do not have the knowledge and the right strategies to survive and win the difficult market battle which all firms, and especially those with new green technologies, must face. Some of these strategic lessons include**:**

1. **Correct timing** to enter the market, where timing issues are complex and difficult to measure, but are essential for market survival and leadership.
2. **Accept uncertainty and maintain options** without trying to control and predict risk, while learning to make adjustments during unexpected situations. The authors suggest several techniques to successfully manage uncertainty, and one of them is 'Scenario Thinking' (p.41), where managers have different possibilities to make adjustments when faced with unforeseen events.
3. **Anticipate where the money will be** by having first a vision of the future and then designing a strategy to protect market positions. Success in emerging technologies depends on "anticipation, keeping an eye on the market and on the competition that will shape its trajectory" (p.42).
4. **Become ambidextrous** by having 'vigilant' (p.44) leaders who watch the periphery and are able to identify early warnings of trouble or opportunity, respond quickly, be proactive instead of reactive, and be able to deal with chaos. Some ambidextrous companies also support start-ups and risky projects as part of their operations. On the other hand, operational managers, versus ambidextrous leaders, are good at execution and short-term efficiency but cannot deal with chaos.
5. **Think beyond industry boundaries** by being open minded and thinking outside the box, since often technology innovations get adopted by different industries. An example is ethanol, which can be made from sugarcane, sugar beets and switchgrass.

Another example is the biosciences industry whose innovations are applied in national security, climate change and green technologies.

6. **Collaborate and share for joint gain** by establishing strategic alliances with industry associations and between companies in order to share the risks and rewards of investments, and "to develop common positions." (p.39). However, different countries and cultures have different positions and respond differently when it comes to adopting or resisting changes once a market opportunity is identified. For example some countries and cultures are willing to move to a low-carbon economy, while others, such as oil and gas producers, establish barriers against such initiatives.

Espinoza and Vredenburg (2010a; 2010b) present this last trend in two studies on the development of renewable energy as described below.

2.10.5 Emergence of wind energy industry in four jurisdictions

Espinoza and Vredenburg (20010a; 2010b) conducted two studies on the emergence of wind energy industry in two developing countries, Costa Rica and Ecuador, and in a developed country and a jurisdiction, Denmark and Alberta. The economies of Ecuador and Alberta are based on fossil fuels while Costa Rica has large hydropower projects, and Denmark has developed mainly renewable energy. The goal of these studies was to find out if there were other factors that could also contribute to the development of the wind power industry in these economies, their differences and similarities.

The studies showed, among other findings, that the development of energy renewables partially depends on how the countries react to energy crises. Espinoza and Vredenburg (2010a) found that the most important issue for developing a wind power industry for Costa Rica and Ecuador was to ensure the power supply in their countries with additional sources; while a secondary reason was the improvement of the environment. Differently, Alberta and Denmark considered environmental issues as important as economic factors, and both see climate change as a global threat that could weaken their business, which is also a global concern addressed by multinationals. In addition, Espinoza and Vredenburg's (2010b) research identified that a well established

oil industry in Ecuador and Alberta was a significant barrier to the growth of wind energy in both jurisdictions.

2.11 CONCLUSION

The concept of innovation and entrepreneurship as stimulating economic growth, development and social change, was first proposed by Schumpeter in the early twentieth century. This phenomenon takes place within capitalist societies through the ongoing evolution or "creative destruction" of economic structures; and according to the neo-Schumpeterians, creating higher standards of living. This evolution, as described by neo-Schumpeterians, results from radical technological innovations stimulated by many incremental changes and periods of adaptation which drive growth. This technical progress takes place through the accumulation of knowledge within entrepreneurial and innovative firms, including the attainment of tacit knowledge and skills acquired through formal training and in learning by doing, while involving a high degree of risk.

The neo-Schumpeterians expanded Schumpeter's concepts, studying the Systems of Innovation Theory concept in the mid twentieth century, including the processes of innovation, diffusion, and the role of institutional relationships within countries, creating national innovation systems. List was the first to address the concept of a national innovation system in the mid nineteenth century, proposing that nations need "mental capital," meaning access to and development of science and technology, and the support of government policies in order to achieve economic growth, as it happened in Britain and then in Germany. There are several views regarding government policy interventions, and one of them is that for a country to achieve economic growth government support of specific industry sectors is needed. This interventionist approach was taken by the British government during the country's first strong economic development.

Each country has its own national innovation system and technologies, based on its history which creates its own institutional characteristics; where also transfer of technology takes place, creating economic growth as well as economic gaps among countries. As seen with Britain and the US, during their first strong economic growth, both had capitalist economies, cultural connection of government and industry with

science, technology and entrepreneurship, and with naval and military power. The internal characteristics of firms, such as a highly educated workforce, a flat and flexible organization and small project teams are the ones that facilitate innovation. Furthermore, countries that have developed their own defense technologies indirectly create economic growth, also as it happened in Britain and the US.

Different views, positive and negative, are also presented on the patenting system. The negative positions argue that patenting does not work, since it is wrongly based on a linear model of innovation; on the wrong assumption that powerful technology can result in immediate prosperity; and on studies showing that university patenting and licensing are not profitable. Other views look at patents as one of the several factors that have contributed to technology transfer, but that have a major role in the increase in technology transfer from academia to industry. The belief in the concept of technology-push or linear innovation, except for the most radical global innovations, has gone through several stages where today both demand and supply are considered as necessarily interconnected factors for innovation.

Basic or public research has also experienced changes towards more collaboration with industry, often with government financial support, becoming more application oriented, resulting in technology transfer from universities to industry. Nevertheless, the commercial returns of basic research and its effect on economic progress are mainly indirect and although difficult to measure these have been identified by some authors. Alternatively, studies on direct technology transfer, such as the creation of firms, have resulted in lower economic benefits due to high implementation costs and their high failure rates. Nevertheless, the support of government through public-funded research has been vital for technological innovation and economic development of societies.

Research and Development (R&D), further develops basic and applied research and also creates ‘absorptive capacity’ within firms becoming more innovative. R&D also develops the capabilities or ‘adaptive efficiency’ of a country to become more innovative through interactions among its institutions, and to commercialize products.

The literature also suggests that firms with new green technologies have a higher probability of success by entering developing markets than the more saturated developed markets and provides some strategies to survive long term uncertainty and crises.

Scholars also identified different reasons for countries developing renewable energy. For example, two developed countries studied consider the environment and climate change of utmost importance; while two developing nations ensure their power supply with additional renewable energy sources, while improving the environment is secondary. The chapter also indicates that institutional champions in emerging markets in Latin America have played an important role in the development of renewable energy, giving it legitimacy through their position of power and vision.

CHAPTER 3: NATIONAL AND POLITICAL HISTORY- DEVELOPMENT OF ISRAELI SCIENCE AND TECHNOLOGY

3.1 INTRODUCTION

The Jewish people lived and flourished in what was then Palestine before the foundation of the State of Israel in 1948. This chapter begins with a short description of the British Mandate between 1918 and 1948, when the Jewish community established its three top universities and the Israeli Innovation System was born, based on the development of science and technology (S&T). It then addresses Israel's 'Heroic Period' from 1948 to 1973, with an exceptional economic growth and strong recognition of S&T; and also by the implementation of policies and programs that opened the doors to the country's innovation and economic growth in the 1990s. The chapter then examines the period between the 1970s and 1980s, a time of economic stagnation. During this time many scientists and engineers moved from the military to the civilian industries, transferring their knowledge as well, and who may have also participated in Israel`s high-tech developments in the 1990s. The period of the 1990s and 2000s is covered next, with the arrival of a large wave of highly educated immigrants from the former Soviet Union; with an increasing number of R&D programs implemented by the government; the creation of a large number of startups and a strong VC industry.

3.2 THE BRITISH MANDATE: 1918 - 1948

Israel's strong focus on science, technology and higher education started in the 1920s during the British Mandate. During the British Mandate, between 1918 and 1948, the Israeli Innovation System was born with the Jewish immigration, initially from Eastern Europe and then from Arab countries to what was then Palestine. As Teubal (1983) indicates, "The emphasis on science and research is deeply rooted in the history of Israel, since the arrival of the first immigrants from Eastern Europe in the last quarter of the nineteenth century" (p.172).

In 1948, when the State of Israel was established, there were 650,000 Jewish people living in Yishuvim (Jewish Virtual Library, 2017, Immigration to Israel: Aliya Bet 1939-1948); and as Levi-Faur (1998) indicates, the Yishuv's economic growth was miraculous until 1973.[4] During this period, Levi-Faur (1998) adds, the Israeli people had a semi-sovereign economy administered largely by political institutions. [5] During this time, as Senor and Singer (2009, pp. 211-212) explain, they also created the first modern scientific research and technological development institutions, which are Israel's top universities: the Hebrew University of Jerusalem (HU) in 1925; the Israel Institute of Technology (Technion) in 1925; and the Weizmann Institute of Science in 1934, where academic freedom was based on Western tradition. Teubal (1983) discusses that through this period the focus was on applied research, on solving existing problems faced by Israel, such as agricultural research. However, there was no industrial research, except for the Dead Sea Works that privately developed the potash and bromine industry.

3.3 THE "HEROIC PERIOD OF ISRAEL'S STATEHOOD"- 1948 - 1973

3.3.1 Economic growth

Levi-Faur (1998) discusses that Israel's economic growth during its first 25 years of existence was "miraculous" *(*p.65), and took place under "an autonomous and interventionist state as well as by strategies of governed development (in the sphere of finance, investment and international trade)" (p.65). Furthermore, he argues that it is unusual for countries to develop successfully, and that the Israeli political-economy case could be a "developmental state model" (p.65) for developing countries.

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[4] Halamish (2009) explains the concept of the Yishuv (Yishuvim in plural).

[5] Such as the Histadrut, as described by Halamish (2009), established in the late 1920s as a cross country labour organization with several functions, such as a trade union and employer; job placement agency (lishkat avoda), involved in settlement activity, had its own economic institutions (a bank, an insurance company and a pension fund); health care provider; had its own education system, a daily newspaper, a publishing house and a theatre group where it conducted cultural activities. For many years, the Histadrut was in charge of the military arm – the Hagana; as well as a parliament, Asefat ha-Nivharim (the 'National Assembly'); an executive organ, ha-Va'ad ha-Le'umi (the national council or committee).

Avidor (2011) and Levi-Faur (1998) further posit that Israel declared independence on May 18, 1948, at a time when Jewish refugees from the WWII Holocaust were immigrating, and the country was under constant threat of war and terrorism. The economy was centralized until 1979, and it was based on agriculture, housing development, transportation and telecommunication networks. During this period, the Israeli government controlled the country's investments in order for these to finance its budget deficits and implemented austerity measures as well.

Levi-Faur (1998) explains that in the 1950s and 1960s Israel had one of the highest economic growths in the world, maybe only after Japan. Teubal (1993) also calls this period the "heroic period of Israel's statehood" (p.478), a time when government officials were extraordinary individuals and leaders; to whom Espinoza and Vredenburg (2010a; 2010b) would refer as Israel's bureaucratic champions.

Avidor (2011) points out that during these years Israel had low unemployment. Levi-Faur (1998) adds that Israelis in general enjoyed freedom and welfare conditions similar to those of developed countries. Between 1953 and 1973, the country had strong growths in exports, in its annual gross national product (GNP), in its GNP per capita, and annual gross domestic product (GDP). Avidor (2011) further explains that Israel achieved this with a shortage of natural resources; having to import most of its energy and raw materials; a small domestic market, the Arab boycott, significant military expenses, and with the absorption of immigrants and refugees who doubled Israel's population in five years, requiring food, education, housing and welfare. Nevertheless, the country's economy grew with a fairly narrow income inequality, where the income ratio of the top 20 percent of households to the bottom 40 percent was 2.22, versus 4.84 in other development countries, while it was also committed to democracy. In addition, as a result of the Arab boycott the Israeli economy was disconnected from its regional economies; did not benefit from spillover effects, and most multinational companies were not willing to invest in Israel.

Avidor (2011) explains that although one of the government's programs encouraged multinational firms to conduct R&D in Israel through a favourable tax treatment; and as Breznitz (2007b, p.55) adds, the same as in Ireland; however from 1950 to1971 only 20 US-based multinationals invested in Israel, while 59 multinationals invested in Taiwan;

37 in South Korea, and 375 in Brazil. Breznitz (2007b) calls this model presented by Levi-Faur, the “old developmental-state” theory (p.42). As well, in the1960s, Israel’s R&D was conducted mainly by the academic and defense sectors. In 1965, Israel’s total R&D expenditure as a percentage of GDP was under one percent. Out of 10,000 employees, 10 were scientists and engineers, lower than in any Organization for Economic Cooperation and Development (OECD) country (p.42).

Some of Israel’s unique domestic conditions in which its economy developed, as explained by Levi-Faur (1998), was the fact that Israel is home of ancient people with a strong national identity - a trait that is different from other developing countries that do not have a shared identity to build a nation. As well, Breznitz (2007b) further explains that Israel followed its economic development under a national ideology expressed by Prime Minister’s David Ben Gurion in his concept of ‘Mamlachtiut’ or etatism. This “National Ideology” gave a very high rank to Science and Technology (S&T), and allowed scientists to have an easy access to political leaders (p.44).

3.3.2 Role of government

According to Shefer and Frenkel (2005), investment in R&D generates innovation, which in turn creates economic growth. Therefore, in order to innovate, firms must invest in R&D. Trajtenberg (2005) argues that firms investing in knowledge creation do not receive benefits from spillovers of their R&D, but “Social returns (to the country) from innovations may be far larger than private returns” (p.8). Furthermore, R&D largely surpasses returns from other investments, such as physical capital investments and therefore the government should be involved in R&D.

Breznitz (2007b) discusses that although Israel was a social democratic country, its Socialist Labour Party, which ruled from 1968 until 1977, aggressively worked on developing a strong private industry while implementing policies to limit the power of public and semi-public sectors (pp.197-198), and pushing for the establishment of a “strong capitalist industry led by private entrepreneurs” (p.46). However, Government bureaucrats also had an influence on the development of human capital. For example, in the 1960s there was an effort to “professionalize” the government by hiring graduates from the Hebrew University Economics Department into the Israeli bureaucracy, some of

them even before graduating (pp.45-46). Another example is that of the Ministry of Finance which implemented a computerized tax assessment program in 1960, and the users later became the first software industry entrepreneurs (p.49).

Breznitz (2007b) argues that due to the high regard towards science and scholarly activities, during this period as well, Israel's first four Presidents were renowned scientists or academics (p.217, footnote 21). For example Ephraim Katzir was a renowned Israeli Scientist, the head scientist of the Ministry of Defense and a University professor. Ephraim Katzir later became Israel's fourth President from 1973-1978 (Israel Ministry of Foreign Affairs, 2013a).

The economic development of the country was the main objective of Israeli government officials, it was their national priority, and they achieved legitimacy and social support due to the country's excellent economic growth. Through their high autonomy, government officials were also able to make difficult decisions. For example, Prime Minister Ben-Gurion signed the reparation agreement with Germany despite opposition in Israel. Levi-Faur (1998) argues that during this period Israel invested heavily in education, increasing productivity in order to conquer its military and economic vulnerability.

3.3.3 Universities' Technology Transfer Offices (TTOs) and research institutions

Breznitz (2007b) describes that until the late 1970s, one of Israel's high national priorities was to develop the R&D capabilities of academic institutions, which was sometimes an even higher priority than its national security and the development of the defense industry. For example, a department of RAFAEL Advanced Defense Systems Ltd. (Hebrew acronym for Authority for the Development of Armaments) was transferred to the Weizmann Institute, against RAFAEL'S wishes, in order to improve the national academic research infrastructure (p.199). Kalman (2008) further adds that IBM opened its first R&D centre outside of the United States on the Technion Campus in 1972.

As Breznitz (2007a) indicates, in 1947, before the State of Israel was founded, the Advisory Committee of the Applied Mathematics Department of the Weizmann Institute, comprised of Albert Einstein, Hans Kramer, Robert Oppenheimer, John Von Neumann

and Abraham Pais recommended that the Institute build an electronic digital computer. But in 1948, due to the independence war and security threats, the Israeli IT followed a different development.

Teubal (1983) and Senor and Singer (2009, p.211) discuss that in 1949 the Research Council was established, headed by Prime Minister David Ben-Gurion, to expand scientific work in Israel, and in the 1950s, when Israel's population was approximately two million, the government created several research labs such as the Fibers Institute, to support the textile industry, employing over 500,000 Jewish Refugees from Arab countries, and the National Physics Lab. The government founded as well two more universities, the Tel Aviv (in1956) and Bar Ilan (in 1955) Universities. In the 1960s the government founded the University of Haifa (in 1963), and the Ben-Gurion University of the Negev (in 1969); and as Teubal (1983) adds, the National Council for Research and Development (NCRD) and the Israel Academy of Science .

According to Breznitz (2007a), Israeli universities were the ones that developed Israel's competitive advantage since 1968, when the government implemented its industrial R&D policy program, and since then Israeli universities have had the highest GDP percentage of academic publications in the world. Senor and Singer (2009, p.211) further indicate that Israeli research institutions were the first worldwide to commercialize academic inventions. The Weizmann Institute founded Yeda Research and Development Company Ltd. (Yeda means 'knowledge' in Hebrew), its Transfer of Technology Office (TTO) in 1959 to commercialize its discoveries; and the Hebrew University established Yissum (implementation in Hebrew), its TTO in 1964.

3.3.4 Industrial research and development (R&D)

As indicated earlier, until the mid 1960s there was almost no private R&D conducted in Israel, and there was no government support either. Teubal (1983) explains that the promotion of industrial R&D in Israel started in 1967 with the Industrial Research Fund, under the Ministry of Commerce and Industry, in order to encourage and subsidize industrial R&D. This initiative was strongly supported by the Socialist Labour party ruling until 1977, as mentioned earlier. Teubal (1983) argues that the government had two main reasons to support private R&D starting in the late 1960s. First, the main

institutions and the arrangements that connected scientific research and technology were well established. Israeli scientists and engineers who had conducted university research in agriculture and defense could also work in private industry R&D and develop products for the private market. Second, the Israeli economy needed more income from exports, since Israel was having increased lower cost competition in the export of its traditional industries such as textiles and oranges. In order to achieve this there was a need to increase scientific and technological products by increasing R&D. An alternative was to have larger plants in traditional industries, but this was risky since the Israeli market was small.

Teubal (1983) further discusses that the reason the government, since the late 1960s, did not support industrial R&D through universities and government labs was that the focus would have been on the goals and requirements of research institutions, and on technological or scientific novelty or originality instead of promoting high-technology industries focusing on commercial prospects. The government avoided an excessive academic approach to R&D, as found in semi-autonomous government labs, and instead supported R&D in private firms' labs.

Teubal (1983), Teubal (2012b) and Breznitz, (2007b, p. 84) argue that the Industrial Research Fund provided horizontal funding where every project approved received a flat 50 percent subsidy on research expenditures. For example, an approved project in textiles would receive proportionally the same 50 percent funding for R&D as a project in electronics. Funding was neutral, regarding sectors and technologies by not giving preference to any type of industry, technology or product class, while there was bias towards R&D projects that would create exports. As indicated by Teubal (1983), this specific system for promoting industrial technology was different from those implemented by several other countries; and according to Breznitz (2007b) Israel was the first country in the world to implement horizontal and neutral funding policies (p.57).

Breznitz (2007b) explains that in 1966 the government formed the Katchalski Committee,[6] comprised of scientists and government officials, which "formulated Israel's

[6] Sometimes written as the Kachalsky Committee, the Katchalsky brothers Efraim and Aharon were co-founders of RAFAEL Advanced Defense Systems, and Efraim Katchalski (Katzir), a renowned scientist later became President of Israel (Breznitz, 2007b, p.48, p.217 note 21).

science-based policy at the end of the 1960s" (p.48). In 1968 the Committee concluded that due to Israel's lack of natural resources, the country needed to invest in science and technology in order to develop its economy, making therefore a strategic decision to build a science-based industry. Teubal (983) and Breznitz (2007b, p.51) further mention that one of the most important recommendations of the Katchalski Committee was to create offices of chief scientists within ministries to coordinate their activities in research and technology and to encourage applied research; and as Teubal, (1983) adds, that the Office of the Chief Scientist should be under the Ministry of Industry, Trade and Labour (Ministry of Economy and Industry, n.d.).[7] Avidor, 2011points out that as a result of this decision, in 1969 MOITAL created the Office of the Chief Scientist (OCS) to manage applied research that was conducted already in different government sectors, and to stimulate industrial R&D. To achieve this, Teubal (1983) mentions that the OCS provided supporting grants for companies performing R&D, most of them small, and nominated Yitzhak Yaakov as first OCS Chief Scientist from 1969 to 1977.

Breznitz (2007b) describes that under Yitzhak Yaakov's leadership the OCS became almost an independent organization. Yaakov had a military background, where from 1955 to 1973 he had been head of the military R&D division of armament development and of defense R&D (pp. 53-54); he had World Bank connections; and was highly educated - an engineer, with an advanced technology management degree from MIT, and was "ideologically opposed to public research institutions" (p. 199). Yaakov believed that the government could not guide the industry and that successful ideas come from the market and from the people. The ideology of the OCS was that Israel's economic future was in industrial R&D. He cut the budget to public research institutes by 70 percent and financed industry directly (pp. 55, 199).

Breznitz (2007b) describes that during this period, high government positions were often filled by former high military ranking officials. For example, Haim Bar-Lev was Minister of Trade and Industry and former chief of staff in the military. Bar-Lev hired Itzhak Yaakov as first full time Chief Scientist while a large percentage of OCS staff were recruited from the private industry (p.57). During this time as well, industrial R&D

[7] The Ministry of Industry, Trade and Labour changed its name several times, and now its name is Ministry of Economy and Industry (Ministry of Economy and Industry, n.d.d).

was considered very risky and no companies wanted to do it. Yaakov sought to make a change in paradigm, “to create an R&D dynamic” (Breznitz, 2007b, p. 56). To achieve this, Yaakov became actively engaged in the industry by visiting companies across the country and encouraging them to submit R&D proposals. He also approved 70 million lire in proposals in 1974, three and a half times from those in 1973 (Breznitz, 2007b, pp. 55-56; 2007a).

Although according to application forms for Industrial Research Fund projects had to be developed for exports, as Teubal (1983) explains, many projects that did not develop exports received the 50 percent grants anyway. The reason for this being that in its initial years the Chief Scientist was more interested in increasing the number of firms engaged in R&D than in their export commitment. Similarly, Breznitz (2007b) adds that over time the market began to specialize in industries, being the market and not the government that selected the areas of technical specialization, such as IT mainly in telecommunications and medical equipment (p.57).

Breznitz (2007b) indicates that Yaakov also granted to science-based companies the category and benefits of “approved factory” (p.55) under the law for encouragement of capital investment, which also funded plants in Israel’s peripheral areas. Also, as Teubal (1983) indicates, locating the OCS in the Ministry of Commerce and Industry resulted in a commercial focus rather than in scientific originality; while scientific originality was considered only if the projects had commercial projections.

Trajtenberg (2005) argues that notwithstanding the neutrality of R&D policies, the OCS provided support almost entirely to product innovations than to process innovations resulting in an unintended bias towards ICT. Seventy nine percent of Industrial R&D went to ICT while the average for OECD countries was 21 percent. The OCS did not openly exclude process and service sectors, but rather this was a “natural selection process,” towards electronics, communications, computerized equipment, and other ICT components. However, Breznitz (2007b) adds that when Yaakov left the OCS, the organization experienced some serious problems, mainly since it was not based in law; it was highly bureaucratic and it supported a small number of high-tech industrial groups with political influence (p.63).

As well, in the late 1960s and early 1970s, Breznitz (2007a) explains that there were some successful global Israeli hardware companies, a few data processing centres and IT units in military offices and in large organizations, but there was no software industry. However, local demand for IT was created by the rapid development of defense R&D and its graduates from technological units, and by an increase in IT skills by university graduates, as Prof. Lavie (Personal communication, July 16, 2014) pointed out, the Technion opened its faculty of computer engineering in 1969.

Breznitz (2007b) posits that since the 1970s a new trend also started in Israel where Israeli senior R&D managers in American MNCs returned to Israel to open R&D centres for their MNCs. Intel was the first to open and R&D centre in 1974, and in 1985 the company opened its first fabrication of silicon chips outside of the US. Two more such companies were Semi-Conductors and KLA (pp.195, 234, footnote 3).

3.3.5 Intellectual property rights

Avidor (2011) indicates that Israel's intellectual property regime started under the British Mandate in 1924 with the Patent and Design Ordinance, and was later revised in the Patent Act of 1967 which extended the term of patent protection to 20 years from the date of application. In 1988 the government added software to its protected copyrights, giving inventors 70 years protection. In addition, Israel was signatory to all major relevant treaties of the World Intellectual Property Organization, including the Berne Convention, Paris Convention, Patent Cooperation Treaty, and later on it joined the World Trade Organization's Agreement on Trade-Related aspects of Intellectual Property Rights (TRIPS). This allowed Israeli inventors to enforce patents in any country within the signatory group and in other markets in the US and Europe. This cooperation played an important role in Israel's international trade, and as a foundation for its innovation capabilities.

3.3.6 Military R&D

Heller (2011) states that Israel has a unique military history of integration with industry, and therefore had an important role in the country's innovation system and a

role in energy innovation as well. For example, RAFAEL Advanced Defense Systems Ltd., which develops and sells high-tech defense systems to the Israeli military, is a participant in the Eilat-Eilot consortium that is developing renewable energy.

Breznitz (2007b) explains that in 1948 RAFAEL was established within the Israeli military, initially under the name of Science Corps, to develop weapons and military technology. RAFAEL was the first and only organization to conduct high-technology R&D for many years in Israel, and it also built an analog computer, the Itzik computer, for large scale simulation. Until the early 1990s RAFAEL functioned as an applied academic institution, treating its researchers as academics and sending them during sabbatical years to leading universities and IT companies worldwide. It also funded the graduate studies for a few thousands of its employees in Israel and overseas, in top US engineering universities such as MIT and Stanford, who later returned to these universities as visiting scholars (p.48). RAFAEL was also "used as an incubation center to 'infect' other defense and civilian companies and organizations with IT R&D capabilities" (p.48), for example in the creation of MAMRAM or MMRM, the Israeli military central computer unit in 1960 (p.48).

Breznitz (2005) and de Fontenay and Carmel (2004) explain that the MAMRAM School for Computer-Related Profession (CRP School) is the main military training unit for programming and software engineering, which has played an important role in the development of the IT industry in Israel. For example, As Breznitz (2005) describes, the structure of the reserve duty in Israel is unique in that reservists who work in the private sector and in universities, as IT technicians and engineers, meet once a year as part of their reserve obligation to collaborate in an environment based on trust and on a "sense of patriotic camaraderie" (p.39); an experience that is exclusive to the Israeli military and which would not take place in an industry setting.

Breznitz (2005) further adds that the CRP School Reservists are in charge of teaching, developing and upgrading CRP school curricula, and of creating and writing instructional material that they take back to their firms and universities for their own use, acting as a channel between industry, academia and the military. As well, some of these reservists have opened their own computer programming schools in Israel where they teach the MAMRAM curriculum.

De Fontenay and Carmel (2004) propose that the military R&D has been more available and therefore has stimulated more commercial innovation than patented civilian R&D. The military protects less its knowledge than industry does, and except for its cryptography knowledge, it does not impose any restriction on military graduates who wish to develop technology in areas in which they worked during their military service. Consequently, Israeli firms became leaders in global software markets, and many were created by MAMRAM graduates.

De Fontenay and Carmel (2004), Avidor (2011) and Frenkel et al. (2011) recount that during this time Israel also depended on the French government for its supply of arms. However, after the 1967 Six Day War, due to the French arms embargo and de Gaulle's refusal to provide a French jet to Israel that had been developed with Israeli expertise, Israel increased its defense R&D through domestic production of high-tech weapons and systems and established close ties with the United States military.

Levi-Faur (1998) explains that Israel's remarkably high economic achievements during its first 25 years since its independence have been "played down, ignored, or taken for granted" (p.87), while forgetting that Israel's economic performance, from 1974 to 1989, during the era of liberalization, was poor. The low economic performance between 1974 and 1989 should have created debates about its possible reasons, but instead academia talked about privatization and liberalization. Levi-Faur further states that culture could not have played a role. He poses that although culture may be important for development, how can it influence economic growth if the same culture changed the economic performance in Israel from excellent to poor? He further states that although culture may play a role in economic development, policies are more important and an essential component of the developmental state model.

3.4 ECONOMIC DOWNTURN, THE "PARADOX" OF THE 1970s AND 1980s

Pugatch et al. (2009) explain that since 1948 Israel's population grew by 280 percent to 3.3 million in 1970; education and skill of labour also grew due to heavy government investments in education and training. Avidor (2011) adds that private industrial R&D increased 12 times to $347 million; and as Breznitz (2007b, pp.42-43)

states, S&T focused almost entirely on improving technological R&D skills. This section presents two views on the 1970s and 1980s economic crisis.

Teubal (1993) discusses that in the 1970s and 1980s Israel experienced an economic downturn, while at the same time there was an abundance of skill which lead to the rise of the high-tech industry and which could have created economic development. Instead the result was economic stagnation due to a lack of the right technological infrastructures; a government without a vision and institutional obstacles, such as no long-term policies and strategies to achieve economic growth; no coordination and collaboration among ministries or among the different institutions – government, industry and universities. For example, there was little diffusion from the military to private industries; ministers were incompetent and with little understanding of the importance of technology to society. There was also a call for the professionalization of Israel's public service in order to develop a "self-conscious, well educated civil service" which would understand the "importance of, and relationships between technology and society" (p.496).

This was a period that Teubal (1993) calls the "paradox" of the 1970s and 1980s. As well, Israel's technological policies supported R&D investment only, resulting in too much R&D carried out while only a small proportion had been successfully applied, since there was no support for post R&D development that would sustain the whole innovation process. As Teubal (1983) further explains, the OCS' investment in private industrial R&D increased from $34 million in 1965 to more than $230 million in 1978. The number of R&D scientists and engineers increased from 886 in 1969, to over 3,000 in 1981; while the number of R&D facilities grew from 210 in 1969, to only 228 in 1975, and to over 500 in 1980. Differently, Breznitz (2007b) discusses that the increase in number of scientists and engineers was due to the defense industry "major R&D efforts" (p.53) for the production of military equipment.

However, in the 1970s, according to Teubal (1983), although Israelis had developed excellent R&D skills, thinking that R&D was enough for success, had a poor "understanding of the process of innovation and of the conditions for commercial success in innovation" (p.187), and a poor understanding of market users and of marketing

techniques. The firms that survived had initially experienced difficulties and failures, but were probably ‘fast learners,’ rather than having selected the right R&D projects.

Both, Teubal (1993) and Levi-Faur (1998) indicate that the possible reasons for Israel’s declining economic performance after the 1973 Yom Kippur War were a domestic political crisis, when there was a change from a centre-left to a centre-right government which reduced the autonomy of the state, changing the government’s economic strategies by implementing ‘liberal’ policies, with no “long term, strategic thinking” (Teubal, 1993, p.496).

3.4.1 Role of Government

3.4.1.1 Financial Reforms and Market Liberalization in the 1980s

Avidor (2011) discusses that between 1984 and 1985 Israel’s inflation was up to 375 percent, when the government implemented economic stabilization policies and reduced the budget deficit from 15 percent in 1984, to a two percent surplus in 1986. Avidor (2011), Halevi (2010) and Morgenstern (2010) add that after the stabilization program, the Israeli government started to decentralize the economy through financial reforms and privatization of many of its enterprises in order to reduce its deficit and size of the sector. Some of the financial reforms involved additional capital investments in the private sector, once the government reduced the budget deficit significantly, channeling more public savings into the private sector investments, and reduction of barriers to international capital movements.

3.4.1.2 Research and Development (R&D)

Breznitz (2005) discusses that the same as in the 1950s and 1960s, Science and Technology industrial policies focused mainly on new R&D products, and the government facilitated the networking between private and public R&D to improve and increase the exchange of knowledge, information and ideas. Different from Teubal (1983 and 1993) above, Breznitz (2007b) states that the government continued encouraging private R&D by providing funding to private industry and by supporting the flow of R&D knowledge from university and defense sectors to industry.

Teubal (1983) also maintains that Israel's export growth since 1967 in intensive R&D industries especially in electronics, was remarkable due to the support given by the OCS; and alternatively, Trajtenberg (2005) poses that this was a "natural selection process" (p.23, footnote 11). Teubal (1983) discusses that the defense industry was the main producer of military electronic equipment, influencing therefore the R&D support by the OCS for ICT. As Teubal (1993) discusses:

> The brilliant successes of Israel's entrepreneurs (market forces) to a very large extent had been achieved despite the existence of a vast array of government policies and semipublic mechanisms and institutions, at least in the last decade and a half (p.497) that may have created strong obstacles to the country's economic growth.

3.4.1.3 Office of the Chief Scientist (OCS) Grant programs:

According to Avidor (2011), in the 1980s the OCS significantly increased its R&D grants and created several grant programs to promote projects in various disciplines which resulted in growth of new technologies in many sectors, in human capital development and, same as Breznitz (2007b), diffusion of innovation capabilities. The most important R&D programs created in the 1980s were:

The Law for Encouragement of Industrial R&D – 1984, with the goal of promoting knowledge intensive industries by increasing R&D and Science and Technology infrastructure. In 1984, Breznitz (2007b) indicates that the R&D Law assigned the OCS as Israel's official science and technology industrial agency, and therefore becoming a professional agency.

The Direct Grants Program, within the Law for the Encouragement of industrial R&D-1984, was the largest government R&D program, as described by Avidor (2011), where firms submitted grant proposals for specific R&D projects.

The National Programme, as Teubal (1983) explains, was implemented in 1976/1977 as a new R&D support system that targeted only successful firms willing to invest in major and risky R&D projects.

The MATIMOP program (Hebrew Acronym for Israeli Centre for R&D), as Teubal (2013) describes, is the executive agency of the OCS, and the National Agency

for industrial R&D cooperation. MATIMOP implements and manages international industrial R&D programs between Israeli and foreign ventures, such as the Israel-US Binational Industrial Research and Development (BIRD) [8] foundation with the United States (US) established in 1977 (Teubal, 2013). These programs are further explored in Chapter Four. Breznitz (2007b) indicates that Israeli R&D policy was developed on a trial and error basis. For example, the BIRD model was selected after its Director and his team had worked on several projects, and "had some cases to build on" (p.59). Differently, in Ireland and Taiwan, policy was developed as an "orderly overall strategic plan" (Breznitz, 2007b, p. 61).

3.4.1.4 A Bureaucratic Champion

The BIRD foundation, as Breznitz (2007b) discusses, became successful thanks to a bureaucratic champion, Ed Mlavsky, who was hired as Director of BIRD from 1979 to 1993. Mlavsky was an American who moved to Israel to assume this position. He was a member of the US-Israel Advisory Council on Industrial R&D, and also a co-founder of the company Tyco International. BIRD coaches Israeli firms on how to work with US companies; helps Israeli R&D executives who wish to return to Israel; and it also invites MNCs that worked in successful BIRD projects to open R&D centres in Israel. These subsidiaries are registered as Israeli, and qualify for both BIRD and OCS funding.

3.4.2 Military R&D

Avidor (2011) and de Fontenay and Carmel (2004, p.60) discuss that in the late 1970s Israel and the US began working on the Lavi military aircraft project, but due to delays and cost overruns the project was cancelled in 1987, also at a time when the military experienced extensive restructuring and reduction of its industries due to the

[8] According to Interviewee G3, "BIRD receives its main funds from an endowment provided by both countries, Israel and the US, for a total of $110M. In addition, there is income for BIRD Energy (separate annual funding, provided by both countries) of about $4M annual. The BIRD Foundation operates under a special law as a 'corporation by law.' Its Board of Governors is composed of senior officials from the U.S. and Israel. Therefore, in principle, BIRD is not 'under the OCS'. However, in practice, in Israel, our main connection is with the OCS because of the nature of our work. Similarly, in the U.S., our main connection is with NIST" (National Institute of Standards and Technology), (personal communication, September 6, 2016).

country's economic crisis (p.60, note 22). Consequently, Breznitz (2007b, p. 221, footnote 58) adds, in the early 1990s the defense industries laid off more than twenty thousand skilled and unskilled employees. As Avidor (2011) states, heavy investment in military development had resulted in the domination of the economy by the defense industry, representing 20 percent of GDP between 1980 and 1984, employing 20 percent of the industrial force, and 50 percent of Israel's scientists and engineers during these years.

De Fontenay and Carmel (2004, p.60) and Avidor (2011) discuss that hundreds of engineers who became unemployed, with the cancellation of the Lavi project, were hired by the civilian high-tech industry, while others developed startups with OCS funding. However, 60 percent of startups failed and closed since they could not obtain additional financing for marketing and business development (Jerusalem Institute of Management Report, 1987, cited in Teubal, 2013, p. 19). In addition, Teubal (2013) indicates that these failures were also due to weak management and business knowledge, and a lack of added value support that Venture Capital (VC) could provide together with finance but which did not exist in Israel at that time. Both, the human capital movement and the high-tech startups resulted in a large military-civilian technology transfer flow which may have also been an important factor in Israel's high-tech boom later in the 1990s, since any successful and also failed cases possibly added to the body of knowledge of the Israeli entrepreneurial system.

Breznitz (2007b) points out that between 1967 and 1980 there was a significant increase of scientists and engineers employed by the defense industry, at a 260 percentage, the highest in the world. The Lavi fighter jet project alone employed 10 percent of all Israeli R&D scientists and engineers (p.217, note 25). However, in the mid 1980s this strategy began to have negative effects on the economy by crowding out the private industry in the labour market. Nevertheless, the defense industry had a definite influence on Israel's labour force development (p.53).

Two of the main military programs that support R&D are:

MAFAT, acronym for the Administration for the Development of Weapons and Technological Infrastructure, established around 1982, which coordinates between the

Ministry of Defense, the Israel Defense Forces (IDF) and Israel's military industries (Frenkel et al., 2011).

TALPIOT, an elite IDF training program established in 1979, as de Fontenay and Carmel (2004, p.47) and Frenkel et al. (2011) discuss, which selects every year the top 30 students in sciences, physics and mathematics, while combining university education in science and engineering with extended military service. Frenkel et al. (2011) and Chorev and Anderson (2006) recount that through TALPIOT, graduates acquire entrepreneurial skills, work experience and management skills, while working in a high pressure environment. After their military service many of them are hired by the high-tech sector while many others have also established startups since the early 1990s.

3.5 THE 1990s AND 2000s

3.5.1 Human capital

Being a country with scarce natural resources, and a large intellectual endowment, Israel's system of innovation dynamics are human capital oriented. Chorev and Anderson (2006) indicate that in 1997 Israel had 130 scientists and engineers for every 10,000 workers, while the US had 80 and Japan 75. Avidor (2011) states that in 2001 Israel had the highest number of scientists and engineers per capita in the labour force of any OECD country at 135 for every 10,000 thousand workers, while the United States had 80, and Canada 45, per 10,000 workers respectively.

Getz and Segal (2008) explain that the human capital development in Israel experienced a significant growth during the 1990s and 2000s. In 1950, Israelis educated in natural sciences, engineering and agriculture were less than 2,000; in 1970 there were more than 37,000; while PhDs increased from 10 to 196 in same period; and in the early 2000, fifty five percent of Israelis had a university education across disciplines.

Senor and Singer (2009) indicate that immigrants are risk takers, and as a nation of immigrants, Israel may be a "nation of entrepreneurs" (p.121). Nevertheless, Avidor (2011) points out that immigration can result in slower economic growth due to lower education levels resulting in lower labour productivity, as it happened in some states in

the US. However, except for the first large immigration wave after WWII, the education level of immigrants to Israel was higher than that of its existing population, with periods of increased immigration and an increase in output per capita (Avidor, 2011).[9]

Breznitz (2007b) recounts that in the 1990s there was a large wave of immigrants and human capital from the former Soviet Union, becoming 20 percent of the Israeli population in a decade, with 57,000 engineer and 12,000 physician immigrants from Russia in 1993 only (p. 77); in addition to mathematicians, as de Fontenay and Carmel (2004) mention, turning Israel into a superpower in mathematics (p.47). Avidor (2011) further points out that about 60 percent of the Russian immigrants, who arrived between 1989 and 1990 had secondary education, versus 30 percent of native Israelis. A less enthusiastic view is provided by Levi-Faur (1998), who points out that the immigration of Russian Jews from 1990 to 1994, who were highly educated, created an annual growth rate of 3.6 percent but only with an annual growth of 2.2 percent GNP per capita, which was less than half the annual growth during Israel's economic "golden era" of the 1950s and 1960s.

3.5.2 Role of Government

3.5.2.1 Market and Trade Liberalization

Israel experienced a long transition from a fixed exchange rate system, with occasional devaluations, to a floating system that lasted from 1989 to the mid 1997 (Elkayam, November 2003), when in the 1990s its movements of capital were further liberalized substantially. Nadav Halevi (2010) and Joseph Morgenstern (2010) explain that the government involvement in the economy decreased while social programs increased; government enterprises continued to be privatized, reducing the size of its

[9] This has not always been the case. The Ministry of Aliya and Immigrant Absorption. (n.d.a), indicates that during Operation Moses in 1984 approximately 8,000 Jews immigrated to Israel from Ethiopia. Following a regime change in Ethiopia in 1991, the new government agreed, for a sum of 40 million dollars, to permit the remaining Jews of Ethiopia to immigrate to Israel; The Ministry of Aliya and Immigrant Absorption. (n.d.b) also explains that "During 'Operation Solomon' which lasted less than 48 hours, 14,000 persons were brought to Israel" (para.1). The level of education of Ethiopian Jews was not high.

sector and its deficit, and the country opened its doors to foreign investors by the end of the 1980s. Israel did this in order to be part of and to compete with the global markets.

3.5.2.2 R&D Programs and Policies

Trajtenberg (2005) and Breznitz (2007a) discuss that in 1965 Israel's industrial R&D per GDP was one of the lowest in the world at one percent. The OCS had an important role in its increase to 4.6 percent of GDP in 2004, becoming the highest in the world with about 4,000 high-technology companies and developing an intensive IT industry, while R&D grants, as stated by Teubal (2012a), hit the highest point in 2000. In addition Prof. Peretz Lavie (2014) pointed out that in 2014 Israel had 6,500 startups, a higher number than Germany, France, and the UK. Trajtenberg (2005) adds that Israel's innovation success, mainly in Information and Communication Technologies (ICT), resulted from a coordinated, long-term government support strategy for commercial R&D, which took advantage of the potential of Israel's highly skilled labour force.

Getz and Segal (2008) describe that in the 1990s, the Office of the Chief Scientist (OCS) implemented several programs, which it has revised on an ongoing basis. Trajtenberg (2005) and Teubal (2013) discuss that two of the most important programs under the OCS are the MAGNET, established in 1992, which stimulates cooperation between industry and academia, complementing the activity of TTOs; and the Public Technological Incubators, established in 1991, which helps new entrepreneurs to develop technological ideas and commercialize them. These two programs are further examined in the next chapter. Frenkel et al. (2011) point out that other important programs established by the OCS were the MAGNETON program that provides technology transfer support to an existing relationship between an academic institution and a company for up to two years. The NOFAR program, for industrial application of academic research, bridges the gap between basic and applied research. The MAHAT program, acronym for Government Institution for Technological and Scientific Training, incorporates mainly ultra-orthodox Jewish men, and mostly women from the Arab population into the workforce.

Avnimelech and Teubal (2006) and Teubal (2013) argue that the objectives of these programs were to increase R&D, create high-tech firms with an export orientation, and

implement a “process of collective learning” (p.14) about R&D, innovation and technological entrepreneurship. Trajtenberg (2005) adds that the OCS reviews the technological and commercial feasibility of projects, their value and risk, which should be high, and their possibility of producing spillovers, which also became a criteria after the rewriting of the Law for the Encouragement of Industrial Research and Development—1984 (The R&D Law**)** in 2005. Another reason for the 1984 R&D Law review on April 2005 by the Knesset - the Israeli Parliament, as Breznitz (2007b, p.85) and Getz and Segal (2008) further explain, was to pass a new Industrial R&D Law allowing companies to transfer knowledge developed in Israel to foreign countries with permission from the OCS.[10]

According to Breznitz (2007a), the government faced a top priority with the large immigration from the former Soviet Union and the thousands of engineers who were laid off by the military in the late 1980s early 1990s, when the Lavi project was cancelled, and on how to have access and use this body of knowledge, providing a political window of opportunity of which the OCS took advantage. Breznitz (2007a) further maintains that the Russian immigration created an excuse for the OCS to obtain finance and implement its programs, since by 2004, although the Russian immigrants provided high skilled labour, they had not become successful high-technology entrepreneurs. A research conducted at the Central Bureau of Statistics, 2014, showed that among 151 founders of Israeli public startup companies on foreign exchanges, there were no Russian immigrants.

With regards to government support policies, Getz and Segal (2008) discuss that Israel does not follow an explicit innovation policy; there are no specific measures to encourage innovation with specific objectives, and innovation is supported as a consequence of programs that encourage R&D. Although innovation is vital, the goal is to promote R&D that will produce manufacturing, employment and export, meaning, to be commercialized (p.8). Differently, Breznitz (2007a) points out that the objective of the OCS was to develop a “novel products R&D based industry” (p.1465); to “maximize and institutionalize R&D” (p.1466); to create technological change. These goals were achieved by designing its programs for the different development stages of new high-

[10] As explained later and as I found out through my interviews, export of technology developed in Israel entails a maximum penalty of six times the grants received by the OCS.

technology firms, which were creation -such as MAGNET, MAGNETON and NOFAR; growth - through Technological Incubators; and long-term sustainable competitive lead - through VCs; achieving therefore a state-industry co-evolution in the early 1990s, and resulting in the quick growth of the R&D industry.

Breznitz (2007a) argues that in the early 1990s a limited R&D grant budget was established, but by then the number of grants had grown significantly since the enactment of the R&D Law in 1984, with many successful international projects, resulting in an increasing amount recovered by the OCS as repayment for successful projects, of 50 percent loans. The amounts the OCS recovered increased from $8 million in 1988 to $139 million in 1999, which were re-injected into new projects. Breznitz, (2007b) further states that the reinvestment of royalties by the OCS and BIRD is a unique feature of the Israeli Innovation System. However, many entrepreneurs could not move forward since there was no Venture Capital industry (p.60).

3.5.2.3 Defense Industry

Breznitz (2007b) states that the success of the IT industry in Israel is extraordinary, and the Israeli IT industry is a worldwide top competitor and leader in IT technology (p.41). Israel had a starting strength since the mid-1980s in software-data-security due to the defense sector and its universities,[11] and in the 1990s it was the most successful industry in the country. Examples of key technologies developed in Israel are encrypton, authentication, intellectual property right protection (IPR), antiviral protection and firewalls developed by Checkpoint. MNCs also acquired Israeli companies to establish their data security R&D centres in Israel, such as Microsoft. Consequently, there are no independent Israeli antivirus firms (p.92).

[11] Such as Adi Shamir from the Weizmann Institute, “one of the three developers of the famous RSA algorithm (the S stands for Shamir), which has been the basis for the public-private key data-security infrastructure, and from which RSA corporation took its name.” Invented in 1977. (Breznitz, 2007b, p.223, note 77).

3.5.3 Industrial Research and Development (R&D)

3.5.3.1 Venture Capital Industry (VC) - The Yozma Program

Avnimelech and Teubal (2006) indicate that in response to the lack of resources in Israel to support companies after their R&D phases of the innovation process, when Yigal Erlich's position as Chief Scientist of the OCS was ending, he created the Yozma (initiative in Hebrew) program between 1993 and 1997, which successfully shaped the Venture Capital (VC) industry in Israel. This initiative was policy driven and successfully followed the Silicon Valley VC model, involving an extensive and intensive research process which took place within the right timing but that not all countries may be willing to go through. Yigal Erlich consulted with key Israelis in Silicon Valley and with the US Small Business Administration, among others, and decided to adopt and adapt the Silicon Valley model by promoting a domestic early phase VC industry. Breznitz (2007b, p.223), and Breznitz (2007a) recount that in 1998 Israel invested more than 78 percent of R&D on telecommunications; and in 2000 the Israeli IT industry represented more than 70 percent of GDP growth.

As Teubal (2013) mentions, Israel had about 300 startups in 1993, and 2,500 startups by the end of the 1990s. Chorev and Anderson (2006) further discuss that in 2000 Israel had the largest number of startups worldwide in relation to population size; and Prof. Lavie (2014) mentioned that in 2014 it had 6,500 startups.

Avnimelech and Teubal (2006) explain that in addition, there were four VCs in Israel in 1992, and 50 in 2000, with investments of $8 billion by the end of 2000. With the success of the VC industry, the Israeli high-tech industry was transformed from being dominated by the military to a successful private high-tech cluster.

Breznitz (2007b) discusses that the success of the VC industry can be witnessed when by 2004 Israel had "shaken off the NASDAQ's dot-com crush" (p.41), raising US$727 million in 2004 and $1.2 billion in 2005 without government involvement (p.81), an amount that was 60 percent higher than the OECD average (p.223). After the dot-com crash most of the Israeli industrial financing was foreign, American and European, with a decrease in Israeli investors, and an increase in its relation with global financial markets (p.204).

Through the Yozma program, Teubal (2013) recounts that within a few years, Erlich's policies achieved immediate economic growth for the country. As Breznitz (2007b), indicates, Israel's leaders, the same as in Germany first and then in Japan in the late nineteenth century, were aware of the high price they would pay if they failed "to build successful national industries (which) would have meant the destruction of their societies as independent social units (since) Israel had only recently gained the right to independent existence after long, bitter and bloody struggles" (p.10). Israel's leaders who directed its success -"politicians, civil servants, and businessmen and entrepreneurs-were all of a generation keenly aware of the price of failure" (p.10), and they acted within a national development effort. Israel's leaders also defined the country's "national sociopolitical identity" (p.10) as Jewish - as a home of ancient people. As Breznitz (2007b) concludes, and according to the analysis above, the Israeli Business model is based on intensive R&D, on product innovation, on foreign Initial Public Offerings (IPOs) and on mergers and acquisitions by US companies, which leads to American startup models (Breznitz, 2007b, pp. 27, 214, endnote 22).

3.5.3.2 External or historical events

Teubal (2013) considers the question: why was Israel so incredibly successful, since it did not have a "well established strategy innovation policy (SIP) structure" (p.42), and its priorities were only implicit and partially formulated, with the exception of Yozma. In addition to its unique endogenous factors mentioned above, Teubal (2013) states that there were historical or exogenous events that contributed to Israel's successful creation of its Venture Capital, which he calls historical luck, and these include:

First, according to Teubal (2013), there was an increased globalization and a related financial growth, such as of foreign direct investments (FDI) and the globalization of NASDAQ in the 1980s, an opportunity that Israel seized by having Initial Public Offerings (IPOs) in NASDAQ and in other international capital markets. There were technological changes worldwide such as the development of the Internet and the continuous ICT technological revolution; and the liberalization - opening up to competition, of global communications and markets in the early 1980s, and as Breznitz (2007b, p.81) adds, creating a high growth and demand for IT. Second, Breznitz (2007b)

indicates that the experience Israelis acquired by working with Multinational Companies (MNCs) in Israel, where US semiconductor MNCs are also very active, and by also working overseas, allowed some of them later to become startup entrepreneurs or partners in VCs in Israel (p.86).

Breznitz (2007b) further argues that Israel's achievements mentioned above were supported by other programs, also pointed out earlier, for example the government developed strong networks, mainly with the United States (US) through Israeli expatriates, such as Mlavski, who became the Director of the BIRD program in 1978, establishing links with academics and students and relations with US firms. In this way Israel was able to seize all these opportunities by being ready when these exogenous events took place (p.58).

In addition, Teubal (2013) discusses that an entrepreneurial system with competent Startups (SUs) and support organizations, such as early phase Venture Capital with international networking, can create structural changes. For example these can take place in energy and environment, such as solar and wind power, and electric cars, as it happened in Israel.

3.5.3.3 Renewable energy

The Israeli government is preparing to have 10 percent of the country's electricity generated by renewable technology by 2020, and is also planning to invest US$600 million in the next decade to achieve fossil fuel energy independence**.** To achieve this goal, in a national bid in September 2010, the OCS selected the Eilat-Eilot Renewable Energy Initiative to establish and operate a renewable energy R&D center located in the city of Eilat, in the southern tip of Israel (iPLanet News, 2010).

The Eilat-Eilot consortium includes several partners such as RAFAEL Advanced Defense Systems Ltd. that sells high-tech defense systems to the Israeli Military; Ormat Industries Ltd. specializes in geothermal power, recovered energy generation (REG) and remote power; Elbit Systems Ltd. manufactures and integrates advanced, high-performance defense electronic and electro-optic systems; ProSeed Venture Capital Fund; Britain's Consensus Business Group, and the Ben-Gurion University, with strong green energy programs (iPlanetNews, 2010).

Aron Heller (2011) discusses that the number of cleantech companies has also increased significantly. For example, in 2006 Israel had about 120 cleantech companies, and since then 120 have been established every year, including Venture Capital firms such as the ProSeed Venture Capital Fund, and the Israel Cleantech Ventures, Israel's largest VC firm which focuses only on green energy and water.

3.5.4 Israeli Universities

Breznitz (2007a) states that during Israel's industrial change, in the 1990s, when the high-technology industry grew and while the "traditional industry… lost ground" (p.1473), there was also an increase in science and technology enrollment in universities, which were public until 1995. For example, without including students in private computing and IT schools who were in the low thousands per year in the 1990s, there were 7,911 engineering students in 1979 and 14,003 in 1999. There were 6,560 students in math and natural sciences in 1979 and 17,004 in 1999. In math, computer science and statistics there were 2,618 in 1979 and 8,657 in 1999. As well, Breznitz (2007b, p.86) explains that Israeli Universities together with US semiconductor MNCs, such as Intel, Motorola and IBM, produced the largest numbers of international patents.

3.5.4.1 Transfer of Technology Offices (TTOs)

Israel has eight universities and seven of them are involved in both teaching and research. Each university has a Technology Transfer Office (TTO) which patents and commercializes new discoveries produced by the universities. Differently from studies in the United States and the United Kingdom, Frenkel et al. (2011) explain that Israeli Universities' Transfer of Technology Offices (TTOs) are very profitable. For example, since 2001, Yeda, the TTO of the Weizmann Institute, has been the third most profitable TTO in the world with earnings of more than one billion NIS (US$ 256 million) in royalties. Senor and Singer (2009), provide different numbers, where from 2001 to 2004 Yeda earned one billion shekels, about US$200 million in royalties; and by 2006 Yeda had the highest income in royalties among global academic institutions (p.211).

Senor and Singer (2009, p.211) point out that Yissum, the TTO of the Hebrew University, has granted over 450 technology licenses with earnings on sales of over US $1 billion worldwide per year.[12] Kalman (2008) adds that the university's largest revenues come from drug royalties for Alzheimer and cancer. As well, the Technion Technology Transfer (T3) Office started in 2007 to receive royalties from Azilect, to treat Parkinson's disease. Avidor (2011) argues that the close relationship between Israeli universities and industry stimulate innovation in a similar way that Stanford University and the Massachusetts Institute of Technology (MIT) stimulated innovation in the United States in the twentieth century.

Frenkel et al. (2011) indicate that TTOs are the major players in production and dissemination of knowledge in Israel while stimulating economic growth. For example, as de Fontenay and Carmel (2006, p.46) and Prof. Peretz Lavie (2014) argue, in 2004 the Technion had one of the largest computer science departments in the world, with about 1,500 majors, being one of the backbones of Israel's technologies.

However, according to Kalman (2008), at the time of his research the government was cutting university funding and planning to increase student fees, and since 2006 there were students' and professors' strikes. In addition, such cuts could cause a decline in education and research, and Israel could lose its leading position in R&D, which could also affect the high-technology and defense industries.

3.5.4.2 Universities involved in R&D in Green Energy

Several Israeli universities conduct research in energy innovation. Both, the Weizmann Institute of Science (Weizmann Institute) and the Israel Institute of Technology (Technion), through its Grand Technion Energy Program (GTEP), have energy programs that focus on environmental R&D technologies in the energy sector. Their research includes carbon free fuels and carbon sequestration, as well as alternative and renewable energy programs such as solar (Grand Technion Energy Program, n.d.). In

[12] Fort Mills (n.d.) points out that Yissum currently generates "$2 billion in annual sales. Ranked among the top technology transfer companies in the world, Yissum has registered over 8,100 patents covering 2,300 inventions; has licensed out 700 technologies and has created 80 companies" (para.6). Yissum has business partners worldwide, including companies such as Monsanto, Roche, Novartis, Microsoft, Johnson & Johnson, Intel, and Teva among others.

2010 the Technion's Energy Program received a $20 million U.S. donation. The program has four clusters and one of them is on alternative fuels, including biological fuels, hydrogen technology and carbon free fuels (Technion Israel Institute of Technology, 2010).

The Ben-Gurion University of the Negev (BGU) in southern Israel focuses on renewable energy and on some wind power, but mainly on solar projects due to the sunny climate in the Negev. One of these projects involves a study of the stability and power quality in the Negev region with solar farms, studying the connection of a large solar farm in the Negev to the national electric power system. Another project from the Israeli Start-up Zenith Solar, a spinoff from the BGU, which built a solar farm 20 km south of Tel Aviv, uses a new technology that collects more than 70 percent of solar energy (iPlanetNews, 2011).[13] This company was acquired by the Chinese Suncore Photovoltaic Technology Company Limited through a subsidiary in the US (PV Magazine, 2013).

3.5.5 Israeli Military

3.5.5.1 Military Training

As pointed out earlier, Israel's elite units recruit high school graduates who excel in science and place them in accelerated university training (de Fontenay and Carmel, 2004, p.47; Frenkel et al., 2011; Kalman, 2008) or in their own technological education programs, such as TALPIOT and PSAGOT, and they become in charge of developing new defense technologies (Kalman, 2008). Some of the most successful high-tech start-ups are created by graduates from these programs, mainly in the computer and engineering fields. Also, soldiers from these units have professional education and work experience, and are in high demand in the high-technology sector, in wireless communication and even in cancer research (IDF Background Information, n.d.).

In this way, Israel's strong investment in defense technology achieves two goals. First, it boosts national moral, political power and fosters economic growth, as suggested

[13] According to Dr. Cooper Langford, one of my Thesis Supervisors, "Collecting 70 percent is straightforward to understand. The interesting question is what is the conversion percent to electrical energy? That can't be 70 percent (above theory limit). Are they using the energy in the form of heat, for example hot water production?" Personal communication, May 24, 2014.

by Freeman (2004). Second, its trained graduates contribute to the economic development of the country by creating successful startups, and by transferring their technology knowledge once they move on to work with industry. Furthermore, as mentioned earlier, the defense industry actively participates in the MAGNET consortiums which promote the flow of information and transfer of knowledge, through cooperation between private, defense industries and academia.

3.5.5.2 Military Culture

De Fontenay and Carmel (2004, p. 51) and Chorev and Anderson (2006) discuss that the Israeli military training has a strong influence in shaping the character of Israeli youth by stimulating skills and qualities such as teamwork, loyalty to the group, out-of-the-box thinking, improvisation, and the tendency to challenge collective wisdom, which become part of the Israeli business culture. The Israeli military has a flat leadership structure where young soldiers have huge responsibilities and make life or death decisions at lower levels than their Western counterparts; and are encouraged to question orders and to express their opinions to their superiors. De Fontenay and Carmel (2004, pp.52-53) further add that soldiers are trained to work within independent small to medium sized teams and operations, which are also a characteristic of startups, where they acquire managing and leadership skills. Loyalty to the group as well is a trait that results in low turnover rates for high-tech firms and good team work.

In addition, many Israeli scientists and engineers have served as military officers and they may bring some traits that have been identified as positive characteristics for the successful transfer of technology such as team coordination, flexible thinking, and the capability to implement the findings of the projects, among others (ISERD, 2003). Due to these Israeli cultural traits, de Fontenay and Carmel (2004, pp.72-73) explain, that although many Israeli firms have moved their sales, customer support and marketing divisions to the US, they have kept their core R&D functions in Israel.

However, Breznitz (2007a) explains that other military cultural attributes could also become a challenge. For example, Israeli software companies that were successful worldwide “changed their product lines and even reinvented themselves according to changing technologies (where) one of the most important assets for an Israeli software

company is its ability to innovate constantly" (p.1479). Breznitz (2007b) further adds that a strength of the Israeli model is the "ability of firms to secure a technological edge and react quickly to changes" (p.66), attributes that may be acquired in the military service. Nevertheless, Breznitz (2007a) points out that these could also become a challenge when trying to become globally competitive, although companies such as Amdocs, Comverse and others have done this successfully, have also stayed in Israel and remained independent.

3.5.6 Israeli Culture

Getz and Segal, (2008) point at Israel's culture as one that places importance on education; as a multicultural society with many languages where English is commonly spoken; it has high tolerance for entrepreneurial failure; where companies must be internationally oriented due to the small size of the market; and as having high individual risk tolerance and ability to adapt quickly as a result of military experience. In this way, the Israeli culture also contributed to the development of its innovative economy.

On the other hand, as mentioned earlier, Levi-Faur (1998:83-84) questions how can culture influence economic growth if the same culture changed the economic performance in Israel, from excellent to poor-from the 1950s and 1960s to the 1970s and 1980s. Levi-Faur argues that although culture may play a role, policies are more important and are an essential component of the developmental state model. Alternatively, Malach-Pines (2005) discusses that at the same time that the Israeli economy was liberalized the Israeli culture became more individualistic, which may be more related to entrepreneurship and risk taking. [14] Avidor (2011) explains that entrepreneurs were considered heroes and role models, and entrepreneurship drove the market development.

3.6 CONCLUSION

There are several facts that stand out about Israel, and some of which are unique to Israel as well:

[14] Singh (2014) mentions that although Canadians are individualistic they are low risk takers.

Israeli governments have played a major role in Israel's economic growth through the development of its industries and technologies. Their role during the first 20 years of the foundation of the state was so important that they were considered heroes during what scholars call Israel's "Heroic period." Israel has had outstanding bureaucratic champions not only during this period, but throughout its history, such as Yitzhak Yaakov, Israel's first Chief Scientist in 1969; Ed Mlavsky, the Director of BIRD in 1977; and Yigal Erlich, the founder of Yozma in 1992.

There are some situations that may be unique to Israel. For example, Israel is home of ancient people with a strong national identity which makes it different from other developing countries that do not have a shared identity to build a nation. As well, Israel followed its economic development under a national ideology that gave a high rank to Science and Technology (S&T).

As Teubal (1983) maintains, science and technology - research and development, have been "deeply rooted in the history of Israel" (p.172) since the period of the British Mandate. During this period Israeli universities conducted applied and commercial R&D, and later on as well with the creation of the OCS programs established in the 1990s. Due to Israel's early and large number of commercial R&D, Israelis enacted Intellectual Property (IP) Rights already under the British Mandate. Also, since S&T has been highly regarded scientists have had an easy access to political leaders**.** Furthermore, we see Israel's high regard for S&T in its first four presidents who were renowned scientists and academics.

Israel is a country of immigrants, who tend to be risk takers and entrepreneurs, and its large immigration of Russian Jews further strengthened the country's S&T knowledge and absorptive capacity. Israel also has a close link and an intertwined relationship between government, academia, the military and industry. For example, the fourth Israeli president who was an academic scientist had also been the Head Scientist of the Ministry of Defense. As well, the country's first Chief Scientist, Yitzhak Yaakov, had a military background as head of armament development and of defense R&D. Moreover, high government positions have often been filled by former high military ranking officials. However, OCS staff has been hired from private industry, therefore increasing private industry involvement within government. Locating the OCS within the Ministry of

Commerce and Industry (today the Ministry of Economy and Industry) provided the OCS with a commercial and industrial focus on product innovation.

As seen earlier, military service is mandatory and continues for about a month every year until age 45, within the reserve duty, after soldiers complete their regular military service (IDF Info, 2015). In this way, knowledge is continuously transferred to industry, academia and government, and back to the military, a process that may be unique to Israel.

Another situation that may be distinctive to Israel is the Eilat-Eilot region in southern Israel which plans to become fossil fuel energy independent by 2020, where there is also a three way transfer of knowledge and technology through its partners from the defense and private industry, academia and government, notwithstanding the country's large oil and gas discoveries. Nevertheless, as of 2017, the Eilat-Eilot region has moved its goal to be energy independent by 2025 (Eilat-Eilot Renewable Energy Ltd., n.d.).

Additionally, transfer of technology also takes place through a three way interaction and flow in the different OCS programs, where universities, defense and private industries conduct basic research together. There are two different views regarding the objectives of the OCS. One view indicates that its objective has been to create technological change. A second view discusses that its goal has been to develop new products through commercial R&D, while it has not been following an explicit innovation policy. Instead, innovation takes place as a result of R&D programs in order to create manufacturing, employment and export. As seen in this chapter, this second objective has not been successfully achieved since most Israeli discoveries are manufactured overseas, and therefore Israel has been exporting mainly its technological discoveries and not manufactured products. A reason given for this position is that Israeli companies must be globally oriented due to the small size of Israel's market.

As seen in this chapter as well, the OCS is proactive in its approach to innovation in that it revises its programs on an ongoing basis. An example is its 2005 revision of the 1984 Industrial R&D program, where one criteria was the possibility of technology to produce spillovers, and to allow Israeli technologies to be exported with the OCS

approval. By this time when Israeli high-tech companies were global, the government enacted stronger IP protection of Israeli software discoveries.

Although there is a debate on whether the Israeli culture influenced Israel's entrepreneurship and economic growth in the last 20 years, most scholars agree that culture did, and does have an influence. One important side of this influence is the compulsory military service for all Israelis which shapes their character, stimulating skills such as out-of-the-box thinking, improvisation, challenging collective wisdom, flexible thinking, ability to adapt quickly and high individual risk tolerance. In addition, training in elite units also creates entrepreneurs, and the ability to constantly innovate, all of which have also become part of the business culture. Nevertheless, constant innovation can become a global competitive challenge as well. Israelis also have high tolerance for failure, and the entrepreneurial experience is recognized as adding knowledge that is applied in future efforts, while also becoming the collective knowledge of the entrepreneurial community. At the same time, as some authors indicate, the Israeli culture became more individualistic, which is more applicable to entrepreneurship and risk taking.

CHAPTER 4: INSTITUTIONAL STRATEGIES – HOW IT WORKS

4.1 INTRODUCTION

This chapter examines how Israel's innovation system is organized and it looks at the strategies of its institutions starting in the 1970s and up to the 2000s. The chapter studies the different government Research and Development (R&D) programs established in those years, with its horizontal policies, where "equal benefits were handed out to all who applied and met the basic criteria," (Avidor, 2011:34), and its neutral policies, where grants were approved based on criteria other than industry or technology segment, and by "not targeting and selecting specific industries or products to support." (Avidor, 2011, p.34). The R&D programs have been implemented and managed by the Office of the Chief Scientist (OCS) within the Ministry of Economy and Industry.

The first section addresses the programs implemented in the 1970s and1980s, most of which have been very successful and still exist today, such as MATIMOP, the Israeli Centre for R&D, and that may have influenced the development in Israel of the very successful high-tech sector. As well, some of these programs became models for other countries, such as the Bi-National Industrial R&D Foundation (BIRD) with the United States. During these years, Israel also implemented a strong intellectual property enforcement to protect its IT developments, which Fortuna et al. (2015) call "the crown of the Israeli Industry" (p.32), that drove Israel's economy.

The next section analyzes the most important programs and policies established in the 1990s and 2000s, such as the Public Technological Incubator Program, which was government owned and then privatized; the MAGNET program, formed by consortiums comprising private firms, including defense, and at least one academic research institution. These policies also reflect the flexible bureaucratic structure of the government in its relationship with industry, which has also strengthened the State and industry relationship. Next, the growth of the venture capital (VC) industry is examined, developed by Yigal Erlich, who is considered as one of Israel's bureaucratic champion, propelling Israel to its rapid economic growth.

The ability of the Transfer of Technology Offices (TTOs) in Israeli Universities to transfer and commercialize technology is then analyzed, indicating that Israeli

Universities receive only 10 percent of civilian funding; having a lag in transfer of technology and commercialization in the year 2000, and suggesting that it is necessary to study all institutions, academia, government and industry, in order to understand the reasons for this lag. Nevertheless, in later years this transfer of technology gap has been narrowed.

Intellectual property - patents and licenses are explained next, where Israel's patenting strength is in biotechnology, computers and communication (ICT). This section also addresses the increasing number of patents owned by Multinational Companies (MNCs) established in Israel and the question whether the country's economy would benefit from its innovations in the long-term if it continues this same path.

Several weaknesses of the Israeli Innovation System are presented such as companies' lack of long-term leadership to grow in their fields due to poor management, business skills, and financial strength, and a lack of large Israeli companies that would benefit the local economy; institutional and structural weaknesses due to an R&D focus and limited manufacturing capabilities, which makes the Israeli economy vulnerable; increased importance of the US market, and the possible decreased importance of the Israeli one; negative and positive effects of the VC industry and of MNCs on the Israeli economy; the creation of a dual economy, where while there has been a high-tech success, the traditional industries, with the highest labour employment, have had a slow growth.

Based mainly on two documents from the Samuel Neaman (Research) Institute located in the Technion, the last section addresses recommendations to strengthen the Israeli Innovation System including the Information and Communication Technology (ICT) industry, the Cleantech sector and its renewable energy subsector. Two of the main recommendations include the development of a local manufacturing industry and a government policy to help grow Israeli companies in becoming large global players. Fortuna et al. (2015) conclude that Israeli culture and its unique innovation drivers are the source of Israel's "innovation performance and policies" (p.35) that will continue to drive its high-tech industry. This situation is meant to change through the Israel Innovation Authority (IIA), former Office of the Chief Scientist, which is implementing new

programs to help companies to grow after their incubation stage (Solomon, July 11, 2017), [15] and large companies to become multinational (Solomon, July 13, 2017).

4.2 THE 1970s AND 1980s

4.2.1 Office of the Chief Scientist (OCS) grant programs

Breznitz (2007a) contends that Israel's horizontal technology policies shaped the country's National Innovation System through the Office of the Chief Scientist (OCS), by "influencing supply (of) and demand for R&D" (p.1467), as well as R&D skills and competencies. The R&D policies of the OCS were horizontal in that "equal benefits were handed out to all who applied and met the basic criteria" (Avidor, 2011:34), and also neutral in terms of sectors, industries and technologies, in that the OCS approved "grants…based on criteria other than industry or technology segment" (Avidor, 2011, p.34), its goal being to encourage Research and Development (R&D) activities by industry (Breznitz, 2007a). The most important programs created by the OCS in the 1980s were:

4.2.1.1 The Law for Encouragement of Industrial R&D – 1984 (R&D Law)

According to Teubal (2013) the goal of this Law was to promote knowledge intensive industries by increasing R&D and Science and Technology (S&T) infrastructure, by utilizing the country's human resources, creating employment, and absorbing its immigrating scientists and engineers. In addition, Avidor (2011) indicates that the objective of the Law was to create exports and to improve the balance of payments, through a direct grants program, providing matching funds, tax exemptions, loans, and other incentives. As Breznitz (2007a) explains, the R&D Law stated that the OCS would not have a limited R&D grant budget, and would provide funding to all approved projects submitted by the private industry to develop high-technology products.

[15] Solomon (2017, July 11) explains that the Israeli government is already implementing such program as of July 2017, with "four high-tech investment funds that will be traded on the (Tel Aviv) stock exchange and given state protection for losses," (para.1)..

Teubal (1991) further adds that the result was an increase in R&D awards to private industry and the emergence of high tech as a compilation of R&D intensive firms, what Teubal (1991) calls "a very significant event indeed" (cited in Teubal, 2013, p.15). In addition, Pugtach et al. (2009) state that the same as previous OCS policies, the Law is neutral in that it does not specify industry or products (cited in Avidor, 2011, p.34).

4.2.1.2 The Direct Grants Program-within the R&D Law

As addressed by Avidor (2011), within the R&D Law, the Direct Grants Program was the largest government R&D program where firms submitted grant proposals for specific R&D projects with a 70 percent approval rate. Government grants amounted up to 50 percent of the declared budget, and up to 66 percent for startups. This type of risk-sharing promoted responsible use of funds and discouraged the rushed development of high-risk projects. Funds' recipients had to abide by certain formal conditions such as: the firms themselves had to develop the projects and their products had to be made in Israel;[16] grants up to 30 percent for improvement in existing civilian products; grants up to 20 percent for improvement of military products; and projects in assigned peripheral areas received an added 10 percent grant. Grant payback was required only for successful projects generating revenues. Avidor (2011) argues that these policies had an influence on the development of Israel's high-tech sector since they created competitive advantages in software, communications hardware, and in medical devices, which were at the centre of the ICT high-tech boom of the 1990s. This program still exists today (Ministry of Industry, Trade & Labour, n.d.).

4.2.1.3 MATIMOP

De Fontenay and Carmel (2004, p.56) and Teubal (2013) discus that MATIMOP-Hebrew Acronym for Israeli Centre for R&D, is the executive agency of the OCS, and the National Agency for Industrial R&D Cooperation, established in 1977. MATIMOP implements and manages international industrial R&D programs between Israeli and

[16] As seen in the previous Chapter 3, National and Political History, this condition changed with the revision of the R&D Law in 2005.

foreign ventures, such as the Bi-National Industrial R&D Foundation (BIRD) with the US, established in 1977; and the Canada-Israel Industrial Research and Development Foundation (CIIRDF), as Frenkel et al. (2011) and Avidor (2011) add, founded in 1995, among several others. MATIMOP also offers international companies tax deductions and other incentives to open R&D centres in Israel, such as to IBM, Alcatel, Motorola and others (Frenkel et al., 2011; Avidor, 2011; de Fontenay and Carmel, 2004, p.58).

Breznitz (2007b, p.59) points out that BIRD coaches Israeli firms on how to work with US companies; helps Israeli R&D executives who wish to return to Israel; and it also invites MNCs that worked in successful BIRD projects to open R&D centres in Israel. These subsidiaries are registered as Israeli, and qualify for both BIRD and OCS funding. De Fontenay and Carmel (2004, p.56) add that the organization also connects Israeli companies with medium-to-large US firms, where typically the Israeli company develops new technologies and the American company offers large-scale product development and commercialization.

Breznitz (2007b, p.65) and Breznitz (2007a) mention that some successful Israeli entrepreneurs working overseas who were attracted to the OCS financing and BIRD support returned to Israel and established their companies, such as Comverse, a leader in voicemail, Mercury, SMS, and MMS. Comverse, which was established in 1984, received 69 R&D grants for its projects between 1990 and 2000, from the OCS. The OCS and the BIRD foundation provided grants for projects versus grants for companies, and therefore Comverse received these many grants.

BIRD's success became a model for other countries, as Breznitz (2007b, p.218) recounts. Thirty nine countries approached the US to set-up similar programs, and several countries have also established similar programs with Israel. From 1979 to 1989, Yahalomi (1991) discusses, BIRD funded 156 projects, and 69 of them, meaning 44 percent, successfully sold new products (cited in Breznitz, 2007b, p.218).

4.2.1.4 National Programme – Collaboration between successful firms and university scientists

Teubal (1983) describes that in 1976-1977 the OCS implemented a new R&D support system, called the National Programme that targeted only successful firms willing to invest in major and risky R&D projects. Its goal was to strengthen the firms' success and to produce new and more complex products with new technological inventions. Although this program did discriminate, it kept neutrality regarding type of industry and products providing over 30 percent of the total funding per year, through collaboration with university scientists, while the companies acquired experience in marketing and a reputation. Teubal (1983) believes that these firms possibly contributed substantially to the growth of the high-technology industry after 1976. The author also indicates that this program was closed in the early 1980s.

Breznitz (2007b) argues that during this time, mid 1980s and early 1990s, the Israeli IT industry expanded, and both, hardware and software companies, achieved international success (pp.4, 74). However, Breznitz (2007a) adds that the borders of both industries became blurred, since some companies sold software first and then hardware. Breznitz (2007b) also adds that the Israeli software industry is unique in that Israeli software companies initially developed products that offered solutions to their own hardware and software programming industry which already existed (p.73); and according to Breznitz (2007a), in that it competes successfully with American software startups in obtaining US capital.

Breznitz (2007a) and Breznitz (2007b, p.72) further explain that due to the fact that in this period there was no Venture Capital available to firms, the business model of many firms was to Joint Venture with a more established company that would provide guidance and financial support or be the main client; or a company would find a first client before developing the product. Also, these companies usually exported first to Europe, since they could not raise capital to open subsidiaries in the Unites States.

4.2.1.5 Changes in R&D neutrality

Teubal (1983) indicates that from 1967 to the mid 1970s, during the neutral promotion of industrial technology R&D, the total funds available were higher than the grants expenditures on projects. After about 1975 there was a shortage of funds, when 50 percent subsidies could not be fully implemented, and changes in the neutrality policy were introduced, such as increased support for R&D in electronics, at 32 percent in 1979, versus four percent in rubber and plastics. Nevertheless, Teubal (1983) discusses that neutrality in Israel was never completely neutral, since the development of military technology concentrates on electronics, which in the 1970s was the sector with the highest average expenditure in R&D from the OCS, and especially on communications equipment (hardware), which spilled over to the private sector.

Teubal (1983) contends that the departure from neutrality in Israel happened gradually and not quickly enough. During the first decade of neutral policies these were necessary, since there was little information and knowledge as to what R&D projects would be financially successful. In addition, neutral R&D should have allowed the accumulation of extensive and diverse experience and information. Once this knowledge was obtained and gathered, it could have indicated which industries and sectors had the highest possibilities of commercial success. However, the move away from neutrality by the Chief Scientist was not sufficient or optimal, since there was not enough effort made to collect, organize and analyze information on the OCS funding experience in the ten years earlier. Thus, the OCS could not predict ‘winners’ from the different industries which stalled this departure process as well. In conclusion, Teubal (1983) maintains that the system provided support for specific R&D projects with ‘commercial prospects,’ and promoted the “emergence of new, usually young, technologically sophisticated entrepreneurs” (p.196).

Breznitz (2007a) provides a more enthusiastic point of view, indicating that Israel’s Horizontal and neutral technology R&D policies were the ones that stimulated the successful growth of its IT industry, while having a competitive advantage from its R&D capabilities. He adds that during this period, most entrepreneurs were former government employees, or the government was first and main client of the inventors, or government employees were the inventors themselves. For example, Amdocs, a global

telecommunications leader was established in 1982 by a team that worked for the Israeli Postal and Telecommunications Ministry. Another company called 4th Dimension, that later changed its name to New Dimension, was founded when a software technologist in a military intelligence unit acquired the technology from the Ministry of Defense, "in exchange for a promise to update and maintain it" (p.1473, footnote 11).

4.2.1.6 Intellectual property rights (IP)

Avidor (2011) states that Israel was signatory to all major treaties of the World Intellectual property Organization, including the Berne Convention, Paris Convention, Patent Cooperation Treaty; and later on it also joined the World Trade Organization's Agreement on Trade-Related aspects of Intellectual Property Rights (TRIPS). This allowed Israeli inventors to enforce patents in any country within the signatory group. Pugatch et al. (2009) discuss that in 1988, Israel added software to its protected copyrights, giving inventors 70 years protection (cited in Avidor, 2011, p.51). According to Avidor, this strong Intellectual Property enforcement was important for Israel's high-tech development.

4.3 THE 1990s and 2000s

A few factors that proved crucial for Israel's IT industrial growth were already in place. The three most important were the continuous growth of an educated workforce and a highly capable university research sector, a small but expanding R&D sector, and a national ideology that gave very high status to science and technology (with scientists having easy access to political leaders) (Breznitz, 2007b, p.44).

4.3.1 Government's structure and role

According to Breznitz (2007b), compared to other development countries, Israel's government has a 'chaotic and flexible structured bureaucracy' (pp.8, 44), with the objective of establishing a balance between bureaucracy and politicians being able to

implement their will. In this way, Deri (1993) and Sharkansky (1989) point out that the Israeli bureaucracy functions in a similar way to the United States bureaucracy, where the Israeli government structure gives political leaders the power to implement their views through policies, in a similar way that the United States civil service does (cited in Breznitz 2007b, p.44). For example, Breznitz (2007b) points out, politicians hire top executives from outside of the government structure - from industry, such as director generals of state ministries, which have influenced the Israeli "politics of industrial development" (p.8). These government-industrial relations resulted in the growth of the "IT industry as a national interest" where developing and implementing policies was done "with relative ease" (p.44). In this way, Israel's "co-evolution of state-industry relationships" (p.49) was driven by private entrepreneurs who propelled policy decisions, including the financing of R&D ventures, starting with the recommendations of the Katchalski's Committee in 1966**,** and the government's early attachment to industry.

The Israeli Ministry of Trade and Industry implements what Breznitz (2007b) calls a porous borders strategy, where the ministry uses a "revolving door recruitment-and-training strategy, enabling scientists and industry leaders to move back and forth from state to private industry" (p.32); and where there is a free flow of information and influence as well (p.33). As the OCS became 'embedded' within the industry, it created strong networks, where relationships were considered as equal; where the role of the government was as a facilitator versus a planner and leader, creating a state-industry co-evolution (pp.34, 40). This state-industry co-evolution took place by the government shifting its initial direct involvement in creating the industry, from a "position of power to one of support" (p.19); to one where Israel's old model was based on the government having the authority and responsibility to guide and control the country's industrial development, to one where, according to Breznitz (2007b), the OCS assisted in materializing the choices made by industry through neutral and horizontal policies, and by providing R&D grants for products and programs for different development stages (pp.34-35) as it is described below.

Breznitz (2007b) explains that by the end of the 1990s the OCS became more institutionalized and supervised through the Parliamentary Committee for Science and Technology (a public committee), that nominates individuals for the chief scientist

position, and becomes more transparent in its activities. For example, today the OCS is the most transparent organization in providing information about its activities when compared with those of Ireland and Taiwan (pp.77-78).

In the 1990s, Getz and Segal (2008) note that the OCS implemented several programs, which it revises on an ongoing basis. Trajtenberg (2005) and Teubal, (2013) discuss that two of the most important programs are the Public Technological Incubator, established in 1991, which helps new entrepreneurs, mainly immigrants from Russia, to develop technological ideas and commercialize them; and the MAGNET, established in 1992, which stimulates cooperation between industry and academia, complementing the activity of Technology Transfer Offices. These two programs still exist today.

4.3.1.1 The Public Technological Incubator Program

Maital et al., (2008) define a business incubator as a "programme aimed at keeping 'infant' entrepreneurial companies warm and safe, through a variety of support resources and services, until they are strong and mature enough to leave the incubator and thrive on their own" (p.2). Trajtenberg (2005) and Avidor (2011) indicate that many Russian immigrants in the 1990s had ideas for innovative products but did not have knowledge of western commercial practices, managerial ability, access to capital, and no Hebrew or English language skills. The objective of the Incubators program, as described by Breznitz (2007a) and Breznitz (2007b, p.79) was to train new entrepreneurs, including Russians, to become successful by providing management skills and resources; help them to raise very early stage financing; assist Russian immigrants to find work and integrate them into the Israeli capitalist society; and secure VC financing for companies after two years. The same as with other OCS programs, the selection of incubator projects was neutral and market-based. Trajtenberg (2005) and Avidor (2011) add that although this program targeted new immigrants, it was open to everyone; and Maital et al. (2008) further point out that about half of the projects implemented were the ideas of Russian immigrants.

Between 1991 and 2013 the Incubator Program assisted over 1,900 projects; establishing 70 to 80 new startups every year; and with over 1,600 companies graduating from the incubators during this period. Of these graduates, 60 percent raised private

investments, and by the end of 2013, approximately 35 percent of the incubators graduates were still operating. The total cumulative private investment in graduated incubator companies was over US$4 billion. For every dollar the government invested in an incubator company, the startup raised an additional US$5 to US$6 dollars from the private sector (Ministry of Economy and Industry, n.d.a).

According to Breznitz (2007b), the impact of the incubators has been a change in technologists' and scientists' preference in becoming entrepreneurs; and during the 2000-2003 economic crisis, the incubator program produced more than one hundred startups per year, proving to be independent of VCs (p.79). Moreover, as of 2003, a few VCs only acquired and managed a small number of incubators (p.79).

By 2010, twenty three of the 26 existing incubators had been privatized, and therefore changed from non-profit organizations to for profit companies. The goal of the privatization process was to increase the participation of private investors in incubator activities, including the incubator owners, while the government's financial support did not decrease. The program has an annual budget of about US$50 million, with an average of 160 to 200 projects at different R&D stages, providing entrepreneurs with office space, business support and administrative assistance (Ministry of Economy and Industry, n.d.a).

Same as with other OCS programs, in order to qualify, projects must develop a new idea with export potential. Projects receive two year grants of between US$500,000 to US$800,000, depending on the field of the project; and projects in peripheral incubators get an additional US$125,000. The incubator finances 15 percent of the total budget; the government finances 85 percent as a grant; and its royalty payments are based on success (Ministry of Economy and Industry, n.d., Technological Incubators program).

Avidor (2011) indicates that the incubator program increased the probability of success (p. 43). However differently, Maital et al., (2008) argue that "by providing a warm and safe environment" (p.4), the new ventures do not feel the urgency and the pressure to enter the market, something that non incubator startups experience from the beginning, and which is a cause of failure of many incubator projects.

Rothschild and Darr (2005) examined the informal networks of innovation in an incubator located within the Technion, called the Technion Entrepreneurial Incubator Company (TEIC), a subsidiary of the Technion. It includes the incubator's entrepreneurs,

Technion staff and industry, and it examines how, within this linear innovation model, information flows back and forth through the social networks during the innovation process. The incubator provides a bridge between the university and industry, while also being part of a broader innovation network as explained below. The authors argue that this is one of the most successful incubators managed by the government, and its projects have been commercially very successful (p.67). [17]

This incubator functions within three environments: academic, government and industry, as explained by Rothschild and Darr (2005). For example, the government implements restrictions on the size of the initial project, number of staff in each project, reports to submit, funding provided, and so on. Many incubator personnel have a degree from the Technion and they continue to consult with faculty members, transferring information to the Technion and back to the incubator's projects. Also, some employees work in both, the incubator and the Technion as professors and researchers creating a similar information and knowledge exchange. In this way, project employees with industry experience transfer their knowledge to the university and back to industry. Industry experts are consulted regarding the need of incubator projects in specific industry sectors and the projects "imitate organizational structures and procedures" (p.62), according to successful companies in the field. Nevertheless, as Rothschild and Darr (2005) discuss, the advantages of the formal affiliation of the incubator with the Technion, a prestigious research university, include assisting projects to obtain scientific credibility due to the Technion's reputation, and meeting international investors by displaying the incubators internationally, by showcasing them in international events and in its newspapers which reaches international audiences. Alternatively, the incubator turns "knowledge into practical solutions and economic gains" (Rothschild and Darr, 2005, p.65); and through the involvement of academics in the 'real world', it also helps them to publish articles. In this way "the incubator enriches the theoretical and practical realms" (p.65).

[17] According to my interviews, this incubator does not belong to the Technion anymore since it has been privatized (Interviewee A1).

a) Influence of national culture

In their study of incubator programs in Israel and India, Maital et al. (2008) discuss how national culture has a strong mediating effect between incubator operations and processes, and with the national and international business environment. For example, Israel has “a powerful risk-favouring entrepreneurial culture that stems in part from the country's history, as a small embattled nation with few resources, forced to improvise in order to survive” (p.4). However, this culture that favours improvisation may be a problem since the transition from an incubator project to an organized business requires a “disciplined operational process” (p.4). Notwithstanding this, Maital et al. (2008) also found that in Israel, the capabilities of senior management teams and leaders are the main success factors of incubator projects. Nevertheless, in their study of the Van Leer Technology Ventures incubator, located on the campus of the Hebrew University, in Givat Ram, the authors found that although human capital was the key success factor, the main criteria during the selection process were innovativeness and feasibility, while human resources were secondary.

Similarly, in their study on success of Israeli high-tech startups, Chorev and Anderson (2006) found that success is critically dependent on the core team commitment, which had the highest ranking in their study, since people are the ones who create success. Core team commitment involves “team motivation and association with the startup goals” (p.170), and quality of the R&D team.

4.3.1.2 The MAGNET program

Avidor (2011) and Teubal (2012a) discuss that the MAGNET program (acronym for pre-competitive generic technology) was established in 1992 to support generic or pre-competitive R&D, which pre-dates the development of commercial technologies or products, and its discoveries cannot be patented. This takes place within a consortium that involves several private firms, including defense companies, all of them operating in a specific field, and at least one academic research institution, that conduct relevant research, in order to learn from each other’s knowledge. A foreign company can also participate in a project if it brings a unique contribution to the consortium. An example is

Britain's Consensus Business Group, which participated in the Eilat-Eilot Consortium, mentioned in the previous chapter. Vekstein (1999) explains that Grants to business partners are 66 percent of R&D costs and to the academic partners are 80 percent of R&D costs. These grants are partially financed by the Ministry of Defense, and when there is a technology developed that can be used for defense purposes the Ministry of Defense can take control of it.

Breznitz (2007a) indicates that the MAGNET program addresses two problems related to later stages of start-ups. First, most Israeli firms are too small to conduct ongoing R&D and compete with MNCs; and second, there has been a lack of exploitation of Israeli academic research. Teubal (2013) further states that this program increased the flow of information and transfer of knowledge by stimulating R&D cooperation between private and defense industries, and academia, which "strongly complemented the growing activity of Technology Transfer Offices (TTOs) at major Israeli Universities" (p.15). Avidor (2011) argues that in 2000 there were 18 MAGNET consortia operating in several R&D fields, and four of them included defense organizations. Today, "one out of three MAGNET consortia includes a defense company" (Interviewee G5, personal communication, August 16, 2016). Vekstein1(999) mentions that one of the consortia, ConSolar established in 1995, involved in solar energy R&D, included the Ben Gurion University, the Weizmann Institute, the Tel Aviv University, the Israel Aircraft Industry, and Ormat Technologies, among other private firms.

Breznitz (2007a) asserts that MAGNET has been crucial for the software industry by providing access to knowledge areas and to markets that otherwise would be out of the industry's reach or that it would not understand; and to developing new technologies and products not able to do on its own. However, a different view is presented by Vekstein (1999), who argues that the MAGNET program involves mainly the largest defense firms in Israel and the wealthiest industrial companies. These firms are members in several networks, and are developing dual technologies for military and civilian applications by using a large pool of knowledge which benefits only those few wealthy firms. Vekstein (1999) gives an example of how, the state owned company, Israel Aerospace Industries (IAI), has transferred its military aviation knowledge to various civilian commercial programs, for example to the global civilian aircraft market.

Vekstein (1999) also indicates that MAGNET allows the Ministry of Defense to control R&D that can produce military technologies. Instead of the MAGNET program**,** the author suggests a centralized national technology policy that would address the transfer of technology and implementation accumulated by the defense industry, through an open process of collective learning across all industries, and which would stimulate Israel's economic growth.

Other significant programs established by the OCS are:

4.3.1.3 The MAGNETON program

Frenkel et al. (2011) and Getz and Segal (2008) argue that the MAGNETON program provides technology transfer support to an existing relationship between an academic institution and a company for up to two years, with a grant of 66 percent of R&D costs, and up to US$800,000 in funding; while royalty payments are not required (Ministry of Economy and Industry, n.d., About).

4.3.1.4 The NOFAR program

Frenkel et al. (2011) note that the NOFAR program for industrial application of academic research, bridges the gap between basic and applied research in bio and nano technologies, medical devices and energy storage, by supporting applied academic research up to one year, that is of business interest and is supported by industry, but not yet directed to a specific product, with the objective of transferring the technology to industry. Nofar grants are up to 90 percent to projects, and royalty payments are not required.

4.3.1.5 The MAHAT program

Frenkel et al. (2011) indicate that the MAHAT - acronym for Government Institution for Technological and Scientific Training, was created to incorporate mainly ultra-orthodox Jewish men, and mostly women from the Arab population into the workforce, since they have a religious education or an education that is not applicable to

the workforce. A successful example is that about 20 percent of the 600 employees in the Jerusalem division of Intel are ultra-orthodox men who have graduated from the MAHAT program.

4.3.2 Universities' Technology Transfer Offices (TTOs) and research institutions

Getz and Segal (2008) indicate that the technology that comes out of the universities belongs to the universities and not to the researchers and inventors. Royalties from patented technologies are usually divided between inventors and universities, for example, the Ben Gurion University gives 60 percent to inventors; the Technion 50 percent, and the Hebrew University 30 to 35 percent. As pointed out earlier, Israeli Universities are also closely involved with the MAGNET, MAGNETON and NOFAR programs established by the OCS to create partnerships and technology transfer between them and industry.

Meseri and Maital (2001) conducted a survey of Israeli Universities` TTOs to identify how these evaluate projects, since the authors argued then that Israel had a problem with its technology transfer. The authors argue that although Israel is a world leader in the productivity and intensity of its basic research in science and technology, it lagged behind in its ability to transfer technology and commercialize it. An example was in its trade deficit "in recent years" (p.115), at 10 percent of GDP. Also, according to the 2000 IMD report, Israel ranked 41st in "company-university cooperation" and 40th in development and application of technology (cited in Meseri and Maital, 2001, p.115). Meseri and Maital (2001) further argue that a significant amount of basic research was conducted by Israeli universities, while only 10 percent of "civilian R&D resources…(were) allocated to universities" (p.115). Kalman (2008) also describes that according to his interview of Nava Swersky Sofer, CEO of Yissum, there is an increase in industry research funding, which accounts for 10 percent of the Hebrew's University research spending, being positive for both sides, since government funding for university education is decreasing.

Therefore, Meseri and and Maital (2001) concluded that Israeli universities conducted a disproportionately large portion of basic research, and assumed that the

problem lied within the transfer of technology from universities to the private sector (115). However, the authors found that the selection criteria of Israeli TTOs for projects, was similar to that of VCs and of MIT, a university with very aggressive start-up policies. Their findings showed, the same as VCs, that regarding the question on the projects' potential contribution to Israel's national economy, it ranked low on importance, while their focus on market was high. Similarly, according to Chorev and Anderson (2006), VCs are concerned with quick exits and not with benefiting the whole country. According to their survey findings, Meseri and Maital (2001) concluded that if Israel did have a transfer of technology problem, it was not in the process. They indicate that "Technology transfer is a complex process involving the diffusion of basic research and its ultimate commercialization" (p.122). In order to understand all the phases of the process, the authors point out that it is necessary to study the interactions among all related stakeholders, such as government, industry and university scientists, rather than only its TTOs.

4.3.3 Industrial research and development (R&D)

Breznitz (2007b) argues that while Israeli firms had "the ability to secure a technological edge and react quickly to changes" (p.66), alternatively, they lacked skills in professional management, long-term planning, and business development skills. Furthermore, what the IT industry was missing in order to grow was Venture Capital financing, business management skills and information on international markets, since although a few successful Israeli firms were familiar with the US and its financial markets, "there was no systematic sharing and dissemination of that knowledge" (Breznitz, 2007a). As Teubal (1993) proposes, for this to happen, Israel needed a bureaucratic leader with the courage to promote this change.

4.3.3.1 The Venture Capital Industry (VC) – The Yozma program

Teubal (2013) stresses that Yigal Erlich, the founder of the very successful Israeli Venture Capital Industry, in the late 1992, was a government entrepreneur who

implemented ‘out of the box’ and long term policies. Espinoza and Vredenburg (2010a, 2010b) would refer to Erlich as an Israeli bureaucratic champion.

Avnimelech and Teubal (2006) and Avidor (2011) argue that Erlich convinced the government to create a US$100 million government-owned fund of funds, called ‘Yozma Funds,’ within the OCS. Yozma invested $80 million in 10 private VC funds: $8 million in each fund, and $20 million in the Yozma Venture Fund that was owned by the government. Teubal, 2013 explains that each one of these VC funds was required to partner with one or more foreign private equity firms, an Israeli bank, and create a limited partnership (LP). Each VC fund received 40 percent funding from Yozma and 60 percent funding from the private VC investments, while the 20 percent (US$20 million) owned by the government was directly invested in the VCs’ startups. Teubal (2013) and Avnimelech and Teubal (2006) discuss that the VC funds had the option to purchase the 40 percent of the government’s share within five years at a price that included the principal amount and 5 to 7 percent interest. The OCS raised another US$150 million and invested all that money in about 200 startups. This VC model had been successfully adopted by startups in the United States (US). Breznitz (2007b) notes that in Israel, similarly to the US, the characteristic background of the VC partner is as an entrepreneur or manager of an R&D firm while in other countries, such as Ireland and Taiwan, they do not have entrepreneurial or IT management backgrounds. Breznitz (2007b) further points out that due to its success, Yozma became a model for VC policy worldwide, with a high level of professionalism and education provided by venture capitalists.

As indicated earlier, Breznitz (2007a) and Avnimelech and Teubal (2006) state that a main goal of the Yozma program had been for the Israeli fund managers to acquire knowledge and expertise by partnering with foreign firms, and Foreign VCs brought management talent, international contacts and counselling. Avidor (2011) mentions that at the same time, in his position as Manager of the Yozma Directorate, Erlich encouraged informal advising and network interactions by participating in all fund board meetings and co-investing in high-tech companies among Yozma funds; and as Teubal (2013) describes, fulfilling Yozma’s original strategic goal of generating a “process of collective learning” (p.14) in management and business skills. Differently from Israel, conventional

policy implemented by other countries supports efforts such as subsidies and government owned VCs.[18]

Two unique features of the Israeli Innovation System, as described by Breznitz (2007a) are that over 50 percent of its VC comes from US investors, and that the business model of Israeli firms is geared towards an Initial Public Offering (IPO) on Nasdaq or being acquired by a US company. Israel's international high-tech reputation improved with each successful IPO and corporate acquisition, and as Teubal (2012b) indicates, there were 91 acquisitions in Israel between 1993 and 2000. During this time, Avidor, (2011) indicates that foreign investment banks and foreign VCs opened local offices in the country, and Multinational companies (MNCs) such as IBM, Cisco, Intel, Nokia, AOL and others, invested in Israeli VCs, and access to global information through these organizations resulted in better decision-making and learning. Breznitz (2007a) also maintains that in addition to Yozma's goal of obtaining VC financing for Israeli firms, its second objective was to systematically educate the Israeli high-technology industry on the US financial markets.

Drawing a comparison with other countries, Teubal (2013) points out that between 1993 and 2000 Israel had a high share of Early Stage VC investments, where more than 50 percent of VC investments were allocated to early startup stages versus 25 percent in the US and about eight percent average in all other OECD countries. Also, Israel had the highest VC investment per GNP at 0.7 percent, versus the US at 0.48 percent, and less than 0.35 percent in all other OECD countries. Israel also had about 90 percent of VC investments in ICT and Life Sciences versus approximately six percent in the US. Israel had as well a significant share of VC entrepreneurs with Science and Technology education and high tech background, versus the European Union (EU) with mainly financial background; and versus the US, where they were equally divided between financial and science and technology experience. For example, nine of the ten Yozma funds had at least one partner with science and technology education, while only two funds did not have partners with high tech experience. In addition, most Israeli exits were

[18] Israel had such a program, called Inbal that supported Public VC funds, raising capital at the Tel Aviv Stock Exchange. The program was established in 1992, but it failed within a year. The OCS learned from this failure, and in 1993 Yozma was established (Teubal, 2012; Teubal, 2013; Breznitz, 2007a).

in IPOs in NASDAQ, with more than 120 IPOs during this period, being the highest number after the US and Canada, while 50 percent of these were VC-backed. Differently, Trajtenberg (2005) indicates that Israel was the foreign country with the largest number of IPOs in NASDAQ, with Canada coming a second close, while Breznitz (2007b, p.37), the same as Teubal (2013), indicate that Israel came third after Canada.

Teubal (2013) points out that the benefits presented above took place because of Israel's government "timely and well designed (VC) policies" (p.41). He also argues that Yozma was radical and unique in its approach to VC policy, creating a VC-Startup co-evolution, and as indicated above, achieving its goal of creating a "strong process of collective learning" (p.14).

Breznitz (2007a), and Avnimelech and Teubal (2005) (cited in Trajtenberg, 2005, pp.20-21), explain that together with the VC industry, the number of startups grew significantly, from four VCs in Israel in 1992, to 50 in 2000, and to 70 in 2004; with investments of US$8 to US$10 billion, and with the creation of 80 funds, all by the end of the year 2000. Breznitz (2007a), Breshanan et al. (2001, 2004) (cited in Teubal, 2013, pp.3,17), and Prof. Peretz Lavie (Personal communication, July 16, 2014) discuss that in 1993 Israel had about 300 startups, many of them of high quality, and by the end of the 1990s it had 2,500, and 6,500 in 2014. Breznitz (2007b, p.81) and Teubal (2013) further describe that these developments created Israel's economic growth in the 1990s, and especially between 2004 and 2007; and according to Avnimelech and Teubal (2005), establishing a world record of VC-backed investments of 2.7 percent of GDP in 2000 (cited in Trajtenberg, 2005, pp. 20-21). Avidor (2011) adds that in this way, a positive feedback loop was created, with a correlation between VCs and the number of startups from 1991 to 2003. According to Trajtenberg (2005), in the 1990s the average growth rate of the ICT sector was 16 percent per year, increasing from five percent of GDP in 1990 to 14 percent in 2000; ICT exports in the 1990s increased by a factor of 6 to $15 billion in 2000, representing one third of Israel's total exports.

Avnimelech and Teubal (2006) discuss that in order for a VC industry to emerge there must be a demand for VC services, and timing of the policy is important. Taking Israel's model, as Teubal (2013) points out, although in Israel there were about 300 start-ups in 1993, which was a high demand for VC services, this demand alone would have

probably not created the VC supply without Yozma, which it indirectly targeted an entrepreneurial ICT-oriented, high-tech cluster (EHTC). Both, the early phase VC industry and the promotion of R&D intensive industry became the government's strategic priorities, and these eventually created a VC/ICT/EHTC. Furthermore, in order for startups to survive and move forward, they must have access to experienced early stage VCs. The reason being, that mature stage VCs are more financially oriented, while experienced early stage VCs are more interested in cutting edge technologies.

Teubal (2013) proposes that in order for economies to succeed with a VC strategy, governments must design and implement out of the box policies such as networking and linking with successful nationals living in the diaspora, as Israel did by consulting with successful Israeli nationals – individuals and companies, in the Silicon Valley who provided mentoring. Also, by being flexible and responsive to change, and by enhancing the reputation of the cluster, which in the case of Israel took place through the MNCs in the country. This process requires an entrepreneurial policy maker, who is willing to take risks, such as Erlich did, if the social benefits are high. However, out of the box policies may be difficult to implement in "normal times," but there may be a window of opportunity to implement such policy, as it happened in Israel with the Soviet Immigration in the 1990s. Avidor (2011) points out that from its establishment in late 1992, Yozma was expected to be in place for seven years, but due to its success it ended its activities in 1997 when it was privatized; and in 2002, five funds exercised their option on the government's 40 percent.

4.3.3.2 Multinational Companies (MNCs)

Many, if not all United States (US) Multinational Companies (MNCs), as Breznitz, (2007a) presents, opened R&D centres in Israel, or acquired Israeli high-tech companies and turned them into R&D centres. As well, many founders and managers of Israeli hardware companies are former MNC employees; many venture capitalists also have experience working with MNCs in Israel and overseas; and VC divisions of MNCs are closely involved with the Israeli industry. Today, according to Breznitz (2007b), most MNCs enter the Israeli high-technology market by acquiring Israeli companies and turning them into their own R&D centres, while in the past they would open their own

R&D centres. As an example, Breznitz (2007b) cites an interview with a VP of an American MNC who indicated that in 2000 the company was very attracted to Israeli technology, and that Israeli firms were developing something of every technology in which this American MNC was interested. According to this VP: "Israel is the capital of the 'rest of the world" (p.91).

4.3.4 Intellectual property – patents and licenses

Breznitz (2007a) argues that Israel has one of the fastest growing patents per capita in the world. Trajtenberg (2001) examined Israeli patents filed in the US, where 7,000 Israeli patents were issued between the 1960s and 1990s in the NASDAQ, since Israeli technology is developed mainly for export**.** Trajtenberg's (2001) patent analysis shows that there is a strong parallel between the OCS policies and the global patenting of Israeli firms, where increases in Israeli industrial R&D spending result in increases in patent filings by about one to three years, while the opposite is also true. Furthermore, since the emergence of the high-tech sector in Israel was strongly driven by OCS policies designed to support industrial R&D, Israel's patenting strength is in biotechnology, computers and communications.

With regards to who owns the rights and controls the Israeli inventions and will benefit economically from them, according to Trajtenberg (2001), the patent trends showed that in the 1990s the percentage of Israeli assignees was about 60 percent and of foreign assignees (multinational companies established in Israel since the 1960s) was more than 20 percent –from two in 1968 to 70 in 1995. This means that MNCs established in Israel are competing for Israel's most important resources, which are its human capital, its technologies and intellectual property. According to the Technology Assessment and Forecast (TAF) Branch, 2002, the US semiconductor multinationals are very active in Israel, and Intel, Motorola and IBM, and Israeli Universities have produced the largest numbers of international patents (cited in Breznitz, 2007b, p.86). However, University patents have a lower probability of being commercialized than those issued by the corporate sector. As Trajtenberg (2001) explains, within Israeli patents, about 50 percent belong to the corporate sector, with the highest probability of getting commercialized, versus university patents, and unassigned patents, of individual inventors

working on their own who "have not yet assigned the rights of the patent to a legal entity at the time of issue, [19] and with a lower probability of being commercialized.

Trajtenberg (2001) adds that in 1999 Israel ranked third globally in patents per capita, after the US and Japan. However, Israel's absolute number of patents in 1999 was behind the G7 countries and the 'Asian Tigers,' and he questioned whether Israel's economy would be able to develop its high-tech sector for the long term and reap the economic benefits from those innovations.

4.4 WEAKNESS OF ISRAEL'S INNOVATION SYSTEM

4.4.1 Lack of long-term leadership and of large Israeli companies to benefit Israel's economy

Beznitz (2007b), concludes that Israel's strengths in its IT industry have been "superior technology and pioneering R&D" (p.92); and its weaknesses, as seen earlier, have been the lack of market knowledge and, often, management skills, and difficulties in *"growing into true leaders in the field"* (92). Differently, Fortuna (2012) suggests that the management knowledge acquired by the ICT industry should be shared with Israel's traditional industries.

However, Breznitz (2007b) argues that Israeli companies do not have the experience and skills required to develop and keep their leadership position. Due to a lack of understanding in management and business skills, many Israeli companies cannot sustain their initial success for the long term, where "many market niches that were pioneered and controlled by Israeli firms no longer have any Israeli firms operating in them…it is extremely rare to see market niches where Israeli industry has had a long-term leadership" (p.43).

[19] "There are individual inventors who work on their own and have not yet assigned the rights of the patent to a legal entity at the time of issue, in which case the patent is classified as unassigned or assigned to individuals. For most patents, the inventors are typically employees of a firm, in which case the assignee is the firm itself… That is, the inventor herself may appear as the legal entity that owns the patent rights." (Trajtenberg, 2001, p. 375)

Furthermore, Breznitz (2007b) suggests that Israeli companies that use pioneering or technological leadership business models in a market niche, have a window of opportunity of two to four years to establish themselves in the market, before dealing with strong competition from MNCs and US startups that are better organized and with stronger financing, that enter Israeli niche markets. Also, when their products become commoditized, Israeli companies face competition from technologically advanced and cheaper players, such as the Taiwanese. In addition, although Israeli companies imitate the US startup model, they don't have the US infrastructure of MNCs.

Breznitz (2007b) explains that while the strength of Israeli companies is their ability to reinvent themselves, this may also be their weakness. Due to a lack of confidence in skills to survive competition, the strategies of Israeli companies are to change niches and products when facing strong competition, and to reinvent themselves "from one technology trend to another" (p.89), being difficult to achieve long term sustained sales and leadership; or to "agree to be acquired" by an MNC or another startup that has supposedly better management skills. Breznitz (2007b) gives Galileo Technology as an example. The company was listed on the NASDAQ, with 50 percent growth in annual sales since 1993 when it was listed; it was considered a top promising Israeli company and suddenly in 2001 it agreed to be acquired by a newer US startup that had lower sales. This situation has created a lack of large Israeli companies that would benefit the country's economy.

Teubal and Kuznetsov (2012) discuss that by the end of the 1990s, Israel adopted an antitrust legislation where monopoly was defined in regards to international markets and not to the local market, which would help domestic companies to grow. Nevertheless, Teubal (2013) specifies that Israel has not produced enough large companies able to generate important contributions to the country, while this has happened only partially. In addition, this situation is the result of a lack of a systematic approach to a policy that would reflect "an explicit new national priority" (p.42). However, as seen earlier, the Israel Innovation Authority (IIA), former Office of the Chief Scientist, is implementing new programs to help companies grow after their incubation stage, and large companies to become international.

4.4.2 Institutional and structural weaknesses

Breznitz (2007a; 2007b, pp.89, 96) presents two issues related to the fact that Israeli firms are far away from their international markets, resulting in institutional and structural weakness. The first issue mentions that Israel's strong focus on R&D may have limited the country's manufacturing capabilities, which instead take place overseas where customers are located. He sees a disadvantage of Israeli companies in not having a domestic IT manufacturing industry with which to work, a point that is also supported by Fortuna (2015). Second, the Israeli software industry developed a strong relationship with the United States market, which was also the main source of its huge success, and where its customers, investors and shareholders are located, while the Israeli market may become less important, and Israeli companies may transfer more of their activities to the United States.

4.4.3 Negative effects of the VC industry

Breznitz (2007b) presents the negative effects of the VC industry, such as quick financial exits, within five to seven years, especially those first time VCs that need to have a reputation in order to obtain investments for their next funds, as Trajtenberg (2005) also indicates. Although Israel has had a large number of IPOs in the NASDAQ, as mentioned earlier by Teubal (2013), Breznitz (2007b) points out that VCs prefer acquisitions to IPOs, since IPOs involve a more difficult process, and through acquisitions VC firms have no more obligations to the company.

4.4.4 Control by MNCs of the Israeli economy

The same as Trajtenberg (2001), Breznitz (2007b) explains that due to the high participation of MNCs in Israel's IT industry, they control a large portion of the intellectual property (IP) produced in Israel and an increasing portion of the industry's revenues and profits. Getz and Segal (2014) also found that in the last decade there is an increase of Israeli intellectual property transferred to MNCs, through their acquisition of Israeli companies and startups. This situation is more severe especially with those MNCs that run small R&D centres, since their short-term goal is usually to access the

technology or the IP developed by the local firm that they acquire. Differently, large and more established MNCs that have Israeli IP have extensive "spillover effects on the Israeli labour market and national economy" (p. 30), through demand for goods and services supplied in part by local companies.

Getz and Segal (2014) also found that there is an increase in transfer of technology and know-how from Israeli research universities to MNCs. The authors suggest that the government should control this trend by expanding MAGNET programs to include MNCs in its consortiums.

4.4.5 Creation of a dual economy

Trajtenberg (2005), Fortuna (2012) and Teubal and Kuznetzov (2012) discuss that despite Israel's high-tech success, the rest of its economy has had a slow growth. Trajtenberg (2005) describes that from 1996 to 2004 the ICT sector grew by an average of 10.5 percent per year, while the rest of the economy, which represents 85 percent, grew only 2.3 percent, and in many traditional sectors, such as transportation, construction, retailing and business services the total factor productivity declined. In addition, Trajtenberg (2005) and Fortuna (2012) indicate that the traditional sectors in Israel did not adopt the ICT technology, since it was not designed for them, and the two sectors did not interact, resulting in low total factor productivity. As Trajtenberg (2005) further specifies, this economic gap also resulted in a socio-economic inequality, creating a 'dual economy' (p.22). This situation may have an effect on the economic development with a decrease in the future availability of skilled labour, due to "the constraint on the supply side" (Israel Innovation Authority report, 2016). This fact mentioned by Trajtenberg (2005) is pointed out seven years later by Fortuna (2012) who states that Israel is faced with a shortage of engineers, and only the improvement of traditional industries will reduce the existing gaps in salaries and social gaps. To change this situation, the Israel National Authority is implementing a new six to 12 month program to train college graduates in the sciences, interested in a career in computer and programming (The Times of Israel Web site, July 17, 2017).

Trajtenberg (2005) further argues that in Israel, since most industrial R&D was developed for export it had little impact on the economy. Although Israelis probably

adopted some of the innovations, this was a secondary and not a primary effect, and spillovers took place mainly in the importing countries. For example, local labs of multinational companies conduct a substantial amount of industrial R&D, such as Motorola, IBM, and many others as well, accounting for about 15 percent of Israel's industrial R&D and 0.5 percent of GDP. Most of their knowledge and intellectual property (IP) is exported, with little spillovers to the Israeli economy, except to those with local suppliers, such as Intel, as Fortuna (2012) mentions; and Philips and Flextronics (Interviewee A7, personal communication, August 24, 2016).

Breznitz (2007b) adds that the Israeli business model makes it vulnerable, and Fortuna (2012) also discusses that an economy based on R&D only is unsustainable. Breznitz (2007b) discusses that Ireland and Taiwan achieved economic growth and equality while in Israel inequality in economic growth has increased, since a large number of Israelis have not benefited from the fruits of its remarkable IT success**.**

Trajtenberg (2005) recommends developing a domestic ICT industry, and establishing alliances with ICT multinationals in order to open the economy, which would further develop local technological skills, managerial knowledge, and "world-class standards in ICT," and trade expansion; all this with the intention of creating spillovers to the rest of the Israeli economy, but which cannot happen unless the government intervenes. In addition, innovation strategies should address not only the production of knowledge, but also its destination and economic impact.

4.4.6 An Alternative view - Teubal's Comments

Teubal (2013) provides comments on Trajtenberg's (2005) analysis above, and on other authors, agreeing on some issues and presenting alternative views on others.

4.4.6.1 Creation of a dual economy

Teubal (2013) agrees with Trajtenberg's (2005) concern for the lack of support by the OCS of R&D implementation in traditional industries, such as design, engineering, technology transfer, new production equipment, and others, which, according to Teubal and Kuznetsov (2012) created indeed a "dual economy and slow growth in the rest of the

economy" (p.209); and the fact that Israel should have adopted a wider R&D strategy than the existing one. As Teubal (2013) explains, the main reason for this outcome was that all OCS programs supported formal R&D in the high-tech industry and projects with commercial innovation potential, and not projects for the "adoption of new technology or user innovations" (p.40) of more traditional industries. The OCS became aware of this mistake, and with a late response, in 2005 it implemented the Traditional Industries Upgrade program. A deficiency in this program, identified by Teubal (2013), is that the program focuses only on R&D, instead of encompassing other factors such as engineering, technology transfer, design, and others.

Teubal (2013) also agrees with Trajtenberg (2005) in that the export bias of grants supported R&D, while the OCS should have also encouraged user innovation and adoption of new technologies for the domestic market. Therefore, the mistake of the OCS was in supporting economic growth, instead of encouraging inclusive economic growth. Nonetheless, Teubal (2013) affirms that both, foreigners and Israelis benefited from the R&D grants, which had a positive and huge macro and social benefits impact on Israel's economic growth and on its balance of payments, a fact that is also supported by Fortuna (2012).

4.4.6.2 Positive effects and benefits of MNCs

Differently from Trajtenberg (2005), Teubal (2013) discusses that there were benefits which resulted from the learning effects of Israelis working with MNCs, beyond managerial learning, and which had a strong impact on the R&D grants and the Yozma program. In addition, the export of Israeli innovations created capabilities within Israel such as knowledge and penetration of international markets. Teubal (2013) and Fortuna, (2012) argue that this acquired knowledge drove and created the right conditions for the emergence of the Venture Capital/ICT cluster in the 1990s. Nevertheless, implementing policies to improve supplier networks to MNCs, would have probably increased benefits as well.

Therefore, as Teubal (2013) discusses, since the Venture capital / Entrepreneurial High Tech Cluster (VC/EHTC) had a huge positive impact on Israel's economic growth in different areas, such as massive capital inflows, employment of highly skilled workers,

including new Soviet immigrants, the issue of foreign acquisitions of Israeli startups should be considered as a cost that made possible for these benefits to take place.

In support of Teubal (2013), Getz and Segal (2014) found that regarding large and well established MNCs operating in Israel, there is a two-way flow of innovation and knowledge, producing a positive impact on the Israeli economy in several ways. This includes creating demand for domestic goods and services, and technological spillovers to Israeli firms, mainly to startups. As well, junior and senior management levels of the Israeli high-tech industry learn the "organizational culture of giant multinational firms" (p. 30), and this learning experience improved the performance and efficiency of Israeli companies.

Teubal (2013) further points out that when the development of an entrepreneurial system, such as Israel's, is located in a developing economy, foreign acquisitions, backed or not by VCs, are a requirement for SUs to survive and move forward, especially when new markets are being consolidated. Also, IPOs in NASDAQ, are a way for companies to enter international markets and to start or speed up growth, such as some very successful Israeli companies did, for example the very successful company CheckPoint in the mid 1990s.

4.5 RECOMMENDATIONS TO STRENGTHEN THE ISRAELI INNOVATION SYSTEM

Fortuna (2012) indicates that presently Israel faces new global competitive challenges requiring the implementation of broad and flexible national policies for industrial innovation, where companies should be encouraged to invest in both, R&D and production in order to be successful. This is a fact since Israeli companies that invested in both, R&D and production were the most successful such as the TAMI Institute for R&D Ltd.[20] while those that invested in R&D or in manufacturing only, such as independent

[20] According to IMI TAMI's Website (2011), it "is a private company and the largest industrial chemistry R&D centre in Israel," (para.1).

state research institutions involved in fibre, plastics, rubber and ceramics, failed. Fortuna (2012) proposes that the OCS should take several steps as described below:

a) Israel excels in R&D, but R&D alone does not create economic success. Instead, innovation policies and government programs must address and include the full value chain as well as local manufacturing which "is an engine of national economic growth" (p.14). Production is important since it keeps the R&D institutions up to date on new manufacturing technologies, while also creating "employment opportunities across all the workforce segments" (p.36). Therefore the first recommendation is that R&D and production in Israel must be the government's national priority. As addressed earlier, Israel's globalization strategy encourages multinational companies (MNCs) to establish research and development (R&D) centres in the country. The Israeli government must implement policies to encourage the local manufacturing by MNCs of some of the Israeli discoveries, instead of exporting and producing all of them overseas. Of the large numbers of MNCs in Israel, Intel, which has a supply chain in Israel, is an example of how these should operate in the country. Intel has local manufacturing plants and also sub-contracts to traditional and high-tech industries in Israel.

b) Second, the government should promote the establishment of infrastructures, such as industrial and high-tech parks where industry-incubators, businesses, and academia work together and collaborate. Such arrangements would address the "importance of academia's contribution to research and the slow adaptation of academia-to-industry knowledge transfer" (p.4), by improving the relations between academia and industry and the transfer of knowledge to industry within Israel; also by linking the different industry sectors such as ICT, Cleantech[21] and traditional industries, and turning the country's R&D success "into manufacturing industries" (pp. 3, 36). Such an infrastructural example is the MATAM High-Tech Park in Haifa (Hebrew Acronym for Scientific Industries Centre), where "the municipality, the Technion, scientific incubators, startups and mature knowledge-intensive industries work together" (p.3).

[21] Cleantech also includes water and waste, which are not covered in this dissertation.

c) Third, assistance with raising funds starting at the proof of concept or beta site, during the incubator stage, and up to the establishment of a local company. Recommendations to strengthen specific Israeli industries include cleantech and ICT.

4.5.1 Recommendations for the cleantech sector (environmental sciences)

Fortuna (2012) proposes that the OCS take further steps as described below:

a) The Israeli government has assigned large R&D budgets to solve strategic issues related to the reduction of greenhouse emissions, and to finding alternative energy sources. According to Fortuna et al. (2015), this may be reflected in The Global Cleantech Innovation Index (2014) study, done by the Cleantech Group and the World Wide Fund (WWF), where Israel ranked number one in Cleantech innovation out of 40 countries such as Finland and the United States. However, Israel ranked number eight in its ability to commercialize its cleantech technologies. Nevertheless, this study places Israel in a better position, although it could certainly improve its performance, than that of the 2000 IMD Report where Israel ranked 40th in development and application of technology. As Fortuna et al. (2015) indicate that most Israeli Cleantech startups face some unique challenges related to financing during the transition from technology proof/beta site to the commercialization stage, while many do not get to the commercialization stage at all. Recommendations include creation of infrastructures for pilot projects/beta-sites and creation of conditions for sufficient availability of financing.

b) The cleantech sector needs a longer time interval between proof of concept and the attainment of a startup; needs to deepen the support for establishing relations and partnerships and target customers in the global arena, which could be achieved by accessing the knowledge already acquired by the ICT industry. There is also a need to complete regulatory processes allowing rapid build-up of the cleantech industry in Israel, and encourage the implementation of new innovations in order to establish a domestic "and export-oriented Cleantech industry" (p.7).

c) Penetrate emerging markets, especially India and China.

d) Encourage mature and traditional industries to participate and innovate in the Cleantech industry through local manufacturing.

In order to achieve the goals above, Fortuna (2012) suggests the government invest US $250 million over five years; about US$50 million a year, which will create much higher returns, with the goal of reaching within a decade US$20 billion in annual exports while creating 400,000 jobs. He also suggests that the Israeli government lead the early development of this industry, since private industry would not be able to compete in these international markets. As leader, the government must adapt the Chief Scientist (OCS) programs to Cleantech sectors; use its existing incentive programs to encourage private capital investment in the Cleantech industry as it has done with the Fuel Choices Initiative; and encourage the Israeli market to produce "innovative Cleantech solutions" (p.7), since it is a government priority.

4.5.2 Recommendations for the renewable energy subsector [22]

Fortuna et al. (2015) discuss that regarding the renewable energy subsector, startup companies face many challenges that are "unique to this sector" (p.3) such as high-capital investments and regulatory barriers among others. While renewable energy R&D gets a high level of support from the OCS, from the Ministry of Energy, and from incubators and VCs, same as other cleantech sectors, commercial demonstrations or Beta sites get little support from the OCS in terms of scale and funding; and only large scale projects with mature technologies get bank and corporate funding. Therefore the main commercialization barrier for renewable energy startups is funding once they reach the beta site and commercialization stages, although the technological risk at this stages is much lower than at the R&D stage.

Some of the recommendations by Fortuna et al. (2015) are:

a) The government should establish a joint capital fund with government and public support – banks and institutional investors, and private investors, available to new renewable energy projects based on Israeli technology that are at the commercialization stage and for the export market; and at an attractive interest rate when compared to market rates. This fund should invest in at least five projects a year, with an average of

[22] The original article is in Hebrew and the Executive Summary in English, which I used for my Thesis.

US$10 million on each project. The government's investment share should be not more than 50 percent and the remaining amount should come from corporate sources. As well, most of the increase in solar energy installations takes place in the developing countries, which have already become target markets for the Israeli renewable energy sector.[23] However, Israeli companies have also built solar fields in California, for example BrightSource Energy built the huge Ivanpah solar field in the Mojave Desert and is now building another major project in Israel's Negev Desert.

b) Israel has a lead position through its support of "exceptionally innovative developments and applications" (Fortuna et al., 2015, p.1) in the renewable energy generation field, due to the interaction and cooperation that exists between the defense and high-tech industries, and its entrepreneurship ecosystem. An example of such applications is the smart grid, off-grid power, and others. Therefore, Israel must take advantage of its strength in this sector; fully develop it, and achieve the benefits that its growth would provide to Israel's economy by creating employment, exports, "emissions reduction and energy savings" (p.1).

4.5.3 Recommendations for the Information and Communication Technology (ICT) Industry

As Trajtenberg (2005) explains, Israel's innovation success, mainly in Information and Communication Technologies (ICT), resulted from a coordinated, long-term government support strategy for commercial R&D, which took advantage of the potential of Israel's highly skilled labour force**.**

Furthermore, the ICT industry, which Fortuna (2012) calls the "crown of the Israeli industry," has been "the main growth engine of the Israeli economy" (p.32) in the last 20 years, and in "transforming the entire economy along with its own global success" (p.32). The ICT industry has propelled Israel into becoming a developed country and a member of the Organization for Economic Cooperation and Development OECD; and according

[23] For example, as explained by Srebrnik (2016), "Innovation Africa, an Israeli organization dedicated to improving the lives of rural villagers in Africa, has provided the people they serve with access to many Israeli technologies…(also the) Israeli firm Gigawatt Global began a project to increase solar energy capacity in Rwanda during February 2014."

to Trajtenberg (2001), will continue to be the "growth engine of the Israeli economy in the 1990s and in the future" (p.363).

Some of the largest Israeli ICT companies representing this industry are Check Point Software Technologies Ltd., with headquarters in Israel; Amdocs, with headquarters in Israel and the US and an office in Ontario; and ECI Telecom Ltd., among others, together with a large number of medium, small and startup companies. However, a serious problem is that in the last 15 years, most Israeli ICT companies, with very high potential, have sold their technologies to MNCs instead of growing into large Israeli global companies.

Today, global market changes could threaten Israel's high-tech competitive advantages. Fortuna (2012) identifies several barriers to the "sustainable growth and leadership" (p.9) of Israeli high-tech industries which are: shortage of engineers, an issue that was mentioned seven years earlier by Trajtenberg (2005); decreased available capital; and "early exits and sale of promising technology companies abroad" (Fortuna, 2012, p.9).

Fortuna (2012) recommends that the government should promote and support the growth of the ICT industry through the following strategies: **a)** expanding the existing manufacturing plants, instead of companies selling their discoveries and transferring their production overseas; **b)** funding 1,500 engineering students per year "for at least the next five years," with an approximate cost of US$30,000 per student per year, and a total of US$45million; **c)** increasing the OCS budget by at least 15 percent per year in the next five years, by US$250 million; offering "tax credits and other incentives for mergers and acquisitions by and between Israeli companies" to create economies of scale (p.9).

4.5.4 The strength of the Israeli culture on its Innovation System

Fortuna (2012) proposes that the four main innovation drivers of a National Innovation System are culture; institutions - including policy; infrastructure - scientific, educational and physical; and resources – human and physical capital. Therefore, National Innovation Systems and their policies must align and be consistent with their "national culture and institutions…(as) every country has a given number of innovation 'drivers' – processes and capabilities that underlie its innovation success" (p.33). In the

case of Israel, its sources of “innovation lie deep in the history and culture of the nation, and reflect a foundation that does not become obsolete” (p.35) since the country’s top cultural innovation drivers are: resilience, creativity, stubborn persistence, role models, entrepreneurship, desire to change the world, and no fear of risk. According to Fortuna (2012) these are the sources of Israel’s “innovation performance and policies” (p.33), qualities that will continue driving the innovation of its high-tech industry.

Therefore, as Fortuna (2012) asserts, Israel’s institutions that promote innovation are also exclusive to Israel. For example its military support for R&D, the Office of the Chief Scientist, its Law for Encouragement of R&D and others, are essential to Israel’s innovation and should be proactively monitored on an ongoing basis. He also found that innovators thrive in a democratic society, such as Israel’s, that “offers opportunities outside the conventional educational system” (p.34) to exceptional entrepreneurs who break the rules of, and are rejected by the “formal traditional educational system. Only a society and economy that offer opportunities to innovators outside the conventional system will fully exploit its creative potential” (p.34).

4.6 CONCLUSION

This chapter examines the main institutional strategies of the Israeli Innovation System, including the interactions among its government, industrial and academic institutions. Although there are different points of view on the policies and programs of the Office of the Chief Scientist (OCS), some more positive and others more negative such as on the Israeli Venture Capital (VC) industry, Multinational Companies (MNCs) operating in Israel, University Transfer of Technology Offices (TTOs), the incubators and the MAGNET program, where one of the views considers MAGNET as a program that benefits only the large and wealthy participating firms and the defense companies, nevertheless, these policies did achieve their implementation objectives. At the same time, the OCS also tends to be proactive by revising an on an ongoing basis the several programs it has implemented.

As examined, the Yozma program drove the successful creation of the Israeli early phase, high risk, VC industry. Another example was the OCS objective of Israeli high-

tech startups becoming familiar with the US and its financial markets, where today they compete successfully for US investments. Israeli policies to attract Multinational Companies have also been very successful, since all American Multinational companies, about 300 of them, in the ICT industry have established research centres in Israel, and some of them manufacturing plants as well. The combination of all these policies and strategies propelled the rapid economic growth of Israel and to become a member of the Organization for Economic Cooperation and Development (OECD) in 2010.

Universities' TTOs became increasingly successful as well, and also by participating in the OCS programs such as the MAGNET, MAGNETON, NOFAR and others, increasing university-industry cooperation. We can see this progress from the 2000 IMD report that ranked Israel in 40th place in its commercialization of technology, to number eight in its ability to commercialize its cleantech technologies, according to The Global Cleantech Innovation Index (2014) study, done by the Cleantech Group and World Wide Fund (WWF). However, a study found that although TTOs have an efficient transfer of technology process, they were not as successful as VCs probably because the universities conducted mostly basic research.

Although there are different views on the incubator program, the Technion Entrepreneurial Incubator Company (TEIC) is presented as very successfully acting as a linear bridge between industry and academia. Nonetheless, all incubators, including this one, have been privatized, and it does not belong to the Technion anymore (Interviewee A1). The Israeli culture has also played an important role in Israel's entrepreneurial success through the capabilities of senior management, team commitment and a risk-favouring entrepreneurial culture.

Notwithstanding the successes of Israel's economy, the OCS policies and programs present some weaknesses as well that need to be addressed. For example, as a study explains, Venture Capital firms look for quick exits within five to six years, while focusing on international markets and not on the contribution of their projects to Israel's economy. University TTOs, the same as VCs, focus on the International markets where they transfer their technologies, and not on benefitting the Israeli economy. The export of innovation has had additional negative consequences in Israel as well, by creating a

growth gap between Israel's high-tech industry and the rest of its economy which had a slow growth, and resulting in a dual economy with socio-economic inequality.

The Israeli culture favours improvisation as well, an Israeli cultural survival trait, but that may be a problem once the incubator projects transition to disciplined and organized businesses. In addition, while the strength of Israeli companies is their ability to reinvent themselves, a weakness may be their constant change and reinvention, and their acquisitions by foreign companies, instead of being able to grow.

Also, while renewable energy R&D gets a high level of support from the Office of the Chief Scientist (OCS), from the Ministry of Energy, and from incubators and venture capital firms (VCs), commercial demonstrations or Beta sites get little support from the OCS in terms of scale and funding. Only large scale projects with mature technologies get bank and corporate funding.

Several recommendations are provided to strengthen the Israeli Innovation System. The most pressing ones being the government's national priority to implement policies encouraging MNCs to conduct both local R&D and manufacturing, which would include local supplier networks that would create a more inclusive economic growth and benefit the Israeli economy; promoting the growth of small and medium sized Israeli companies to expand existing manufacturing plants and local manufacturing; and offer incentives for Israeli mergers and acquisitions (M&A), among others.

A strong government role is also needed in supporting startup companies, starting at their proof of concept or beta site, during the incubator stage, during their 'Valley of Death' transition and up to the commercialization stage. Solar energy should also consider the developing countries where there is an increase in solar energy installations and which are already a target for Israeli companies.

As an author concludes, Israel has had 20 years of very successful economic growth through the right innovation policies and programs, but now it is time for change. Now Israel must 'innovate' its National Innovation System.

CHAPTER 5: ISRAEL IS HOME TO ANCIENT PEOPLE / ISRAEL'S HIGH-TECH ENTREPRENEURIAL CULTURE

5.1. INTRODUCTION

Israel is a young 68 year old country founded by Jews who came from different countries across the globe; and who as "one people" have an emotional tie, a Zionist [24] connection, to their ancient land. For over 2000 years, and since the creation of the State of Israel, with little natural resources, the Jewish people had only their intellectual endowment and strong value for education, developing the country's economy through technology innovation.

In order to understand the dynamics of the Israeli Innovation System, it is important to recognize what may be the uniqueness of the Israeli culture which comprises the Jewish culture during its 2000 years in the Western and Eastern Diaspora, and the emergence of a more recent Israeli culture within the foundation of the State of Israel.

This chapter presents the characteristics of the Israeli culture, where military service plays an important cultural role such as risk taking and creativity; as well as its strengths and weaknesses. It also addresses the strong influence of the military service with its low hierarchical distance; where Israelis form strong bonds during their military service; and where they learn to take risks; while these experiences spill over to the business sector.

The data in this chapter and in the next three interview chapters stem from an in-depth investigation of the views of actual interviewees in the process. The footnotes expand on some of the information provided by the interviewees, and some include my opinion as well. These views are important since these factors do not exist in other countries, and are deeply culturally instilled, creating very strong motivations to succeed. This chapter does not include at all my personal opinion.

Practically every Israeli interviewed mentioned the important role that Israeli culture plays in the Israeli Innovation System. Therefore, in order to understand Israeli Innovation, it is important to present first the culture of the Israeli people which has

[24] The Jewish Virtual Library (2015a) states that the general definition of Zionism "means the national movement for the return of the Jewish people to their homeland and the resumption of Jewish sovereignty in the Land of Israel" (para.1).

created their entrepreneurial spirit. I have organized the chapter according to themes that were mentioned during my interviews, which will offer a background of the Israeli culture and that of the high-tech entrepreneurial community.

5.2 A HOME TO ANCIENT PEOPLE

"Jews have been praying to return to Israel and to Jerusalem for 2000 years, and for the past 70 years, to achieve that dream…and to participate in this dream, to…make it work is a real privilege" (Interviewee P2).

As a new nation, Israel was established by Jews from 50 different countries, but nevertheless, Jews are "still one people" (Interviewee P3) who came to their homeland for different reasons, whether Zionist or because they experienced persecution in their countries of origin, and Israel absorbed them (Interviewee I1). Differently from most countries, such as Canada and the United States, who have immigrants from diverse countries, religious backgrounds and experiences, both Israeli immigrants and those Israeli Jews who have lived in the land for centuries see Israel as their ancient home.

All interviewees in my research, who immigrated to Israel did this for Zionist reasons: to fulfil their 'Zionist dream' they arrived from different countries, to "play a role in building the country, the economy….a first opportunity in thousands of years (to) live in a Jewish sovereign state" (Interviewees P5 and P11); to participate in its history. As expressed by an interviewee, "I really felt I was coming here to help build the nation…the Jewish State (and) I feel I am" (Interviewee A3). One interviewee explained that he came for Zionist reasons and also to work in the high-tech sector, since Israel is the best place in the world to work in the Venture Capital industry (Interviewee P1); to volunteer in a Kibbutz, as another interviewee mentioned, and feeling today still very connected to the land, to Israel; and because in Israel only Jews can criticize their government. One interviewee's family, at least, came from an Arab country, where Jews were persecuted and expelled when the State of Israel was established [25] (Interviewee I1).

[25] The Jewish Virtual Library (2015b) indicates that "Of the 820,000 Jewish refugees from the Arab countries, between 1948 and 1972, more than 200,000 found refuge in Europe and North America

One interviewee who did his post-doctorate in physics in the US, was invited to stay, but he returned to Israel to raise his family, since as he indicated, he "could not live in a country where he is a minority" (Interviewee G1). Nevertheless, the achievement of this Zionist dream may have given Israelis a sense of purpose [26] (Interviewees A3 and P11).

Most Israelis keep the Jewish traditions as well. As an example of being 'one people,' they know that the Sabbath (Shabbat in Hebrew) is a different day of the week; on Yom Kippur (Jewish High-Holidays) everything comes to halt in the country, and all stay home and do not drive. These Jewish traditions are passed on through generations (Interviewee A3). A university professor also commented that in Israel there is a "creative vibration." Israel was founded with Jewish creativity, where Jews created a state "out of zero" [27] (Interviewee A6); and it is a fact that for 2000 years the Jewish people only had their intellect and a shortage of resources (Interviewee A1).

Differently however, one interviewee mentioned that the notion of a Jewish nation, especially among young people, up to about 40 years of age, has been modernized into something that is a bit more Israeli, rather than a Jewish state, where they are Israelis first and Jewish afterwards (Interviewee I1). The challenge is not to build a Jewish nation anymore, "but to sustain it" and to develop it to become an equivalent to a Western democracy, "Which has more to do with being an Israeli rather than being Jewish" (Interviewee I1, personal communication, May 16, 2016).

This notion of Israel being home of ancient people is also reflected in the work of Jewish and Zionist private companies and non-profit organizations around the world that

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while 586,000 were resettled in Israel - at the expense of the Israeli government, and without any compensation from the Arab governments who had confiscated their possessions. The majority of the Jewish refugees left their homes penniless and destitute and with nothing more than the shirts on their backs. These Jews, however, had no desire to be repatriated in the Arab World and little is heard about them because they did not remain refugees for long," (para. 6).

[26] Jaskow, R (2015) states that "In 2015 Israeli ranked 11th, "Jewish state above US in World Happiness Report, but below Canada and Australia, among others; Switzerland the happiest," (para.1); and according to Press (2015), "Israel is one of the 'Top 5 Happiest Countries in the World,' according to a new Better Life Index report by the Organization for Economic Co-operation and Development (OECD)," (para.2).

[27] The Scientific American (2015) points out that "Israel is restoring to cultivation a land damaged by a millennium of abuse. The achievement is an example to a world that must face the task of increasing food supplies to feed a rising population," (para.1)

are investing in Israel. For example, one of the SUs interviewed has a large foreign investment company whose executives are Zionist Jews. They are interested in renewable energy and searched for companies in this field in Israel in which to invest (Interviewee P3).

An example of a non-profit Zionist organization created to support Israel as the ancient home of the Jewish people is the Jewish National Fund (JNF),[28] which has been working with the Eilat-Eilot Regional Council, in southern Israel, for 25 years (Udi Gat, personal communication, August 18, 2014). JNF invested US$1 million in the non-profit company Eilat-Eilot Renewable Energy that promotes education, conferences and tourism related to renewable energy in order to bring industrial entrepreneurs to the region, and to develop the Arava fully on renewable energy (Interviewee G2, and Udi Gat, personal communication, August 6, 2014). As well, the JNF invested in the Arava Power Company, an Israeli solar company with headquarters in the city of Eilat, by acquiring six percent equity in the company (Interviewee G7).

5.3 HIGH-TECH ENTREPRENEURIAL CULTURE

"It's a culture where if I made money, I believe in technology, in the innovation of the country, because a lot of money is being pumped in this direction" (Interviewee A5).

5.3.1 A country in crisis

As explained by an Israeli American lawyer and entrepreneur who lived and worked in almost every continent, the entrepreneurial success of Israelis may be due to the fact that Israelis live under constant uncertainty, and out-of-the-box thinking may be an essential requirement because life in Israel is not easy like in North America. Israelis must deal constantly with terrorism and always be vigilant (Interviewee P11); they are

[28] The Jewish National Fund (2016) is a non-profit organization founded in 1901, and it explains that "It all started with a dream. Over the past 113 years, JNF has evolved into a global environmental leader by planting more than 250 million trees, building over 240 reservoirs and dams, developing over 250,000 acres of land, creating more than 2,000 parks, providing the infrastructure for over 1,000 communities, and connecting thousands of children and young adults to Israel and their heritage."

used to making extraordinary efforts and to thinking outside the box; they are forced to go the extra mile, “to punch above” their weight since in Israel you cannot be successful in a way that Americans may consider normal (Interviewee P11). Israelis are more analytical than people in other countries since Israelis are forced to constantly find solutions for everything; to find different ways to do things; and thus gaining “so much breadth and depth of knowledge and experience that it gives (them) a competitive advantage,” and this is an attribute to Israel’s success (Interviewee P11). An example was that a lawyer in New York City makes a six figure salary, while the salary of an Israeli lawyer starting to practice is much lower. From their first day at work, American lawyers, have a good lifestyle, even before they bring results to the law firm, and the firm takes good care of them. Differently, Israelis must find ways to succeed through extraordinary efforts (Interviewee P11). Even though he is a graduate from an American Ivy League Law School, this lawyer indicated that he would be much less capable of developing “something huge in the world than a comparable Israeli (would).” His vision was to work for a large firm, step up the ladder, and have a nice lifestyle. Differently, most Israelis don’t take the path of least resistance, they try to over achieve and excel; and there is a greater percentage of Israelis who take the path of most resistance (Interviewee P11). As another former entrepreneur who emigrated from South Africa pointed out, “having it easy doesn’t create success” (Interviewee G6).

5.3.2 The value of education

A trait that has probably contributed to Israel’s high-tech industry and the country’s economic development is the fact that ‘education’ is a Jewish value. Jews like to complain that things are never good enough. Because of this, Jews try to improve things by obtaining an education; they have “that permanent dissatisfaction, (a) yearning for more, to fix and improve,(which) is part of the (Jewish) heritage, and it passes from one (generation) to the next” (Interviewee A3).

5.3.3 Support and belief in technology and innovation

An additional point of view was that Israelis become rich because they invest mostly in startups versus real estate. This is a culture where investors who made money, "believe in technology, in the innovation of the country, because a lot of money is being pumped in this direction" (Interviewee A5), even if there is a high probability of failure.

5.3.4 Acceptance of failure

Several interviewees indicated that entrepreneurs in Israel, who successfully built a company and grew it, are highly admired; and entrepreneurs who did not succeed are also accepted, and in this way Israelis accept failures as well (Interviewee A5). If entrepreneurs fail no one holds this against them, since they can start all over again with more knowledge of what went wrong and move forward with more experience (Interviewees P11, A2 and P4). As one entrepreneur indicated:

> If you only stay in the areas were you succeed, you will stay in (within) the boundaries, (and) you will not do something new; basically, innovation is operating outside of your boundaries, and (when operating) outside of your boundaries the likelihood of failure is very high (Interviewee P4).

Not only Israelis are motivated to take risks, but the country's "state of mind" is also risk oriented. For example, as a government interviewee indicated, the OCS supports high risk projects which have a high failing rate, "because from every failing startup, a new startup will emerge, and this experience is not lost." (Interviewee G1).

Two interviewees also indicated that when they travel overseas, they are asked why Israelis are successful in creating startups. Some Venture Capital firms (VCs) asked this question to an interviewee at a reception in Berlin, while Germans are not as successful as Israelis. A usual response is that Israelis are not afraid of failing "because they know that failing is part of the process," while the goal of German graduates is to get accepted to work with Siemens and retire there, and if they fail along the road, "it is like a stamp on their foreheads and will never be able to recover." On the other hand, to run a SU,

managers must be very flexible and innovative; be ready for change and constantly live with uncertainty (Interviewee P3).

Such an example is Dov Moran, an Israeli and founder of SanDisk, the USB Stick, whose company was called M-Systems. Mr. Moran is a highly admired entrepreneur in Israel being an example of huge success and failure as well. After Mr. Moran sold his company he invested all the money he made in the SanDisk (USB Flash Drive) invention and on another 10 technologies that failed. In his last attempt he competed unsuccessfully with iPhone. Nevertheless, he is very famous in Israel; he is considered as one of the most innovative people in Israel and "everyone wants to go to his meetings and hear his stories- that's the Israeli culture" (Interviewee A5).

Nevertheless, as another government interviewee explained, companies that have failed in the past can come back and bid, but if they have several past failures, this may impact the government's decision. For example, a company that was evaluated in 2014 was not approved by the OCS since it had received funding several times without being able to reach the commercialization stage, and therefore there was no reason to invest in the company again (Interviewee G6).

5.3.5 Open and informal networking

Also, there were indications that Israelis consider themselves to be more open than Americans as a society and culture, and this allows for a more fluid transfer of technology (Interviewee A5). For example, an interviewee recounted his informal networking experience with RAFAEL Defense Systems where he worked for 25 years. The company's buses picked-up 45 to 50 of its employees and took them to the company that was located outside of the city. The engineers in the bus would communicate during the bus trip, and:

> All the designs of the big complicated systems were done in the bus…since once the employees arrived to the company, they would each (go on to) work on their own small engineering piece within the large company's divisions; while in the bus they all met, …and the guy who was building one component was talking with others; all interactions were done in the bus, and sometimes people would get off

> the bus and we would continue working and talking for another hour until we would go to our office (Interviewee A5).

This informal communication was not something planned, it just happened, and this took place for many years, “I thought this was the best hour, when people were communicating” (Interviewee A5). This is an example of how through informal and interdisciplinary networking many successful innovations have been created (Interviewee A5).

5.3.6 Action oriented

Two interviewees described the Israeli culture as being action oriented due to the country’s history of moving fast, of doing things first and then evaluating the consequences; a culture “that is hands on and the analysis comes later” (Interviewee A5). Israelis:

> Call (this) in Hebrew ‘Litzor Uvdot Bashetach’, making, creating the facts in the field; making a claim first and then justifying it; achieving this through a sense of solidarity between people. The best example is the history of the pioneers who came to Israel. Under the British law, a settlement would be considered legal if it had a tower and a fence around it. That was by law the definition of what constituted a settlement, which the British could not dismantle. What many pioneers did was to sneak out during the night to one of those hills and build a very ‘shady’ tower with a fence around it. Size didn’t matter as long as it was within the boundaries of the fence….because according to the rules, a settlement needed to have only a tower and a fence.” Even now, Israelis still have this ‘need to act’ mentality, although today the country’s situation has changed. Although Israel is a young country, Israelis could now take the time to plan ahead, because issues are not as pressing as they were in the past (Interviewee I1).

Another more recent example of doing first and then planning was the Russian immigration, a very successful project and unique in world history. The Russian

immigration was a shock to Israelis, causing conflicts between Israelis and immigrants. But the thought process was that:

> You bring them home first and then you deal with the issues. With the Russian immigration, one day we woke up and there were one million new immigrants in Israel. These were Jewish immigrants who returned to their homeland. I remember in the news they talked about those lost Jews coming back to the state, but when you live there you kind of cope with every day life, and all of a sudden people say 'we need to give a million jobs away,' some nice package when you immigrate to Israel, and 'hey that's not fair,' I have been here for years and I don't get anything, we (Israelis) didn't get anything. But this goes back to what I said 'you do first, you bring a million people; you bring them home…If we would try and plan this magnitude of an operation, I am not sure it would have happened.' The same with the Ethiopian immigration; you just bring them, because they need help, they are being persecuted [29] (Interviewee I1).

If one would ask the Russian immigrants, at an individual level, if this move was positive or negative, their response would be that they would have preferred to arrive to a country that was better organized, with more structure, knowing what to expect, instead of immigrating to Israel "and then 'will see what happens'…." Nevertheless, "looking at the big picture," this mass immigration was a successful undertaking, although some immigrants left for other countries such as Canada, after they arrived to Israel, because the situation was difficult and chaotic. "But nevertheless it is considered a successful immigration effort" (Interviewee I1).

This cultural trait of doing first and then dealing with the consequences, was also supported by another interviewee who indicated that by not taking the time to plan ahead, this sometimes works to the advantage of Israelis in that they are able to move faster. However sometimes this can be a disadvantage, because Israelis make mistakes that otherwise they could avoid (Interviewee P2).

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[29] Also, watch the British Broadcasting Corporation (BBC) (2016) video.

5.3.7 Military influence

5.3.7.1 An entrepreneurial and risk oriented culture

Since practically every Israeli serves in the military, some interviewees indicated that their military experience spilled over to their entrepreneurial activities. The fact that Israelis are willing to take risks is a theme that was mentioned by almost all interviewees. As an interviewee explained, Israelis are not smarter than anyone else, and probably do not have more knowledge in general, since some other countries have people who are as good or even better than Israelis, but Israel's advantage is that its entrepreneurs take risks (Interviewee P4). Furthermore, Israelis live under so much risk, that they can risk much more, "and that makes us open to innovation (Interviewee A5), like an inherent attribute" (Interviewee A7).

During their military service, a duty most Israelis perform after high school, Israelis learn to take risks and this experience spills over to the business world. In the military, soldiers cannot move up the ladder and become officers unless they take risks, since soldiers who take risks and perform better, are seen as motivated and good candidates for officer positions (Interviewee G1). In this way, Israelis learn not be afraid of taking risks, and students, who after the military complete their graduate degrees in physics or electrical engineering, are not afraid either of taking business risks and creating startups (Interviewee G1). According to several interviewees, young generations should be taught that it is worth while to take risks, because this is the only way for people to progress, succeed, and fulfil their dreams (Interviewees G1, G7 and A2). An example provided by a government interviewee was that he had seen engineers in their 30s and 40s married with families, in high engineering positions with successful companies leave their jobs to open startups; a move that also affected their families (Interviewee G1).

5.3.7.2 A culture formed by military bonding, camaraderie and trust

The military service functions as a melting pot, as Israelis call it, since it allows young people from different backgrounds to get to know each other and to bond. Through this shared experience, Israelis become more open and comfortable with one another, spilling to the business sector as well (Interviewee I1).

This bonding experience has a vast impact on industry as a whole when it comes to networking. For example, a government official may have served in the same unit of the CEO of a big company, and both also served in the military with a university professor, "creating (in) this way a direct communication channel among them which plays a huge role in Israel's Innovation System." Differently, due to its large size, the industry in Canada and the US cannot be as intimate as in Israel (Interviewees A7 and A5).

Another example of bonding during military service is that many business partnerships are formed between Israelis who served together in the military (Interviewee I1), and especially those created by graduates of the elite 8200 Military Unit (Interviewee A6). As an interviewee and graduate of this elite unit described, he had a previous company for semiconductors and sold it. After six months he started looking for new ideas and two other friends who had served with him in the military, many years before, joined him (Interviewee P4).

In November of 2011, as part of my coursework, I interviewed a senior representative from Nexen who had experienced the Israeli culture through his work with the Israeli company Ormat. This company had a demonstration plant with an innovative upgrading technology to be used with the oil sands' SAGD (Steam Assisted Gravity Drainage) in Cold Lake, Alberta. As this interviewee explained, since Ormat was going to operate the plant for a short period of time, it was difficult to hire Canadians for that time. Instead, Ormat hired Israelis who had just completed their military service to work on most of the demonstration plant operations in Cold Lake. He further noticed that "their energy, comradeship, and ability to communicate well with each other resulted from having a common cultural background and military training, which helped them to overcome many challenges" (Interviewee P6)

5.3.7.3 A culture based on perseverance

The military teaches soldiers to stick to their targets, as the CEO of a renewable incubated startup described that he learned during his service in the prestigious elite unit 8200, from which many high-tech entrepreneurs come (Kalman, 2013) - "If you have a target you must fight and reach it; there is no giving up. What you do is too important so you don't give up" (Interviewee P4). An example of perseverance may be that of the

CEO of another renewable energy incubated startup who indicated that without the incubator's support, he would have taken an engineering position. At the same time as well he would have continued raising money for his company, since he had already spent one year focusing on fundraising and not working, which had not been easy (Interviewee P13).

Another example of perseverance, further described by an interviewee in the Transfer of Technology chapter, describes a startup that had survived for almost 10 years after leaving an incubator, with a team that had worked mostly without salaries, being this one reason why the CEO joined, "because there was a grain of sweat and blood, of entrepreneurship; people who believed in it, and were ready to work for years after putting the hours (inaudible); I call it moonlighting." This was the situation until the company finally had a breakthrough with an investor (Interviewee P12).

The Israeli American lawyer mentioned earlier, who lived and worked practically in every continent, also explained that:

> Israelis are much better at thinking out of the box; at crafting solutions; much better at not taking 'no' for an answer and finding better solutions, being persistent… about everything, that they get results, even if it means not everyone liking them along the way. Europeans are the worse, because they are 'in the box thinkers….. Canadians and Americans are good as well, but Israelis are the best (Interviewee P11).

Differently however, as also described in the Transfer of Technology Chapter Six, a scientist interviewed indicated that he tried in the past to get an energy cell developed in Israel. However, it was not successful, since most Israeli companies do not have the money or the patience to develop a product (Interviewee A4).

5.3.7.4 Thinking creatively and out-of-the-box

During military service, young 'kids' 20 or 21 years old, very quickly become officers and must supervise activities that require high levels of responsibility, and to think outside the box to solve complicated issues (Interviewee G7). Once these soldiers

complete their first military training stages, such as boot camp, they must become thinkers; be able to adapt, and to especially show initiative by being problem solvers and daring. When soldiers are given a task they must carry it out even if they do not know how to do it (Interviewee P4). An interviewee gave such an example when during a military exercise the commanders hid their supper and the group had to hide in the field and recover their food, while the commanders wore night vision goggles and protected the food boxes. Such an exercise is a perfect opportunity for soldiers to show initiative, to figure out solutions with the knowledge they had. One of the teammates dressed-up as an officer, wearing the commander's uniform, something that was:

> Very brave of him. (He) walked straight to….the officers' tent…took the food and walked out…full of confidence…the officers there were dealing with their own stuff, not watching…that is a way to show initiative…..even though that soldier broke the rules and got punished for it; he got commanded by the officers in front of everyone, but then he got punished for impersonating an officer, which was not allowed… that is how the system would work (Interviewee I1).

Other stories that are continuously told are those of Ehud Barak, former Israeli Prime Minister and Minister of Defense, when he used to wear women's clothes to infiltrate enemy locations. During the hijacking of the Sabena airplane by Arab terrorists (on May 8, 1972) Ehud Barak together with other undercover soldiers, dressed like plane mechanics and entered the plane. "All those ideas of breaking the rules or bending the situation to fit your situation is somewhat embedded…; it is like having this crazy idea and will try and do that, and that is because we work with not many resources" [30] (Interviewee I1).

This point was further supported by an interviewee who mentioned that most Israeli innovation successes come *"from not playing by the rules."* As Steve Job's biography describes, innovations always come from California, and Dan Senor and Saul Singer in their book *Start-up Nation* (2009) arrive to a similar conclusion. California has a culture

[30] Also see, Omer-Man (2011).

of ex-hippies, not disciplined, and who did not play by the rules. This is a characteristic of most successful Israelis who took risks and did not play by the rules either (Interviewee G6).

5.3.7.5 Strong improvisers with little resources

Before the foundation of the State of Israel, in 1948, and during its fight for Independence, Israelis had to improvise, since they did not have an army. Israelis had only underground militias who built home made bombs and other devices, and when the State was established, these soldiers became its leaders (Interviewee I1). The State of Israel was founded with very little resources while being hugely outnumbered when fighting its enemies. This view, of being able to achieve a lot with scarce resources has remained rooted in the Israeli culture (Interviewee A3). Israelis learn how to improvise in the military, as recounted by a scientist interviewed:

> For example, during military service, I remember one time, we were in the middle of nowhere, and they delivered to us fresh chicken but we didn't have anything else. We siphoned-up fuel from one of the trucks, we added some old 'shmates`, but you don't want the fumes of the fuel, so we put a metal plate, in one of the trucks we had protective armour, something you could dismantle; we dismantled that piece, put that up, that was our cooking service, and then you were supposed to clean it, so we heat it up to clean it. We cooked the chicken that way (Interviewee A3).

Another interviewee pointed out that learning to improvise in the military spills-over to academia, and this is probably one of the reasons for the success of Israeli academic R&D. In Academia as well, Israeli researchers work with less resources and funds than in other countries, such as Canada, which forces them to be innovative and to improvise. Consequently, Israelis are less strict, less formal, and much more flexible when it comes to complying with protocols, since they must deal with limitations (Interviewee I1). As the above Israeli scientist interviewed recounted:

> Sometimes when I go to the lab, the equipment is so ridiculously expensive, or it will take two weeks to arrive, and I don't want to wait two weeks, because I need something now, so you improvise. When I started working I was trained as a theoretician and then it got more and more into lab work. In one of my early experiments I wanted to build a flow cell, a large thing out of glass or plexiglass, and I had colleagues in Germany at the time and they had one of these and sent me the plans to build it. It was going to cost me $US20,000. I was new to the lab; I didn't have US$20,000 to put into this…. so I bought a fish aquarium from a pet shop across the street for US$20. I did my experiments on a small scale and the results in my paper became highly cited (Interviewee A3).

Similarly, an Israeli PhD Candidate in Canada explained his difficulty in following formal procedures. This happened, for example, when something was missing at work and he brought that device from home,

> Instead of following procedures and being a week without working. My boss tells me I am impatient, but no, it is a matter of making things happen….. we improvise something and make it work… it drives me crazy, I see the solution, why do we have to wait for a meeting, we can do it now….. intellectually it makes us stronger, it makes us more daring (Interviewee I1).

However, as expressed by this same interviewee, the weakness in improvising is also that it creates a culture where order and following procedures is not a first priority. Nevertheless, this is an approach that takes time to learn. Israelis tend to compare themselves to societies that have existed for hundreds of years; who have had the time to establish protocols and standards of work, while Israel has not had this privilege. Israelis had to build a house, 'Choma Umigdal' in Hebrew, meaning the tower and the wall around it, in order to claim it as their settlement during the British Mandate, "…will the wall stand for 50 years? Probably not, but we will figure that out later, now we need to make a statement: we're here and we're here to stay" (Interviewee I1).

5.3.7.6 Low hierarchical distance in the military and in industry

As this PhD Candidate interviewed, mentioned above, the low hierarchical distance that exists in the Israeli military also spills over to the work place. When compared to Israel, hierarchy in Canada, for example, is more respected and more rigid. Differently, in Israel CEOs may hire people who have served in the same military unit, together, or CEOs may have served there several years before, and both, he/she and his/her staff, may have a had the same experience which creates an immediate connection.[31] Differently, especially in North America, where people come from so many places and backgrounds, and have nothing in common other than they "speak English or work in the same place, but have absolutely nothing (else) in common," this situation almost never happens in Israel which creates a more family like, rather than a business like atmosphere (Interviewee I1).

Also, as mentioned earlier, according to Steve Jobs` biography, innovations always come from California where there is a culture of ex-hippies, not disciplined, who do not play by the rules, and have no respect for authority (Interviewee G6). Similarly, as posed by an interviewee, and reiterated by another, the Israeli culture:

> Has a healthy amount of disrespect towards authority, which…creates a culture with very little boundaries that respects action over process or procedures, so you do first (build the tower and the wall) and then you build the procedure around that (Interviewee I1).

Maybe also because of this low hierarchical distance in the work place, in Israel there is less separation between family and business, as described above, and "if you need a computer mouse you just bring it from home until you get one ordered from work" (Interviewee I1). Due to this low hierarchical distance there is a big difference between the management culture in Israel and that of the US and Canada. According to the CEO

[31] In my Hebrew school in Mexico we were taught that this hierarchy practically disappears in Israel, since employees at the work place could be in higher ranking positions to their bosses when they both perform their military reserve duties at the same time; or if during their military service the employee was a superior to his boss at the workplace.

of a startup who described that in the past he managed a company that, since it had most of its marketing in the US, the Manager hired a sales and marketing manager in the US who travelled to Israel to participate in the company's quarterly review where they discussed different issues. After three days of meetings the US Marketing Manager resigned because, as he explained, the Manager did not control the company, and his staff were challenging and confronting him. The Manager's response was:

> You got it wrong, I don't need 'yes' men…Mostly Americans, but Europeans as well, have difficulty realizing that if the boss says 'A', then everyone says 'A' even if they think differently. Also in the military, there are many cases (where) subordinates sometimes give opposite opinions to those of their commanders. But eventually, when there is a decision and there is an order, no one argues about it, but there is an open discussion. This is something many foreigners have difficulty accepting (Interviewee P3).

This point was further supported by the senior interviewee from Nexen, who while working with the Israeli company Ormat, he experienced the Israeli entrepreneurial spirit, mentioned in the book *Start-up Nation*, which he had read. This was especially true in the early days of the Israeli company in Alberta, a time and experience that he actually "loved." Israelis were constantly questioning the status-quo. For example, questioning why things in the refinery were in a certain way, and in general questioning established truths, which North Americans would find uncomfortable doing. However, this questioning sometimes resulted in revelations and in new ideas and innovations (Interviewee P6).

5.3.7.7 Ability to cope with change

Differently from the 'Action oriented culture' section above, an interviewee indicated that through his military service he developed the ability to cope with change. He learned to think faster before taking action and to see the long term results of his decisions, which he has applied to his work experience (Interviewee P9).

5.3.8 Downside of the Israeli culture for innovation

5.3.8.1 Israelis tend to be short term thinkers

Two views are presented here where according to one, Israelis prefer to sell their startups and let Multinational Companies (MNCs) develop their technologies. Second, since Israelis are very entrepreneurial, therefore large companies have difficulty finding top professionals.

As an interviewee described, Israelis tend to be short term thinkers, for example, when they have an offer on the table, something that is certain, and that they may not have in the future they take it (Interviewee P2). Nevertheless, as another interviewee pointed out, it would be difficult for anyone to have an offer of US$1billion, or US$40 million, for a startup and not take it (Interviewee G6). However, short term thinking, according to an interviewee, seems to be a national trait, to "not wait until tomorrow or the day after to sell off the company; or to build it…into something that is bigger, because you can make your money today" (Interviewee P2). Building big companies is something that does not happen often in Israel. This seems to be against the national character of the country; but it may also be due to the high level of bureaucracy and red tape. If it were easier to do business in Israel then the country could have a higher number of large companies (Interviewee P2).

A cleantech VC partner provided an alternative view to the one above, indicating that Israel is a small country and it cannot have many large companies because they will not be able to hire people. Israelis are very entrepreneurial and it is difficult to hire "top level talent" (Interviewee P1) since they prefer to build their own startups. MNCs employ mainly technical people and engineers, but even they have problems hiring these professionals as well as business people. When the companies get to a certain size they need managers, marketing and business people, and many of them are too entrepreneurial to work for a big company. "You reach a ladder where you have a company of 100 people, you grow significantly in people, it's difficult to recruit top managers because they want to build their own startups" (Interviewee P1). Due to this shortage of manpower, Israel will hire foreign high-tech workers who will be paid twice the salary of Israeli employees (Times of Israel, January 16, 2017).

5.3.8.2 Israel is a first and a third world country at the same time

As described by an interviewee, "Israel in general ranges from a first world country to a third world country, depending on what you are doing (such as working in the high-or-low-tech sectors), many aspects of society are first world, but certain are third world" (Interviewee P11). Everyday life in Israel is difficult. "Nothing beats the US or Canada regarding the ease of shopping, daily routine. I miss that." There is no infrastructure in Israel, and everything takes an extraordinary effort. For example, to get a car inspected in Israel it takes eight hours, while it should take only 15 minutes (Interviewee P11). On the other hand, Israel is good for kids; like Disney World; it is safe, they can play outside, the neighbourhood is safe, differently from the US, where it is dangerous, and must be watchful of "nut cases around, (while) here it's safe" (Interviewee P11).[32]

5.4 CONCLUSION

As seen in this chapter, Israeli culture, which plays a most important role in building the entrepreneurial spirit of Israelis has been shaped mainly by a 2000 year Jewish Diaspora; by the struggle of the Jewish pioneers in the Land before the foundation of the State of Israel; by Israeli compulsory service in the military; by a life of constant uncertainty and risk; and a culture that fosters formal and informal networking.

Israelis place high importance on education as a Jewish value, and believe strongly in technology innovation and entrepreneurship. As well, Israelis have built their Nation with Jewish creativity and 'out of zero,' when Jewish pioneers arrived to a mostly barren land, with little resources, and only with their intellect developed during 2000 years in the Diaspora. Returning to their ancient land; building the Jewish State, and participating in its history have given Israelis a sense of purpose to their lives.

Furthermore, the every day risks that Israelis face have developed a culture of out-of-the-box thinkers, and a flexible, vigilant and ready-for-change mentality. Due to their history as well, Israelis are action oriented, which has been a strength but also a weakness,

[32] Roberts (2017) points out that "A new report by InterNations lists the nineteen best countries to raise a family (according to expats) listed Israel third, just behind Finland and the Czech Republic," (para. 2).

by otherwise avoidable mistakes. Also as part of their history, Israelis learned to not play by the rules, a similar cultural trait to that of entrepreneurs in California's Silicon Valley.

All these Israeli cultural characteristics described above are further developed and strengthened through compulsory military service. The military plays a strong role in further shaping the Israeli entrepreneurial culture, where Israelis form strong bonds founded on trust, and by establishing formal collaboration networks and transfer of technology across academia, government and industry. In addition, as explained above, the Israeli military strongly encourages creativity, which may be a unique characteristic of the Israeli culture.

Both, the military and the business cultures, have low distance hierarchical cultures, where low ranking officers and industry employees challenge their superiors and bosses, questioning the status quo and resulting in new ideas and innovations.

As well, Israelis tend to be socially open, which facilitates informal networking and transfer of technology. Israelis also accept failure in innovation, to a certain extent, as a learning experience that can be applied to the commercialization of future innovations.

Nevertheless, together with its advanced first class high-tech culture, the Israeli low-tech industry is much less developed, with little or no infrastructure. Another downsize mentioned is that Israelis are short-term thinkers by not developing their startups to become big companies, but at the same time large companies have difficulty hiring top talent, since Israelis are very entrepreneurial and prefer to build their own startups.

CHAPTER 6: RESEARCH AND DEVELOPMENT COLLABORATION (R&D)

6.1 INTRODUCTION

There is a strong R&D interaction in the Israeli Innovation System between government, academia and industry initiated and supported by the government and strengthened by military bonds, as seen in the previous-chapter, being this in part a driver of Israel's innovation success (Interviewees Interviewee A5 and Interviewee A7). In addition, Israel also has

> Many entrepreneurs with very high risk profiles; they are willing to take risks, and this goes back to the army, where they are exposed to different kinds of risks, placing the economic risk in a perspective…Nothing compared to other things they have been exposed (Interviewee A2).

As indicated in the previous chapter, the data in this chapter as well stem from an in-depth investigation of the views of actual interviewees in the process. The information presents an in-depth view of the R&D collaboration among Israel's government, industrial and academic institutions and it adds insight as narrated by the Israeli interviewees, and also offers some different perspectives not covered in the Israeli literature. The chapter includes information provided by key players in the main programs under the umbrella of the Office of the Chief Scientist's (OCS), which provide financial and physical support mainly to industry. For example, it addresses the government's face-to-face evaluation process when selecting the startups in which to invest and incorporate into its OCS programs, such as the Technological Incubator, MAGNET, MAGNETON; and both, the Bilateral Industrial R&D Foundation (BIRD) (Interviewee G3, personal communication, September 6, 2016),[33] and the Canada Israel

[33] As explained by Interviewee G3, "The BIRD Foundation operates under a special law as a 'corporation by law.' Its Board of Governors is composed of senior officials from the U.S. and Israel…The Israeli co-Chairman is the Chief Scientist of the Ministry of Economy; the U.S. co-Chairman is from NIST (Dept. of Commerce)… So, in principle, BIRD is not 'under the OCS'. However, in practice, in Israel, our main connection is with the OCS because of the nature of our work."

Industrial R&D Foundation (CIIRDF) (Interviewee G6, personal communication) [34] under the MATIMOP program, and their energy specific funds.

Next, it examines a more recent program for alternative fuels, the Fuel Choices Initiative, established by the Prime Minister's office; and the journey of the solar energy company, Arava Power, through the renewable energy boom and crisis. It then explains how two universities, the Weizmann Institute and the Technion, collaborate domestically with the Israeli government, the military and industry, and with the Unites States (US) government; their R&D collaboration with international research institutions, mainly with the European Union (EU); and their patenting policies. It briefly addresses the Cleantech Venture Capital (VC) Industry, which also experienced ups and downs in its green energy sector; and the role of Multinational Companies (MNCs) in the Israeli high-tech market.

Subsequently, it addresses the informal and formal R&D collaboration of the military and the defense sector with academia and the private industry; the support of the defense industry towards renewable energy; its diversification into the civilian industry, and the misconception that most innovations come from the military.

Finally, the chapter introduces the IVC Research Centre which acts as a bridge between Israeli high-tech companies and foreign investors that are interested in Israel, through an online database and customized direct services. This chapter also deals with the success rate of the OCS programs, of their green energy programs and their impact; the importance of the US market for Israeli startups; R&D versus commercialization, and the importance of renewable energy for the State of Israel, according to the recounting of the interviewees.

6.2 OFFICE OF THE CHIEF SCIENTIST (OCS) R&D PROGRAMS

Collaboration between industry, academia and the defense industry takes place through strong government support, and mainly through the programs of the Office of the Chief Scientist (OCS) within the Ministry of Economy and Industry (former Ministry of

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[34] Interviewee G6 indicated that "CIIRDF is an independent bilateral foundation setup by treaty between Israel and Canada." Therefore its main connection in Israel is with the OCS because of the nature of their work.

Industry and Trade). The government funds these programs through matching funds, and the programs finance mainly high risk projects (Interviewee G6).

Since the OCS is located within the Ministry of Economy and Industry, it is interested in the impact of innovation on the economy with the mandate of encouraging industrial innovation. As stated by two interviewees, this mandate is different from other countries where large investments fund university research believing that good ideas get diffused from university to industry (Interviewees G7 and G6).

> But from our experience, we believe that if you don't push industrial R&D, even if it is the last mile of R&D, meaning the industrial part (applied R&D) and commercialization steps without this the economy will not benefit enough from the innovation capacity coming out of universities (Interviewee G7).

As explained by a government interviewee, Avi Hasson, The Chief Scientist of the Ministry of Economy, reports directly to the Prime Minister, therefore having more of a Deputy Ministerial role than a scientific one. Mr. Hasson has a very large budget of 1.5 billion shekels (USD$389,391,715) [35] to support industrial innovation, a role that was established in the late 1960s. Other Ministries have a much smaller budget, which can be from 20 to 50 million shekels, and they support mainly University research (Interviewee G6).

The OCS has Research Committees comprised of public members who represent academia, industry and government agencies and who award the projects and the investment amounts. The projects are initially assessed by over 120 evaluators with extensive experience in academia, and in the civilian and defense industries. The submission of proposals to the OCS goes through a process where the companies first submit a summary. Those companies selected get feedback from the government programs; they then submit a full proposal that must include a final product to be commercialized; and are then visited by an evaluator for a couple of days who digs deep into the company, debates with them and makes recommendations. The evaluators then

[35] On October 7, 2015, 1.5 billion Israeli shekels (ILS) were equal to USD$389,391,715 (XE Currency Converter, 2015).

submit an evaluation to the research committee, which makes the final decision (Interviewees G1 and G6).

All evaluation processes are performed by independent professional evaluators contracting with government by law, as explained above. OCS evaluators are selected through an open tender, and each one has a specific know-how in R&D which can include 25 to 30 years of work experience with the defense industry, such as RAFAEL; with academia, as evaluators with the European Program Horizon 2020 (Interviewee G1), and with other organizations. The evaluation is more in depth when it is face-to face than if it is just in paper, and if the company left out some information in the proposal it can have a second chance to win the bid. Each program is evaluated by two people, one more senior and one with less experience, but the two evaluators must sign the evaluation report. Differently, as explained by two government interviewees, this one-on–one interaction and evaluation does not take place in the selection process in Canada (Interviewees G1 and G6). Projects under the OCS umbrella are usually from three to five years, and once the project is awarded, companies must submit a yearly report (Interviewee G1).

Israeli companies can request any funding or grant amount, while the Research Committee makes the final decision based on the company's evaluation. Differently, as further described by the same interviewees, in Canada companies can receive only a maximum amount a year or for each project (CIIRDF, personal communication August 11, 2015),[36] which can be a problem if they have very large projects that need large amounts of resources (Interviewees G1 and G6).

The OCS agencies in charge of administering the different programs, when selecting the companies, assess mainly their research capabilities. Although they do evaluate their business capabilities, their business experience to run a project, these agencies focus mainly on the R&D capabilities of the companies (Interviewee G7).

[36] According to the Canada-Israel Industrial R&D Foundation, the maximum amount is $300,000 Canadian.

6.2.1 Public Technological Incubator program

The goal of the incubators in Israel is to reduce investment risks through a strong government support, being this an incentive also for Multinational Companies (MNCs) such as IBM, INTEL and others, and mainly American MNCs, that have opened R&D centres in Israel (Interviewee G2). Furthermore, thirty to forty years ago the Israeli government was concerned that Multinational Companies (MNCs) established in Israel would appropriate the technology they developed in the country and therefore it stipulated laws to avoid this from happening under the R&D Law (1984). The government limitations through the R&D Law were changed in 2005 allowing Israeli technology to be exported; and in 2012 the government revised the law again, this time specifying that companies exporting Israeli technology had to pay a maximum of six times the amount they received in funding from the Israeli government. Notwithstanding this demand, MNCs continue to open more R&D Centres in the country and employing about 50,000 people[37] (Interviewee G6). If the companies reach the commercialization stage and have sales, they must return their funding to the government through royalties, and if they do not have sales then their loan becomes a grant (Interviewee G2).

The selection of incubators is done through a competitive process that is open to local and foreign companies, and permits today are provided for eight years when the permits are renewed. The incubator requirements can change from year to year. In previous years the permits were for two, then for four years, and now these are for eight years (Interviewee P8, personal communication). Investment amount requirements can also change and go up to 20 million shekels (USD$5,191,440)[38] for the incubators, versus previous years when this required investment was lower (Interviewee P8). Nevertheless, while one incubator interviewed decided to close due to this increase in investment amounts and continue to invest in its current portfolio of companies (Interviewee P8), another indicated that the government's arrangement significantly reduces the incubator's risk. When the government invests US$600,000 or 80 percent of the funding, and the

[37] These numbers vary across the interviews, from 50,000 to 100,000 to 10 percent of the Israeli population.

[38] On October 8, 2015, 20 million Israeli shekels (ILS) were equivalent to USD$5,191,440 (XE Currency Converter, 2015).

incubator invests approximately $100,000 in each company or 20 percent of the funding, this arrangement is much less risky for an incubator budgeting for a portfolio between 15 to 20 companies (Interviewee P1).

An interviewee pointed out that when startups join an incubator, they must have patented their technologies, otherwise they cannot join the incubator (Interviewee G2). After two and a half to three years of a company's incubation, the incubator often searches overseas for investors in the companies (Interviewee G2), and the incubator owners remain as Board Members in the companies (Interviewee P8). Israeli Municipalities can also be investors in incubators. For example the Eilat-Eilot Renewable Energy Ltd., has a 10 percent equity investment in the Capital Nature Venture incubator, which develops only renewable energy technology (Interviewee G2).

Notwithstanding these arrangements, the entrepreneurs interviewed preferred to have large companies as investors, rather than incubators, since the funding of large companies is much higher, and they also have international contacts. Therefore, as stated by four interviewees, usually the entrepreneurs who join incubators are those who do not find large investors for their green energy projects and need the money (Interviewees G2, P3, P13, P4); or are those who are innovating in a technological field that is new to them (Interviewee P4). Nevertheless, the entrepreneurs under the incubator's umbrella were very positive about their experience (Interviewee P4 and P13), indicating that by being within an incubator "it's good, you have someone with whom to consult, to discuss with, to hear another opinion…(and) are well connected" (interviewee P4)

As explained above, the investment of incubators in a startup is around US$600,000 to US$700,000 for two to three years, while through investors a startups could raise a significantly higher amount. For example, the CEO of a startup developing a technology for alternative fuels received US$1 million from a private investor, who then raised another US$9 million from its network of private investors. The CEO of another startup that had been in an incubator and then had survived for ten years developed a technology with application to the oil sands and received over two million US from two foreign investors (Interviewee P12). The company also secured a strong strategic partner, a leader in the semiconductor industry. It is worth mentioning that these two entrepreneurs had managed incubators in the past, and were approached by foreign investors through their

academic and industrial contacts from their previous incubator management positions (Interviewee P3 and P12).

As an interviewee described, an example of a successful Israeli company that raised money on its own without an incubator is SolarEdge, which manufactures smart inverters with a technology that came from electronics R&D within the military. The company itself raised money and became a leader in the renewable energy sector (Interviewee G2).

Two interviewees explained that the government privatized the incubators so they would run more efficiently, while it also planned to have groups that would invest money after the incubation stage, which according to one interviewee, the government did not do this. The government's idea was to invite large companies to inject some money into the startups, and support them while they had enough sales to survive. However, the criteria for choosing an incubator should have been instead to invest in the companies that reach the end of the incubation period and before they "take off" and leave the incubator (Interviewee P3 and P12).

Nevertheless, there seem to be such arrangements in two cases. One is between a clean-tech incubator and a clean-tech VC interviewed, with some of the same owners in both firms, and where after two years in the incubator, its VC arm selects the best companies in which to further invest: "The idea is to build a portfolio of 15 to 20 companies, at early stage, have them, nurture them in the first years, and then we can select the best to fund their next phases" (Interviewee P1). A second similar arrangement was mentioned earlier, where due to an increase in the investment amount required by new incubators permits a clean-tech incubator closed its doors to new technologies in order to continue investing and strengthening its existing portfolio, and to eventually become a holding company (Interviewee P8). For example, this incubator decided to deepen its investments in one of its existing projects and startups, a company that already produced biofuel biologically and whose inventor and founder is an Israeli Arab. The incubator was the first to invest in this startup for seven years, since the incubator was established. The startup left the incubator and has had sales, but the trend is that once large companies invest in the startups the incubator's owners remain invested as well as Board Members after the incubation process (Interviewee P8).

According to two interviewees, the average success rate of the incubators, whose companies have sales, profits and pay back the funding to the government, is between one out of six companies, to two out of ten companies, from 16 percent to 20 percent (Udi Gat, personal communication, August 6, 2014; Interviewee G2). Nevertheless, people from all over the world "come to Israel to learn from its incubators; they come even from the US, and no other country provides the support to its companies as Israel does" (Interviewee P8).

The Capital Nature Venture incubator is the only purely renewable energy incubator in Israel; works closely with universities and directly funds university research, since there is not much industrial R&D in renewable energy in Israel (Interviewee G2). This incubator, established in 2011, budgeted for 25 startups for a period of five years, but by the end of 2014 it had only eight technologies. In order to increase renewable R&D in Israel, the Eilat-Eilot Regional Council in Southern Israel, which is also an investor in the Capital Nature Venture incubator, built an applied research centre in the Arava, at the National Technology and Renewable Energy Center, which opened in 2014 (Interviewee G2 and A7).

Clean-tech Incubators work with the Weizmann Institute, the Technion, Haifa, Tel Aviv and Hebrew Universities in different disciplines. The universities' TTOs usually approach the incubators and request to have their projects developed inside the incubators For example, one incubator has a project from the Hebrew University (HU) for the cleaning of surfaces with water to remove traces of fuel (Interviewee P8).

6.2.2 MAGNET program

The MAGNET program - Hebrew acronym for pre-competitive generic technology, funds high-risk, cutting edge R&D, from three to five years, through collaboration between industrial and academic groups, led by industry's decisions (Interviewees G5 and G1); by transforming basic research into applied research (Interviewee G7); and where each member licenses, free of charge, the technology developed under the MAGNET consortium project (Interviewee G5). Differently, as indicated by a government interviewee, in Canada most of government money goes to academia (Interviewee G6).

An important criterion in the MAGNET program when selecting a consortium is the strength of the role of the academic partner within the project, reflected also in the funding scheme, which encourages the companies to partner with the best researchers, by requesting from industry to fund its academic partners with 20 percent of its project costs (Interviewee G5). Differently from other OCS programs, where the matching grant is 50 percent, the OCS grant to the consortium companies is 66 percent; and to the participating academic institutions is 80 percent, while the industrial partners pay the remaining 20 percent to the academic partner. In this way academia gets 100 percent of its costs. The MAGNET managers believed that if industry did not pay this 20 percent to academia, industry would not select the best researchers to join the consortium (Interviewee G5).

Through the MAGNET program industry has come to understand the benefits and advantages that academia can provide. Before MAGNET there were relationships between industry and academia, but not to the same extent as today. "Looking back, we brought academia to speak with industry, and industry to speak with academia, and for … them to work together" (Interviewee G5).

Currently for example, within the consortiums, researchers meet company employees with whom they collaborate and develop a mutual understanding; and where mutual collaborations develop in different ways, by hiring the researchers as consultants, or signing contracts with university groups to solve their problems (Interviewee G5). However, unfortunately, for most of the projects that MAGNET does not approve, the groups dissolve after writing their proposals, although money is available from other sources, being this a "psychological" issue and an indication that they need to work under the government umbrella (Interviewee G5).

Nevertheless, as a second interviewee indicated, MAGNET projects are complicated. The leader is always industry, although academia can bring the idea, and therefore these are not easy projects. These projects bring different interests, cultures, expectations and bureaucracy. A consortium is never only about research; there is a high degree of socialization, "mingling, transfer of knowledge, networking, egos; run through a special non-profit program…transfer of budget from the Ministry to the partners, reports, and long seven hours logistic meetings" (Interviewee A1). A second selection

criterion is that the MAGNET program must select large and stable companies. Smaller companies are also selected, but these must have been in the market long enough, five to ten years; and for example, have 25 employees and have raised US$35M. Since MAGNET selects only high-risk pre-competitive research and provides pure grants, with no royalties or payback, it must make sure that the companies will not fail, take the money and leave (Interviewees G5 and A1). Nevertheless, the best consortiums include big, medium and small companies, since small companies usually bring interesting technologies to the group, and tend to be more flexible regarding change (Interviewee G5).

A third selection criteria, is the added value to the consortium members, where the MAGNET money invested will create greater change and innovation, and in a discipline where MAGNET can make a real difference. For example, in low-tech projects, such as metal and plastic the program will jump-start the companies, while high-tech companies such as communication firms will take only small steps, since their technology is already more innovative and attractive than that of low-tech companies (Interviewee G5).

A fourth criterion is to select projects that will strengthen and increase the Israeli export market (Interviewee G5), since Israel needs exports to strengthen its economy. This criterion, which benefits the Israeli economy, is more important than the benefit to the companies (Interviewee G5). An exception to this criterion are products that replace imports, since replacing imports helps the Israeli economy as well, and the goal of the OCS and MAGNET is to create economic growth. Furthermore, all OCS proposals, even generic and pre-competitive ones, require the specification of a final product. In this case, even if there are no royalties, the government requires that proposals indicate a final product out of the R&D (Interviewee G1 and G6).

The MAGNET program does not have much activity in the area of energy. The program has presently one green energy project called TEPS (Transportation Electric Power Solutions), partially funded by the Fuel Choices initiative. The group is developing batteries for a car that is fully electric; not a hybrid like the ones manufactured by Renault and Nissan with batteries that run for 150km, but the program is developing a battery that runs for 500km before recharging. “There are several companies and several academic researchers who deal with this technology. This is the

only consortium in energy in Magnet. We have sporadic activities in energy, in Magneton, and most of them are projects for batteries. But in the last 3 years we didn't have more than 5 projects. It is not a leading activity in Israel" (Interviewee G5).

6.2.3 MAGNETON program

The MAGNETON program was established with the goal of furthering technological collaboration between academia and industry on a one-on-one basis (Interviewee G5). After working several years with MAGNET, its managers and the OCS realized that there is academic know-how, discoveries approved in laboratories, and technologies that are not transferred to industry for different reasons, such as if the researcher did not initiate this process, or did not have good publications, or any other reasons. The MAGNETON program was established in 2000, not as a small MAGNET but rather with a different mandate. The program does not develop new technologies, but instead transfers technology developed by academia, applying it to a company through a one-on-one relationship - one company and one academic group. The academic group usually includes one researcher but it can include two researchers and their students. When researchers collaborate from two universities they must sign an agreement indicating who will lead the technology transfer. At the end of the program, which can be up to three years, the company has the license, the tools and the understanding on how to use the technology, as if it researched and developed the technology itself (Interviewee G5).

The MAGNETON program has approximately 25 new projects annually, and around half continue to the second year with about 35 to 40 projects yearly, which is less than what the government expected when it established the program. This program is especially helpful to engineering companies, labelled as mid-tech, that have difficulty investing in R&D due to low profits from sales.

> This program is very useful for companies strong in engineering, and less strong in creativity. Sometimes the lack of creativity is not because the engineers are not good enough, but as a result of the company's environment. We mark them as mid-

> tech, that don't have high benefits from sales, and have difficulty investing in R&D (Interviewee G5).

Sometimes, once they graduate, the companies hire the students involved in the academic research. Although MAGNETON does not require royalty payments, the government is interested in the commercialization of the technology developed as well (Interviewee G5).

The MAGNETON program has had five energy projects in the last three years, and those are mainly projects for batteries, since unfortunately "energy is not a leading activity in Israel," as stated by an interviewee (Interviewee G5), and neither is the Israeli industrial R&D, as mentioned by another interviewee (Interviewee G2). Another reason provided as to why both programs, MAGNET and MAGNETON, have only sporadic activities in energy is that there are other programs in Israel that support energy projects, while with MAGNET they have to compete with other industrial sectors. If they apply to a program dedicated to energy, then they compete within the same industry and not with other industries (Interviewee G5). Furthermore,

> First, there are several academic research groups with good results, but are too big for industry to take on. Second, the energy market is not clear cut. When the price of oil goes up, then they want to look for alternatives; prices go down, then projects don't find funding resources (Interviewee G5).

6.2.4 MATIMOP program

MATIMOP - Hebrew acronym for Israeli Centre for R&D, is the international arm of the OCS. The program has 50 agreements with 35 countries (Interviewee G6), and for each country and region MATIMOP has a desk manager (Interviewee G1). The role of MATIMOP is to establish partnerships to develop Intellectual Property (IP), and to build innovative products with international companies that have complementary technologies to those of Israeli companies through a matchmaking process (Interviewee G7).

MATIMOP receives and evaluates between 300 to 400 bilateral projects yearly; approximately 50 percent get funding from both sides, the Israeli and the international

government, and about 50 percent of those projects are commercialized and the companies pay royalties to the OCS (Interviewee G7). One of its most important programs is the Bilateral Industrial R&D (BIRD) foundation with the United States (US), which has the BIRD Energy program, "which specifically deals with renewable energy and energy efficiency" (Interviewee G3). The Canada-Israel Industrial R&D Foundation (CIIRDF) also has an energy program with Natural Resources Canada (NRCan), "they want the projects to be in energy and 75 percent to be on oil sands" (Interviewee G6).

6.2.4.1 The Bi-National Agency for Industrial R&D Cooperation (BIRD Foundation)

The BIRD foundation was established in 1977 as the first bi-national collaboration framework, with the goal of helping leverage Israeli technology through a technology push to get commercialized in the US market (Interviewee G6). BIRD became the model for every program Israel has had with other countries. The US market:

> It is still very important today, because every Israeli technological company that develops the capability to commercialize into successful products, in most cases they look at the US market as the first market. On the other hand, US companies are looking for innovation outside their borders - actually today US companies, small and large, and BIRD enables that relationship. It is a very synergistic relationship. One of the reasons it is so successful is because it is clearly a mutual benefit relationship (Interviewee G3).

In 2009 the BIRD Energy program was established to conduct R&D in renewable energy and in energy efficiency. This program has additional funding and includes solar and wind energy, as well as research related to energy efficiency, alternative fuels and water-energy nexus. For example, in water desalination plants 50 percent of the cost is in producing energy. This energy production is called 'nexus,' where producing and reusing water is energy intensive, and doing this through an efficient energy process creates a more cost effective system, or water-energy nexus. BIRD works only with civilian

companies, and also with companies involved in homeland security in the US, but not with the Pentagon. Twenty percent of BIRD projects are in energy and water (Interviewee G3).

Bird Energy was the initiative of the Israeli government, but it was implemented with the collaboration of the US Congress through a legislation approved in 2007 called the Energy Independence and Security Act of 2007, where one of its sections describes the US-Israeli collaboration. In November 2014, the Energy fund had 17 projects and had approved five more projects. Two projects had been completed with some success. One of them a startup with headquarters in the US, with the investment of an Israeli cleantech firm, developed a sensor that allows a high resolution measurement of energy consumption in a building or an industry, and already had revenues.

BIRD only supports R&D projects, not their marketing, and the funding is a conditional grant, like most of the OCS grants. The R&D proposal must include the end product or end service, which can be an energy system, or a device, that can be commercialized, and each company keeps its IP (Interviewee G3, personal communication, February 9, 2015). Companies must repay BIRD's investment through royalties only if they have revenues from the projects. Repayments are from 100 and up to 150 percent of the original conditional grant (Interviewee G3, personal communication, February 9, 2015). [39]

The matchmaking process can come from the companies themselves, or the foundation helps them to find a partner. The process can vary, but every company needs a local partner to enter that market. In many cases Israeli startups are the ones that bring the technology to the table, while the US companies conduct the marketing, but partnerships are diverse. When the BIRD program started most partnerships were between young Israeli and larger US companies. However,

> Today, because Israeli companies have matured and people know much better what they are doing, you can find in many cases that an Israeli company is looking for a complementary technology, even if the Israeli company is not a huge company,

[39] Interviewee G3 also provided a pdf presentation indicating that "BIRD funds up to 50 percent of the R&D project, and the maximum grant per project is US$1 million."

> they may partner with a small US company, that has a complementary technology. Both companies can market. Israeli companies are very aggressive and creative in their marketing (Interviewee G3).

The BIRD fund, in general, has approved 900 R&D projects since 1977, and has invested over US$307 million. In average, 20 to 30 percent of projects have reached the commercialization stage, a very high number for this fund, which deals with high risk projects. BIRD does not fund projects that are “more of the same” or low risk projects (Interviewee G3). Although the Israeli renewable energy industry, the same as in the US, is going through hard times as it finds it difficult to raise money, in the last BIRD Energy bidding round, there were several joint proposals including solar, batteries, fuel cells, and water-energy nexus (Interviewee G3).

6.2.4.2 The Canada-Israel Industrial R&D Foundation (CIIRDF)

The Canada Israel Industrial R&D Foundation (CIIRDF) was established in 1994 modeled on the BIRD Foundation. CIIRDF has bilateral treaties funded on five year agreements with matching funds for each country. Collaboration takes place between two companies with R&D innovation on both sides, where each company has complementary technologies that will result in a product or process at the end of the project (Interviewee G6)

CIIRDF has an energy program with Natural Resources Canada (NRCan) which was established under the initiative of the Canadian government. CIIRDF has six projects in total with NRCan. Regarding the success rate of the program, in general, not only the energy program, most companies do not pay back their conditional grant, meaning less than 50 percent do pay back. The Canadian Government has an accounting rating of the percentage of success, but the Israeli team tells them that “this game is more like religion, you got to believe in it and ultimately there may be a pay, and that is what Israel has done” (Interviewee G6), and eventually the government will get paid back. The investment risk is very high during the early stages of the program, and NRCan is in the process of understanding this (Interviewee G6).

6.3 ENERGY SPECIFIC PROGRAMS

6.3.1 Government Sector

6.3.1.1 Fuel Choices Initiative

The Fuel Choices Initiative is one of the newest programs, established by the Prime Minister's Office in 2011, in support of clean alternative transportation fuels, and operates its funding program through the different established OCS programs (Interviewee G4). Fuel Choices has implemented several programs including:

- A co-investment fund for companies that need to find investors, in which the government invests up to 50 percent and gives an option to investors, similarly to the Yozma program.
- A pilot program through bidding calls for companies that want to demonstrate their new technology and capability, and that helps companies to raise more money. Fuel Choices has 20 pilots running.
- A community called 'Eco Motion' on the Fuel Choices Web site, where entrepreneurs are introduced to the market, to stakeholders, and also to one another through annual events in Israel.

Notwithstanding what it may have been the support of Fuel Choices, as an interviewee who received US$140,000 from the Ministry of Energy, mentioned that "the energy programs are very capital intensive and these (government) programs are nice and good, but they are really far from helping. They help in recognition," but nevertheless, although "it's a small thing, but it counts" (Interviewee P3). Nonetheless, the Fuel Choices Initiative program seems to be an incentive for entrepreneurs to choose energy innovation, due to the additional funding and co-investment support to the ones that already exist through the OCS. For example, one of the entrepreneurs interviewed had a previous company for semiconductors and now is developing an energy storage system with an incubator and has further financial support from the Fuel Choices Initiative. The company was manufacturing its prototype, and looking at conducting its next round of financing while in discussions with a Chinese supplier to the Chinese electricity companies (Interviewee P4). As an interviewee explained, IP also plays an

important role with the Fuel Choices Initiative, where one of its measures of success is by the IPs and publications that come out of its programs (Interviewee G4).

6.3.2 Industry Sector

In the industry sector Israeli companies have their own laboratories to the point that if a company has three people, one is the Chief Executive Officer (CEO), a second one is the Chief Financial Officer (CFO) and the third one is the Chief Technical Officer (CTO). This is different from other countries where the CTO is number 20 or 25 in the company, while in Israel "the CTO is part of the game from day one" (Interviewee G7). However, Industrial R&D in green energy in Israel does not focus on core technology and is not subcontracted to a research institute or university. Core technologies are rather produced through basic research in academia. There are many small companies producing innovation in energy, such as special turbines and Photovoltaic (PV) panels, but they do not deal with the full energy system, only with its parts (Interviewees G7 and A8).

6.3.2.1 Solar Energy-The Arava Power Company:

In 2006 the Arava (solar) Power Company was established by a group of entrepreneurial people who were lobbying the government for the development of solar fields in the Negev and the Arava Deserts, in southern Israel. This group established a contractual relationship with the Kibbutzim and Moshavim in the Negev and in the Arava (located halfway between the Dead Sea and the city of Eilat), which have extensive land that could be assigned for solar fields. As stated by an interviewee (Interviewee P7), there is true potential for solar fields in Israel, but at that time the Israeli government was not ready. Therefore, these efforts required "lots of stamina and patience" (Interviewee P7), but were worth while. The motivation of Arava Power to produce solar energy for the State of Israel was both economic and Zionist, by recognizing that there is a need for solar energy in Israel, and that it is inundated with effective sun hours:

> Solar energy in Israel should be based on relationships and partnerships with kibbutzim and moshavim, in the Negev and Arava deserts, with land available and

> the right motivation, both economic and Zionist, to begin producing solar energy for the State of Israel… the initial drive was as much Zionist as commercial (Interviewee P7).

If Germany could develop solar energy back then and England is the hot spot in solar energy today, and both countries have hundreds less sun hours than Israel, then there must be an opportunity in Israel as well. During the first stage the founders of Arava Power lobbied the government and regulators to convince them of the numerous benefits of solar energy to the national economy. According to the same interviewee, the company "was in desperate need…for government support (and) for subsidized tariffs…." (Interviewee P7).

In 2009, Siemens from Germany was looking to invest in developing markets in solar energy, and the company purchased 40 percent equity in Arava Power. [40] Shortly after Siemens' investment, the Jewish National Fund (JNF-KKL, Keren Kayemet Le Israel) purchased six percent equity in the company. Arava Power had by then a close relationship with many kibbutzim and moshavim and started rezoning and preparing the land to be licensed for solar projects. The first solar field was built in 2011 (Interviewee P7). This interviewee indicated that in 2015 the solar energy tariffs would be determined in a different way and be much lower. Therefore, further development of solar projects would depend on the tariffs' level established by the regulator and on whether the industry would continue to grow or not (Interviewee P7).

In addition, the Arava Power works very closely with Professor David Faiman from the Ben-Gurion University, who is Israel's national eminence on solar energy research. Also, the Arava Institute for Environmental Studies (AIES), in Kibbutz Ketura, is a one percent shareholder in the Arava Power Company (Interviewee P7).

An interviewee mentioned that the Ministry of Economy commissioned a research and report on solar energy, by Prof. Eugene Kandel, which presents the benefits of

[40] This interviewee further clarified that Siemens also acquired Solel Solar Systems, an Israeli pioneering company with solar thermal fields, and in 2012 the Siemens management decided to end all its solar investments in Israel due to the economic crisis (Interviewee P13).

renewable energy on Israel's economy, and which was supposed to be included in the 2015 work plan, but in November 2014 there was no government work plan showing this path[41] (Interviewee G2).

6.4 R&D COLLABORATION BY ISRAELI UNIVERSITIES

6.4.1 University-Industry collaboration

6.4.1.1 The Weizmann Institute

Three professors interviewed explained that the Weizmann Institute is a graduate research university, and although it conducts mainly basic research its scientists also work with industry to develop applied research (Interviewees A4, A3 and A8). According to one professor interviewed, Yeda, the TTO of the Weizmann Institute, has a huge number of patents, and in Israel, Yeda is the organization that files the largest number of patents. However, very few of these get commercialized, and the IP always belongs to Weizmann. Weizmann's policy is that if new ideas lead to new IPs while the scientist is consulting with a firm, those will still belong to the Institute and the company will have first option to license the patents, but will legally belong to the Institute (Interviewee A4).

When Weizmann's scientists have a discovery and they believe it has a market, they must convince Yeda that it is worth while for the TTO to patent their technology and that it has a real possibility to produce royalties, because the cost of patents is very high. Yeda writes the patent application with the technical assistance of the scientist and absorbs all the costs. The Institute allows the inventor to consult with the licensing company once a week, while the scientist receives a grant from the company to further develop the next generation technology for the company (Interviewee A8). Yeda takes 60 percent of the royalties and the scientist receives 40 percent. Yeda also has a Web site where it

[41] It seems that this report was submitted a year later, as indicated by Barkat (2013) "…pinning great hopes on a report drawn up by the National Economic Council headed by Prof. Eugene Kandel. The report is a first serious attempt to price the advantages of solar power over natural gas in 'non-economic' areas, such as energy security and pollution reduction. 'The Finance Ministry doesn't like this report,' says Parnass, 'It is being submitted to the government after a year's delay, and then only because of the stature of Professor Kandel," (para.13).

publishes all its technologies by sector, those that are already licensed and those that are available for licensing. The statistics indicate that for every five patents, with luck, about one gets commercialized (Interviewee A3).

Yeda has implemented some changes to its patenting strategy. Five or six years ago it used to file more patents; it patented almost every technology that came out of the Weizmann Institute, but since patenting costs are so high in North America and Europe, Yeda became more selective. Also, in the past Yeda used to patent in the US, but today, due to globalization, each region such as the EU, and every country has its own charges. Therefore, it has also become more selective by patenting only in countries where the technology will be used, for example patents for heavy oil technology are filed in the US and Canada (Interviewee A3).

Most renewable energy research comes from Israeli academic institutions, but these findings are too large for Israeli startups to adopt (Interviewees G5 and A8). University researchers are in touch with entrepreneurs with whom they have worked in the past and contact them when there is an opportunity. For example, when a large foreign investor was searching for investment opportunities with the Weizmann Institute, the researcher contacted an entrepreneur with whom he had worked in the past, this time to develop the technology with the large MNC investor (Interviewee A8 and P3).

As explained by a professor interviewed, the relationship between the scientist and the company must have the right balance with regards to mutual influence in order to successfully commercialize the technology. The scientist wants to develop the best technology, and could develop it forever, while the company wants to achieve a level of development where it can sell it as fast as possible. There are companies that failed because they did not take the time to develop the technology enough; and others that failed because they kept developing the technology. Ideally the company should start selling the product once it is ready for commercialization, even if it is not perfect, while at the same time it continues to develop the technology (Interviewee A8).

As well, there must be an open dialogue between the people in the company itself and with the scientist, since even within the company employees sometimes have opposite points of view and interests, and they must learn to work together. As this professor stated:

> I try to nurture…what I call (a) constructive disagreement, which is a good way to make decisions. It essentially means that…we have different points of view, different approaches, but we understand (this)…and are able to work out something that is the best compromise (Interviewee A8).

This interviewee also explained that regarding incubators and VC firms that approach universities, these develop very small projects. Their investments in each project are small and the time period where they need to get results is also short. Although some of them are interested in Weizmann projects, incubators and VC firms do not have the capability to develop them further and to be applied to large scale industries. On the other hand, there are large foreign companies developing technologies for large scale industries that invest in Israeli technologies, such as the large foreign MNC that invested in the startup with Weizmann's technology (Interviewee A8).

6.4.1.2 The Israel Institute of Technology (Technion):

As described by an interviewee, often the first collaboration stage within the Technion is through the Technion Liaison Office, which was established in 1999 by the Technion R&D Foundation Ltd. (TRDF), an incorporated company and a subsidiary of the Technion. The members on the Board of Directors of the TRDF are half Technion and half industry, and Prof Peretz Lavie, the President of the Technion, is the Head of the Board. The TRDF manages US$120 million per year, of which 60 percent come from global competitive academic grants; about 35 percent comes from the European Union (EU); and 5 percent from industry (Interviewee A1). As stated by another interviewee: "The mandate of the Technion Liaison Office is to maximize research dollars that the Technion receives from government, industry and private sources, by also facilitating and encouraging collaborative research with industry as long as it is pure research" (Interview A2).

When the Liaison Office connects with industry – whether the Liaison Office contacts industry or industry contacts the Liaison Office, the transfer of knowledge can sometimes be both ways, from university to industry and from industry to academia.

Therefore, as an interviewee described: “There must be an understanding and the coming together of two worlds, two visions, through human chemistry that takes place between people” (Interviewee A1). The Liaison Office also identifies a liaison person inside industry with whom to work and to mutually transfer information:

> We try to get someone from the other side, as a liaison, someone who is willing to cooperate with me and who has a good access to the technological groups on the other side, so he can follow up, so we can mutually transfer information. Normally we request for help with a reciprocal list of technological needs from industry, that we process in our office (Interviewee A1).

Once the technology reaches a competitive stage and there is a patent then the Technion Technology Transfer Office (T3) takes over the technology to negotiate its commercialization (Interviewees A1 and A2). When researchers have a discovery, sometimes they contact the T3, or if the T3 finds out about research going on it contacts the professors, who have the choice and the freedom to choose if they want to file patents. If their discoveries are commercialized, they can get 50 percent of the total revenues after the T3 deducts its expenses. The T3 spends US$3 million per year in patents and other activities, and it generates over US$30 million per year in commercialization revenues only (Interviewee A2). The T3 “initially files patents very liberally, and lets the market decide…whether there is interest in the project or not” (Interviewee A2). Furthermore, as a professor interviewed at the Grand Technion Energy Program (GTEP) stated, the T3 encourages researchers to write patents when they have ideas to develop an IP, and since the GTEP was funded and founded in 2010 it already has several startups with more than ten patents (Interviewee A9).

As mentioned as well on the next Transfer of Technology chapter, the T3 files close to 100 patents every year, and has a database with all its technologies listed, with about 450 patent families available for commercialization. It also has 60 companies in its portfolio, spin-offs from the last 10 years, startups and more mature companies in which the T3 holds equity, or a license agreement, or both equity and royalties, which is their “preferred route” (Interviewee A2). These portfolio companies have raised close to

US$300 million in the last three to four years (Interviewee A2). Although the Technion owns the IP, the licensee can make any business decision such as sublicensing the IP to another company and receive royalties as well.

Interesting though, the CEO of a spinoff startup from the T3 described that the TTO is a partner and owns shares in his startup, but it does not own the IP; instead, the startup in Israel and the overseas manufacturing firm own it. The startup negotiated this arrangement around 2005, when companies could do this, but this is not possible anymore (Interviewee P12).

The T3 also has many inventions that are for future commercialization, and has had several technologies that "laid dormant" for many years that were developed when the opportunity presented itself and there was an interest in those technologies. Therefore it must be patient. For example, the T3 has technologies in wind turbine and smart photovoltaic skylight that uses energy from the whole light spectrum and are ahead of their time (Interviewee A2).

6.4.2 University-government collaboration

Weizmann researchers work with government programs such as MATIMOP and the Fuel Choices Initiative, although universities are not the main recipients of OCS funding (Interviewee A4). For example, MATIMOP's research committee includes academic experts, since according to an interviewee the government believes "That good and the most innovative ideas come from universities…Universities in Israel…are quite excellent. We have in Israel more Nobel Prizes than gold Olympic medals" (Interviewee G7).

Government programs, such as Fuel Choices, as well as the Minister of Energy, often contact academic researchers and ask for their feedback (Interviewee A8). Weizmann scientists were also involved in the initial setting-up of the Fuel Choices Initiative (Interviewee A4), and the Technion also has several researchers in its labs developing innovative fuel cells for the Fuel Choices Initiative (Interviewee A2).

An interviewee described that in addition, Weizmann's scientists have collaborated with the US Department of Energy in an R&D project. The scientists published their findings on a solar cell, and the US Department of Energy contacted them and requested

their assistance in finding the solution to this solar cell, which was then transferred to industry and commercialized in the US and worldwide. The Weizmann Institute had tried in the past to develop that cell in Israel, without success. The US company that commercialized this solar cell technology was very successful but also invested large sums of money into trying to commercialize it for over 10 years, while most Israeli companies do not have that patience (Interviewee A4). Weizmann Institute researchers have also been invited by the Alberta government to give a lecture on nano-technology at the National Institute for Nanotechnology in Edmonton which, as explained by a professor, "is interested in focusing on sustainable energy and wanted to learn from someone who has knowledge about this issue" (Interviewee A4).

6.4.3 University-military collaboration

There is ongoing informal collaboration between academia and the military, since university students serve in military reserve units once a year until their 40s, and in this way university knowledge is informally transferred to military units (Interviewee A3). For example, as recounted by an interviewee, a university student working with renewable technologies was in a reservist combat unit where they had problems with water. When he returned to the university, he asked his professor (interviewee A3) how to solve this problem:

> It was an informal channel, this happens all the time. And if I don't know the answer I have someone I can call. And there is the desire to help, because it is our defense force, my kids, my friends' kids I want to help out. I was in the army as well, in a combat unit for many years, doing reserve duty every year until the age of 40. I did my PhD here in Israel (Interviewee A3).

Alternatively, military knowledge is also transferred to universities through students who serve in elite units (Interviewee A1). The Technion has many students who come from MAMRAM (The military computer unit), and from the elite unit 8200, since graduates from these units go to the Technion to study or create their own startups (Interviewee A1).

Also, the Technion Research Authority collaborates directly with the Defense Industry, Elbit and RAFAEL, that have many civilian projects, and with the Research and Development Department (MAFAT**)** of Israel's Ministry of Defense**.** The Technion provides research and the defense industry gets the results (Interviewee A1). As well, a professor interviewed indicated that the Grand Technion Energy Program (GTEP), created in 2010, may also have some projects with a defense connection (Interviewee A9).

6.4.4 Collaboration among academic institutions

The Technion Liaison Office also promotes and supports R&D with international research institutions, mainly with European Union (EU) programs of which Israeli universities are members; and where the Technion researchers also develop alternative energy technologies (Interviewees A1 and G7). As indicated earlier, 35 percent of the Technion budget comes from the EU, while on the other hand, Israeli universities find it difficult to receive grants from the US or Canada (Interviewee G7). [42]

Israel collaborates mainly with the European Union, through the Israel-Europe R&D Directorate (ISERD), since it is a full partner of the EU Framework Programme for Research and Innovation called Horizon 2020, operating from 2014 to 2020, with a budget of €77 billion, a project within the EUREKA program. Israel also participates with other EUREKA programs such as Marie Currie, the European Research Council (ERC), the European Technology Platforms (ETP), the H-Factor, and several other programs (Interviewee A1). The ETP operates through clusters of stakeholders on certain topics such as renewable energy, and the program funds applied research through calls for proposals. The Technion is also a partner in the Energy Platform with developments such as fuel cells (Interviewee A1).

[42] Nevertheless, as Scott (2015) explained, the University of Calgary signed a "formal partnership agreement with the Technion…this spring, with a specific focus to promote collaborative research in energy and neurosciences." (para. 14).

6.5 THE VENTURE CAPITAL (VC) INDUSTRY

The CEO of a green energy startup indicated that VCs did not want to invest in his technology because of the losses they suffered during the last energy crisis which hit Europe (Interviewee P13), and where incentives in Spain were cancelled (Interviewee P2). As a result, Israel was also hit by those losses when VCs lost their appetite to invest again in green energy innovation (Interviewees G5, P3, P12, P13, and A8).

However, the Partner of a cleantech VC firm interviewed, established in January 2007, indicated that in the last 10 years VCs have invested a significant amount of money in green energy, but it was not easy. Many companies succeeded, but many also faced challenges. Nevertheless there is no way that a cleantech VC will not invest in green energy. When VCs invest in a technology they are interested in startups that have a differentiating core technology. Startups can patent their technology with the invested capital or they can file the patent before joining the VC. When the latter is the case, the VC conducts an analysis to make sure the patent will hold and the technology will not be copied (Interviewee P5).

He further pointed out that even if VCs do not build power plants, there have been VCs that invested in companies that developed technologies for new power plants, although some of these VCs did face hard times to get their returns on investment (Interviewee P5). Some companies received extensive capital investments and built large companies, "Solar City being one example; [43] a very successful publicly traded company that started with a lot of VC investment; and there are many others, Enernoc,[44] is very successful in on the more energy efficiency side" (Interviewee P5).

This same clean-tech VC had raised its second round of funds in 2011 which means that the companies under its umbrella were succeeding, and although there had been some failures, the firm only needed a limited number of successes to make up for the failures. Out of its portfolio of eight companies, this VC has invested in three energy companies including a recipient of the BIRD foundation support (Interviewee P5).

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[43] SolarCity (2015) Corporate Website indicated that the company has offices in the US and over 10,000 employees

[44] According to EnerNoc (2015) Corporate Website, the company was established in December 2001, with Headquarters in the US and global offices, including an office in Calgary.

Differently from incubators, Venture Capital firms collaborate with academia on a smaller scale by licensing technologies from TTOs, but mainly in health care. One clean-tech VC had only one university technology, not in energy (Interviewee P5), and a second one had none from academia in the energy sector either (Interviewee P1).

6.6 INDUSTRY-MILITARY R&D COLLABORATION

Industry-Military R&D collaboration takes place in different settings, for example Elbit Systems, a defense and homeland security company, opened its own incubator, Incubit Technology Ventures in 2013, which also supports green energy projects (Interviewee P1). Elbit is also a 20 percent investor, together with RAFAEL Advanced Defense Systems, in the Capital Nature Venture incubator, the only renewable incubator in Israel. As two interviewees explained, Capital Nature is developing energy efficiency technology and mobile energy such as small batteries for energy storage and easy recharge; small applications for military cars and robots in remote military bases, and also for civilian applications. Also, since the defense industries are diversifying into the civilian energy market, they are interested in renewable energy (Interviewee G2, Interviewee P1).

In the past, the defense industries also approached incubators to outsource their energy R&D, but since Elbit Systems opened its own incubator its need to connect with other clean-tech incubators has decreased (Interviewee P1). However, Elbit and RAFAEL do consult with the startups within the Capital Nature incubator when they have questions related to their civilian projects (Interviewee P4).

RAFAEL as well has a fully civilian energy project through BIRD, with a civilian startup from the United States that has developed an advanced battery technology (Interviewee G3). Another example is the company 'Given Imaging' [45] that has a pill (PillCam) developed by a scientist in the missile division of RAFAEL, which the BIRD's Executive Director used to manage. The capsule looks like a missile without the warhead.

[45] According to Given Imaging (2014), the company was acquired by Covidien, a company with headquarters in the US.

RAFAEL has a branch called RAFAEL Development Corporation (RDC), which is the commercialization arm of RAFAEL Advanced Defense Systems; and collaborates with Elron Electronic Industries, in the private sector, to identify capabilities and technologies in RAFAEL and to transfer them to startup companies (Interviewee G3).

Nevertheless, as indicated by several interviewees, most of the green energy technology - renewable and alternative, developed in the incubators does not originate in the military, except for a few technologies. For example a clean-tech incubator interviewed had only one military technology (Interviewee P1). This is the case even when some of the incubator's owners come from the defense industry. For instance, another clean-tech incubator interviewed, established in 1993, is run by managers with military experience where its founder had worked for 17 years as a Science Officer with the Israel Air Force (Interviewee P8). Nevertheless, as this interviewee stated, people who worked in the military have good business experience and are in high demand; these are people with industry management and technology experience (Interviewee P8). As well, some of the startup entrepreneurs in the incubator came from the military industries with their own ideas and technologies, or from companies in previous incubators, but none of the incubator technologies have military origins (Interviewee P8). Another interviewee supported this point of view, indicating that for example, the *Start-up Nation* book does not relate completely to what is going on today in the high tech industry in Israel.

> Although I don't agree with 80 percent of the book, not completely related in what is going on today in high tech. He (they were) was focusing very much in the military units, and experiences they get in the military units. But if you take the 100 successful SU companies in the last five years, very few came from the military (Interviewee G1).

Also there is a world perception that most innovations in Israel come from the military but this is not true. There are some elite units in the military that have implemented some technologies which made Israel famous, since these were successfully implemented in several countries and are well known. But the entrepreneurs who come

from the military are maybe fewer than five percent of all entrepreneurs in Israel, and therefore this is a misconception (Interviewee P3).

6.7 BRIDGE BETWEEN HIGH-TECH COMPANIES AND INVESTMENT COMPANIES

The IVC Research Centre provides, since 1997, business information on high-tech companies mainly to Israeli and foreign investors who are interested in the Israeli high-tech industry, through an online database, providing its services based on a membership business model (Interviewee P9).

IVC defines as high-tech those companies "that develop products through internal R&D efforts;" and it defines a startup, "as a company that if it doesn't receive their next funding they will get shut down; they cannot hold it on their own" (Interviewee P9).

IVC works mainly with private Israeli incubators operating under the OCS license, who reach out to startups through IVC in order to find companies that can enter the incubator program; in order to strengthen their management team; find a Chief Technology Officer (CTO); or sales people, since IVC also profiles executives in companies and investors, as well as the companies in which they invested in the past (Interviewee P9).

Startups that are showcased in the database include entrepreneurs or ventures that produce new technology; or those that need to raise money in order to survive, and are free to be promoted in the database as high-tech startups. Alternatively, investors and technological MNCs that search the database pay IVC a fixed yearly membership fee. This arrangement benefits both startups that get exposure, and the company's clients who get detailed information on the market. These investors in most cases may have already made investments in Israeli startups (Interviewee P9). IVC users also include TTOs that search the database to identify investors; university faculties of management and economics; university libraries and researchers; as well a PhD candidates doing

quantitative research. Government Ministries also use the database such as the OCS (Interviewee P9).

IVC also conducts customized work according to its clients' needs, such as due diligence on specific companies (Interviewee P9). The firm can provide not only the company's contact, name, telephone number, e-mail and fax, but also information on who invested in the startups, who established the company, number of employees, main clients, financing rounds and other information (Interviewees P9 and P14).

The firm covers over 6,000 high-tech companies, which are categorized by sectors, of which approximately 5,500 are startups. In the clean-tech sector IVC covers over 400 firms and within this sector it has an energy subsector. IVC covers these companies from seed or early inception, even before the startups receive any funding, to revenue stages (Interviewee P9). It adds on average 600 to 700 companies every year, and more than 400 companies also close every year, cease to operate and close down. However, in 2013 IVC "added more than 1000 companies (to its database), meaning that the industry grew by 1000 companies" that year (Interviewee P9). Of these, IVC added several green tech companies at the seed stage and at higher stages, many of them in alternative energy and related to electricity. During the first three quarters of 2013 Israeli high-tech companies raised US$2.4 billion. In January 2014 the company added 600 seed companies.

IVC research is based in Israel, but there are several similar research organizations in the United States and the European Union, and the company works with some of those organizations as well. For example, since investors are looking globally for companies in which to invest, it does a global comparison on capital raised by high-tech companies, or looks at specific global industry sectors searching for global problems similar to the ones in Israel.

6.8 CONCLUSION

As seen in this chapter, although the OCS programs have an interest in, and expectation for a final product or service, this is secondary to R&D, and the government supports only R&D and not the commercialization process. For example, an important selection criteria of the MAGNET program when selecting projects is to fund those that will strengthen the Israeli economy by creating exports; a criteria where the benefit to the

Israeli economy is more important than the benefit to the companies themselves. In this way, although MAGNET is strongly considering the end products of its R&D investments, it only supports the companies' R&D. However, as seen in the previous Chapter Five, MATIMOP does not accept companies in its programs that have tried to commercialize their IPs several times without success.

An exception to the support of R&D only is the support to those projects under the co-investment program of the Fuel Choices Initiative. Through this co-invest fund, the government invests 50 percent together with VCs, and gives an option to the investor. As addressed in the previous Israeli literature chapters. The successful Israeli VC industry was established with a similar policy under the Yozma program. My interviews show that only the Fuel Choices Initiative has this government co-investment program for now. As explored further in the next 'Transfer of Technology' Chapter Seven, an interviewee (Interviewee A5) suggests that the government should establish such at program to help startups in their commercialization stage as well once they leave the incubators. This could be one reason why Israeli entrepreneurs may be considered as not having the patience to grow their companies, as a professor interviewed mentioned above, while if they had further financial support there would probably be a higher number of large Israeli companies.

Informal R&D collaboration also takes place extensively through the mobility of key people, where Israeli professionals move positions across different institutions, from working with the defense industry to key positions with the OCS that are directly related to Israel's Innovation System. Also, informal two way R&D collaboration across Israeli institutions is strengthened by the military service of students, professors and of business people who serve as reservists, informally transferring knowledge from the military to academia and industry, and back to the military during their service. On the other hand, formal R&D collaboration across Israel's institutions also takes place where academic researchers work within the OCS programs, and also collaborate and provide R&D to the Israeli Defense Industry, and to the R&D Department of Israel's Ministry of Defense **(**MAFAT). Israel's strong R&D collaboration across its institutions is further supported by the IVC Research Centre, with an arrangement that connects innovation players across

Israeli and foreign institutions such as startups, local and foreign investors, university TTOs, and others.

Most of the green energy technologies developed in incubators, even when the incubators' investors come from the military or from the defense industry, these technologies do not originate in the military or defense industries. As well, even if the startups' entrepreneurs in the incubators come from the defense industries, they bring their own ideas and technologies and not those of the defense industry, although these ideas were probably developed during their employment with those industries. In this way, informal R&D collaboration and transfer of technology is further fostered between the military, the defense and private industry.

Two views are presented regarding the impact of green energy R&D. One view points-out that in Israel there is not much R&D in green energy, and a second one, from the point of view of a VC firm, indicates that VCs will not stop investing in green energy. The defense industries, interested in renewable energy for military use, are also diversifying into the civilian energy market. However, Capital Nature Venture, the only purely renewable energy incubator in Israel, also partially owned by the defense industry, Elbit and RAFAEL, works closely with universities and directly funds university research because there is not much industrial R&D in renewable energy in Israel. As well, the incubator had not yet achieved its goal of having 25 startups for a period of five years, since by the end of 2014, after three years of its foundation, it was working only with eight technologies. Therefore, in order to increase renewable R&D in Israel, an applied research centre in the Arava, the National Technological Center for Green Energy opened in 2014.

It is also important to mention that since Israel is surrounded by unfriendly neighbours, for Israeli technological companies the US is their first target market to develop their technologies, and often before they even enter the Israeli market. Another important point to bring up is that industry's investment in academia in general, not only in green energy, is five percent.

CHAPTER 7: TRANSFER OF TECHNOLOGY

7.1 INTRODUCTION

This chapter examines how the transfer of technology in Israel takes place, and why most of its technologies are exported or acquired by large foreign companies. Since green energy innovation is my target sector, the chapter looks at the barriers the government places on the implementation of renewable energy in Israel and the reasons for these barriers. It also addresses the tenacity of one company that overcame these barriers opening the market to other solar renewable companies; and the growth of renewable energy in the Arava, in southern Israel.

Next, it looks at the programs in green energy from two universities, the Weizmann Institute of Science (Weizmann Institute) and the Israel Institute of Technology (Technion). It examines their licensing of technology mainly to large international companies; the important role of the large number of entrepreneurs that Israel has; the role of scientists during the technology transfer process to the company; the Universities' main successful disciplines, and their licensing to VC firms.

It then addresses the transfer of technology process within the industry sector through incubators and startups; the various reasons why most technologies are acquired mainly by multi national companies (MNCs), including green energy technologies, manufacturing and selling in overseas markets. Finally, it presents the weakness of the Israeli Innovation System, and a proposed solution. Although Israel has been very successful in the last 20 years it is time for the Office of the Chief Scientist (OCS) and for the Israeli Innovation System to change.

The same as with R&D Collaboration, as seen in the previous chapter, Israeli Transfer of Technology takes place at different institutional levels creating an ecosystem that is very strong in many disciplines and that includes the following institutions (Interviewee A5): The Israeli government, which supports and often facilitates the transfer of technology process; Universities, which are very strong in life sciences, and where the Weizmann Institute is one of the leading 10 institutes worldwide; Incubators and venture capital firms (VCs); many small companies or startups producing innovation,

and whose owners have decided to remain independent and not to be acquired; big companies, with over US$1 billion in sales, with approximately 15 global Israeli multinational companies (MNCs) with headquarters in Israel (Interviewee A7, personal communication, November 2, 2017); and about 290 or more foreign MNCs, with R&D centres in Israel. My interviews did not include large Israeli companies or foreign MNCs.

7.2 GOVERNMENT BARRIERS TO IMPLEMENTATION OF RENEWABLE ENERGY TECHNOLOGY

Green energy technology is my target sector for monitoring change in the Israeli Innovation System. The Israeli government places many regulatory barriers on the implementation of renewable energy. It does not place barriers on research and development (R&D) of renewable energy, but there are barriers to implementing it, creating a very slow implementation process. Therefore, today the country's renewable energy is only about one percent of its energy production. The government's goal is to have 10 percent renewable energy supply by 2020, which is a very difficult target since today Israel should be at about five percent and not at one percent (Interviewee G3). The interviews provided several reasons for government barriers on the implementation of renewable energy, such as:

7.2.1 Israel has a socialist culture

Israel, on a per capita basis, is one of the leading developers of clean-tech technologies worldwide, with a significant number of important technologies that have been developed in the country (Interviewee P2). Nevertheless, according to several interviewees, Israel is considered a difficult place to do business since its social and political origins are socialist with a high level of bureaucratic obstacles, with which it is difficult to deal and to overcome (Interviewees P11, A5 and P3). Although the country is experiencing an economic transition to capitalism, it still has many social problems and many gaps in this transition and people's attitude is also socialist. It is not the policies that are socialist, but the people's attitude, which creates a high degree of friction and tension (Interviewee P11).

On the other hand, an American lawyer immigrant explained that differently from the Israeli government, the Federal and State governments in the United States will do anything to help business people (Interviewee P11). Alternatively, in Israel everyone is interested, in theory, in implementing renewable energy projects, with many competing interests, making it more expensive, challenging and time consuming (Interviewee P11). Also, although Germany and Spain created strong incentives to implement renewable energy, Israel has done only a little bit with lots of marketing and little action, which "has not measured with the talk" (Interviewee P2).

Nevertheless, as stated by an interviewee, although the implementation of large projects is "it's a little more complicated here than elsewhere… it's still doable" (Interviewee P11). As another interviewee described:

> There is an interest in Israel to deploy renewable energy. You must look at the broader picture. Israel has bureaucratic barriers in many things. Israel has lots of bureaucratic barriers... How long it took to build the very necessary desalination plants in Israel. If you follow many things in Israel, there are a lot of bureaucratic barriers, and renewable energy is not different…so you cannot say that that's a measure. So the bureaucratic measures in renewable energy are hard, but not more difficult than other barriers that relate to land and nature, because there is a lot of attention regarding the environment… Deploying a lot of solar fields in the Negev, seems to be a very good thing to do, but many people say you're scarifying the environment, or nature (Interviewee G3).

Another example is the Israel Electric Corporation that used to have a monopoly on the electricity market, and in the 1970s, when private companies got interested in selling and placing PV solar collectors for water heating on private homes, factories and chicken coop roofs among others, the Electric Corporation opposed this move although heating water was a big energy drain. The government forced these installations across the country, through a law that was passed in the 1970s, where houses and buildings under certain levels are required to use solar power to heat water, making Israel, for many years, one of the highest users of solar power per capita (Interviewee P2). Another example is the long time

that it took to build the very much needed desalination plants which are now a big success. Looking at these past issues in Israel one can see that there is no difference when it comes to the implementation of renewable energy (Interviewees G3 and A3). In desalination technology Israel is probably a world leader, where about 40 percent of Israel's water goes through a desalination process, turning the sea water into drinking water (Interviewee A2 and G3). Since desalination is energy intensive, Israeli companies are also innovating by producing desalinated water with less energy, being this green energy technology as well. One of the desalination companies focused on this area is IDE Technologies [46] (Interviewee P2).

7.2.2 Issues on electricity pricing and relationship with the Israel Electric Corporation

Given that the Israel Electric Corporation is owned by the government (Interviewees G2, G3 and A5), with the discovery of Israel's offshore gas fields the country can continue using its existing infrastructure and the same electricity company, while on the other hand, renewable energies change the whole electrical structure (Interviewee G2). Furthermore, as this interviewee explained:

> There is more interest in alternative fuels because they don't want to buy fuels from the Arabs. In electricity you are not buying fuel, you are burning coal from China, or South Africa, countries that are not your enemies, it's easier, and you have now natural gas, and you are using the same turbines, the same electricity company. Renewable energies change the whole paradigm of electricity (Interviewee G2).

Nevertheless, since the government is indeed interested in implementing renewable energy it is doing this at a slower pace, as it wants to reduce the electricity prices in Israel (Interviewee G2). Also, because renewable energy is more costly than fossil fuel energy,

[46] The IDE Technologies Corporate Website (2015) points out that the company's Headquarters are in Israel, and it has subsidiaries in California, China, India, Chile, Australia, and Calgary. The company's success is based on its continuous improvement of energy efficiency and on minimizing its environmental impact.

it can make the energy mix much more expensive, become a burden to the country and hinder its industrial competitiveness and economic growth. In addition, renewable energy is also subsidized,[47] which further increases bureaucratic barriers for its implementation (Interviewees G3 and P2).

7.2.3 Environmental issues

There are also barriers related to environmental issues where, although implementing many solar fields in the Negev desert may seem like a good idea, many people are against it since photovoltaic energy needs large spaces of land that affect nature with negative environmental impacts (Interviewee A2, G3, and A3). In addition, wind turbines would be a problem, a hazard to the Israeli Air Force (Interviewee P1).

7.2.4 The small size of the Israeli market

Some interviewees indicated that Israel is not a target market for Israeli energy companies, but only for beta sites, because the Israeli market is very small (Interviewees P2 and G7), while others indicated that there are also barriers to building green energy beta sites (Interviewee A5). This is an issue that university researchers at the Samuel Neaman Institute, at the Technion, are trying to resolve through their relationship with the OCS (Interviewee A5). Differently, another interviewee indicated that the Israeli market is not that small, but double the size of the Alberta market (Interviewee P12).

7.2.5 More money goes into renewable energy in other countries

The energy market in Israel is small when compared to other countries such as China, that has a huge market, or the US, or Europe where there are much larger markets, and where more money goes into these developments than in Israel. Therefore, because of these economic and financial reasons Israeli companies implement renewable energy overseas (Interviewee A8).

[47] Today, solar energy no longer requires any form of subsidy, as seen in Footnote 48 below.

7.2.6 A weak Tel Aviv Stock Exchange Market

Israeli Initial Public Offerings (IPOs) take place mainly in NASDAQ, and also in the NY Stock Exchange, Britain, Italy, and in Israel as well. Researchers at the Samuel Neaman Institute in their communication with the OCS are trying to enhance the Israeli stock exchange again because it had a significant down turn in the last few years, as very few companies had IPOs in the Israeli stock market:

> We are trying to enhance the Israeli stock exchange again because it really went down in the last few years, because not many new companies had IPOs in the Israeli market. In Israel there is a different story, where pension funds are not investing money in innovation, by rule; now we are going to change that rule and create another growth engine (Interviewee A5).

7.2.7 The renewable energy sector is highly regulated

Renewable energy is similar to life sciences in that it is very heavily regulated and has a long development cycle compared to the software market. Renewable energy also needs more resources in order to bring the product to the market (Interviewee A2), since the energy industry will not accept products before these are tested. As a professor interviewed mentioned “when it comes to energy, you usually grow in an evolutionary way, where you demonstrate an idea in a small scale and then you grow it” (Interviewee A9). Also, as described by an interviewee, renewable energy buyers are normally government, municipalities, and not the private sector, and governments dictate the approval system of the technologies to be implemented, a process that usually takes a long time. Furthermore, governments cannot rely on startups that may not survive in the near future, but on large and stable providers such as General Electric (GE) (Interviewee A2). However, as an interviewee indicated, notwithstanding the fact that renewable energy is highly regulated, today there is more privatization with companies installing solar energy in kibbutzim in southern Israel, where renewable energy is growing (Interviewee A3).

7.3 SOLAR ENERGY

"And there is so much sun here. We have sun 300 days a year…." (Interviewee A2).

7.3.1 Arava Power Company (Arava Power)

Arava Power, established in 2006, spent several years having discussions with the Israeli government and dealing with its excessive bureaucracy, "which may have been a daunting challenge," as stated by an interviewee (Interviewee P7). At that time, the government was interested only in small scale rooftop installations and not in ground based solar power fields, since Israel did not have the infrastructure needed to incorporate renewable energy, and also due to environmental concerns by a green movement in Israel (Interviewee P7).

As also discussed by this same interviewee, due to Arava Power's lobbying, in 2009 the National Planning Authority established the national legal processes and plans, rules and regulations to accommodate solar energy and to rezone land for solar power (Interviewee P7). Within about a year Arava Power received the permits to build the solar fields in agricultural land that was not used by the kibbutzim, for a period of 20 years, "paying the Israel Lands Authority an exorbitant amount of money for this long term lease" (Interviewee P7). In Israel there is very little land owned privately. The land belongs to the government and the kibbutz pays a 49 year renewable lease, and at the end of the lease the solar field is completely dismantled (Interviewee P7). This arrangement turned out to be a win/win solution, since the land selected was less suitable for agriculture and there was no population affected (Interviewee P7).

Finally, in 2011, Arava Power built the Ketura solar field, the first to receive a feed-in tariff permit in Israel; and 18 months later other companies also established solar fields in the country (Interviewee P7). Arava Power built seven more projects and it had another 15 projects in the pipeline that were halted because in the mid 2011 there was a "freeze period" imposed by the government, who took about two and half years to decide on a new regulation regarding the implementation of tariffs after 2015, due to ongoing discussions between the Ministry of Energy and the Ministry of Finance, who was concerned that solar energy would increase electricity costs. Arava Power was then

hoping that by mid 2015 it would continue to build its additional solar projects. The company launched, in July 2015, Israel's largest solar field connected to the grid (The Jerusalem Post, July 2015; Globes Business Arena, July 2015).[48]

7.3.2 Eilat-Eilot Renewable Energy Ltd.

The Eilat-Eilot Renewable Energy Ltd, in Southern Israel, which is also an investor in Arava Power, plans to collect 100 percent of solar energy during the day, and to have 44 percent of its power plants producing solar energy in 2016; and by 2020 it plans to be solar energy independent, as explained by a interviewee**.** Eilat-Eilot Renewable Energy has the technology to produce solar power at night, that can pump-up water during the day and drop it at night through a pump storage technology developed by Brenmiller Energy, an Israeli company, and the innovation will be on how to combine this technology with heat storage (Interviewee G2).

7.3.3 LUZ and Solel

Although traditionally there were always scientific developments in Israel in alternative and renewable energy, solar, wind, and others, these were commercialized overseas, where there were more opportunities. For example, in the 1980s, before the founding of Arava Power, an Israeli company called LUZ was the first company to commercialize solar energy in California, installing 11 solar fields, while the company did not install anything in Israel (Interviewee P13). One interviewee's point of view was that in California it was easier to build solar fields, while Israel being a small country, to get a license to build and to get land in the Negev desert, was more difficult than in California. This is still an issue, since energy projects in Israel can be small when compared to the larger markets and projects that Israeli companies can find and develop abroad (Interviewee A8). Another interviewee pointed at the bureaucracy in Israel, where the Israeli government, the Ministry of Energy and the Ministry of Economy erected barriers against solar fields' installations for reasons mentioned earlier (Interviewee P13).

[48] Udasin (2015) explains that Arava Power launched, in July 2015, Israel's largest solar field. "Today, solar energy no longer requires any form of subsidy and contributes significantly to the national economy" (para. 27).

LUZ declared bankruptcy, and two years later Luz's engineers bought the intellectual property (IP) of the company and started a new company called Solel (Interviewee P13), which an interviewee joined in 2007. Nevertheless, since LUZ was established, a large amount of research was done mainly in academia, both in photovoltaic (PV) and in solar thermal energy. In 2006/2007 there was an increase in the number of solar energy companies due to a rise in the solar market demand, which received a boost from the Spanish government by providing generous tariff incentives for solar fields' installations, and where Solel built solar fields as well. Solel was acquired in 2009 by the German company Siemens, which as mentioned in the previous Chapter Six, closed all its solar activities in Israel by the spring of 2014. On the Government of Israel Web site there is a statement from Solel after it was acquired by Siemens:

> Our company deals in all the essential equipment, not only for solar power stations but for the production of electricity as well…The bulk of our activity is in Spain and the United States, but at the same time we are hoping to soon be signing contracts in other parts of the world, like South Africa and Australia. For the meantime, we are marketing only to foreign interests-even though there are plenty of potential projects in Israel, so we are hoping that this situation will change…The new ownership is German, but as a business unit we are still operating as an Israeli-based company (Ministry of Economy and Industry, n.d.b).

7.4 TRANSFER OF TECHNOLOGY FROM ACADEMIA TO INDUSTRY

A professor interviewed explained that in the early 1950s Prime Minister David Ben-Gurion founded a research lab in Jerusalem, based on the UK model, for water and alternative energy programs, as a response to Israel's shortage of water and energy resources. The lab operated for about 10 years and the technology for the solar roof collectors, installed today across Israel, came out of this lab.

In the 1970s, Israeli universities such as the Weizmann Institute of Science (Weizmann Institute), the Israel Institute of Technology (Technion), Ben Gurion University (BGU), and later on Tel Aviv (TAU) and Bar Ilan Universities, all had

programs related to renewable and alternative energy (Interviewee A8). This section includes interviews with the Weizmann Institute and the Technion.

7.4.1 The Weizmann Institute

The Weizmann Institute is mainly a basic research institute. However, half of its scientists work in applied research, especially in the area of life sciences. In addition, aside from working with the Israeli government, its scientists work with foreign governments as well (Interviewee A4). As one professor interviewed explained, he worked for three years on a cell project for the US Department of Energy, and his research results were transferred to a US company which took ten years to commercialize it worldwide (Interviewee A4). As well, Israeli scientists have worked with US industries, but their names are confidential. According to this professor, there are very few innovations implemented in Israel, where a company has:

> Stuck for a long long time with the development of a product, because they (Israeli entrepreneurs) don't have the money and they don't have the patience, while this (technology development) is very special to academia, and the Weizmann is particularly good at it (Interviewee A4).

Nevertheless, academic scientists work as well with Israeli entrepreneurs. When they are interested in developing academic research they contact Yeda, Weizmann's Transfer of Technology Office (TTO), looking for green energy technologies; or scientists themselves have connections with companies and entrepreneurs (Interviewee A8). Scientists know many players in their own fields and in some cases introduce them to Yeda and the relationship develops from there (Interviewee A3).

Yeda works with two incubators to which it licenses its technologies. The TTO signs a contract to get royalties and/or equity and to receive annual reports with the milestones established in the agreement (Interviewee A3). Scientists sign an agreement between Yeda and the incubator stating that they can do the transfer of technology, and after this stage only the TTO is involved in other agreements signed by the company, while scientists do not get involved anymore (Interviewee A3).

During the transfer of technology, the licensing process to industry, which takes from one to two years, scientists are allowed to consult with the incubated company only one day per week while being strongly involved in the decision making process of the technology development only; and once the commercialization is successful, they receive royalties from net sales, shared with the TTO (Interviewee A8). This is different from US universities where scientists set-up companies and run them, while Israeli researchers can only help to set-up a company and act as consultants, otherwise, as a professor interviewed explained, scientists "must take a leave of absence without pay" (Interviewee A4).

Yeda's policy is that if while consulting with a company new ideas lead to a new Intellectual Property (IP) or new patents, those will belong to the Weizmann Institute as well, and the company will have first priority to license the technology from the university. However, the written content of the patents is broad enough that the scientist's input strengthens the existing patent instead of leading to new ones during the incubation stage (Interviewee A3). The incubator can sublicense the technology; or partner with a company and sublicense the technology to the company; and once the startup has profits, it must return the 2 million shekels (US$600,000 approximately) to the government who has no equity in the startup.

Two solar spinoffs from Yeda, produce electricity with solar energy. As a professor interviewed, who discovered the technologies for both startups, explained that these startups did not work with VCs probably because they were not a good match due to the longer process to develop green energy technology, which takes longer than four or five years, as VCs expect. At the end of 2014, both startups were building their demonstration plants in Israel and abroad, and both had relatively large international companies that invested in them (Interviewee A8). Even so, VC firms also look for technologies from academia in which to invest and talk with scientists on an ongoing basis (Interviewee A3).

However, as discussed by a professor, Yeda is sometimes successful and often not. It has profits from a few discoveries and can afford to be very active because it stays "in the black" (Interviewee A4) mainly due to its great success with its well known drugs Copaxone and Rebiff for Multiple Sclerosis (MS), which control 60 percent of the global MS market; Erbitux for treating cancer; and the Encrypton scheme. The most successful

drug, Copaxone, was developed locally by the Israeli Multinational pharmaceutical company Teva (Interviewee A4).

In order to share its scientific discoveries with the Israeli public in general, the Weizmann Institute started an event that it calls “Beer and Science,” and now all universities are having this event as well. Once a year scientists go to different bars, for example Tel Aviv has about 20 bars, where researchers bring lay science to the public. As a professor interviewed described, this is

> A fantastic idea…a lot of people are interested; no power point or anything, I just pick up the mic while people are eating and drinking and tell them about my research; and at least in Israel, there is a real interest in science; people really want to know about the different developments (Interviewee A3).

This event can also result in the licensing of a technology. This happens when successful entrepreneurs attend these presentations (Interviewee A3).

7.4.2 Israel Institute of Technology– Technion

While basic R&D collaboration is under the mandate of the Technion Liaison Office, transfer of technology within the Technion takes place through the Technion Technology Transfer Office (T3) (Interviewee A1) and the Technion R&D Foundation (Interviewee A1). The T3 encourages the mutual transfer of technologies between industry and academia, which in order to take place networking and chemistry between both institutions is very important (Interviewee A1).

The mandate of the T3 is to create a maximum number of companies and technologies that it spins off; it receives royalties on net sales from its technology licenses, and it also has equity in the companies it spins-off. The royalties received from commercialized technologies are invested back into the Technion (Interviewee A2).

According to an interviewee, Israeli universities produce a significant amount of research and commercialization with strong financial returns when compared with those of US universities. The Technion, for example, generates more than US$30 million in income from commercialization, which comprises more than a third of its research

budget (Interviewee A2), as indicated earlier. The Technion's net research budget, not including infrastructure and scholarships, is about US$80 to 85 million per year, mainly from the OCS and the European Union, who are the university's main funding sources for research. This budget is less than half of the research budget of the three top universities in the United States. The research budget of MIT is about US$1.5 billion,[49] or 20 times higher than that of the Technion; while maybe it has only double the number of researchers than those of the Technion. Stanford has about US$800 million and Harvard US$900 million per year. The return in commercialization of MIT is US$50 million; Stanford US$60 to US$70 million; and Harvard, US$20 million; while, as mentioned above, the Technion generates more than US$30 million in income from its commercialization activities (Interviewee A2). In addition, today the T3 spends US$3 million a year on patents and other activities.

Although it is difficult to identify the reasons why the returns of the US Universities relative to those of the Technion are much lower, several possible reasons were suggested (Interviewee A2) such as: First, The business model of MIT is to have as many companies or licenses as possible, while the T3, in addition to commercializing the technologies, may be more aggressive in its demand for a higher rate of royalties as well as equity in the companies that it spins off. Maybe these universities are more lenient in their commercial terms, "because they have very lavish endowments," and their emphasis is not on the economic returns, while for the T3, its income from commercialization comprises about a third of the research budget of the Technion. Second, it could be that these universities are doing more basic research, and if comparing the effectiveness of the Technion research and how much of it is translated into products, the ratio at the Technion is much higher (Interviewee A2).

Another important consideration is that the success of most Israeli universities is mainly in commercializing technologies in the area of life sciences, and specifically in the development of drugs. In addition to Weizmann's successes in drug discoveries, as mentioned earlier, the other two Israeli leading universities, the Hebrew University (HU), and the Technion, each one of them has at least one FDA approved drug in the market.

[49] This amount was confirmed on the MIT Website, where sponsored research is US$1, 479.2 million, MIT Facts (2017).

The Technion has Azilect, for Parkinson's, selling for US$400 million a year; the HU has two main drugs, Doxil and Exelon, with cumulative sales of over a billion US. Azilect, like Copaxone, was further developed in Israel by the Israeli pharmaceutical Teva, and the biggest success and profit source of Teva is Copaxone. These drugs that were invented by Israeli Universities, and were developed in Israel, sell worldwide for US$10 billion. The other drugs that Israeli universities license globally to companies such as Johnson & Johnson, Novartis and others, have global sales of US$30 billion (Interviewee A2).

The Technion has 560 Faculty members while its T3 has a staff of ten people, including three business development individuals responsible for 180 researchers. To leverage this number, the T3 works with a network of entrepreneurs, "something with which Israel has been blessed" (Interviewee A2); and which according to a VC Partner, Israel is a very amazing place for its entrepreneurs, "we have very smart people, very innovative people, and people who take risks" (Interviewee P1).

There are many entrepreneurs, as well, who were working in the past on IT related technologies originating in the military and who are now developing products that come from academia which are in higher market demand. This provides great opportunities for university TTOs, as these entrepreneurs, who come from outside the university are critical for an efficient technology transfer process. The T3 meets with them and checks their background and capabilities, and they become part of its network of entrepreneurs who approach the T3 on an ongoing basis looking for new technologies. "Technology transfer is like science itself, it's about serendipity, you do something and all of a sudden something else happens, and when the opportunity presents itself, you must be ready" (Interviewee A2). The T3 signs an option agreement with them, and if they are able to meet certain milestones, usually raising a certain amount of capital, the T3 will be willing to license the technology to them also under certain conditions (Interviewee A2).

Professors sometimes also approach the T3, and sometimes the T3 learns about the research professors are conducting and it contacts them. Professors have the prerogative and the freedom to decide if they wish to file patents, and they are compensated if their patents are commercialized. The T3 owns the patents and shares 50 percent of revenues with professors after deducting its expenses (Interviewee A2).

The T3 has a database with all its technologies listed and free for anyone to browse. It has 600 patent families of which about 450 are available for commercialization; and it files close to 100 patents every year. Currently the T3 has 60 companies in its portfolio, spin-offs from the last ten years - some are startups and some are more mature, in which either the T3 holds equity, or a license agreement or both, equity and royalties; and these companies have raised close to US$300 million in the last three to four years (Interviewee A2).

In the past the Technion had an incubator called the Technion Seed which is not active anymore (former TEIC as well). It was a government incubator and the Technion was one of its owners. Today the Technion has two incubators, the Alfred Mann Institute at the Technion (AMIT), a biomedical incubator established in 2006 that has already invested close to US$40 million in its projects. A second incubator is the IT Focus Accelerator incubator within the T3, launched at the end of 2014, which is like an incubator but faster (Interviewees A1 and A2). Nevertheless, The T3 works with all the 24 incubators that exist in Israel, including Capital Nature Venture in the area of renewable energy (Interviewee A2). The Capital Nature Venture incubator has a research centre in the Arava with companies that were spinoffs from the Technion, which will allow the incubator to increase its number of renewable energy startups (Interviewees A5, A7 and G2).

7.4.2.1 The Grand Technion Energy Program (The Grand or GTEP)

As explained by an interviewee, the Grand was established in 2006 as an interdisciplinary program involved only in projects that are “beyond state of the art technologies… not with traditional (technology), but only with the most advanced,” and although it is still a young program, it has already generated some green technologies (Interviewee A1). While universities historically have been built as silos, the Grand fosters innovation by mixing scientists from different disciplines (Interviewee A2).

Today there is more applied research conducted at the Technion with the intention of being commercialized, and researchers at the Grand are encouraged to write patents on their discoveries (Interviewee A9). However, although the Technion has many green energy patents, their commercialization process is challenging; it is not a direct move and

it takes years to develop, since these technologies don't have the returns that biomedical or pharma technologies have. As several interviewees discussed, the development of these technologies was very attractive five or six years ago, when oil prices were sky-rocketing and everyone was looking for alternative energy sources, but now with the offshore gas discoveries in Israel and oil prices dropping, there is a decline in Israel in the development of green energy (Interviewees A2, A5, A7, P2, A9).

Also, the Technion, in general, has many projects in green technology and not all of them come from the Grand (Interviewee A1). Of about 80 green energy research groups, around 25 are with the Grand such as hydrogen, renewable energy from plants, new materials and others (Interviewee A1).

Differently from green energy, the Technion has two departments that are very successful in transferring technology to industry and have very good industrial relationships, the Computer Science and the Electrical Engineering departments. Recently maybe also the Mechanical Robotics Engineering department, but energy is not there yet (Interviewees A7 and A5). The computer science program in the Technion is ranked today second worldwide, and electrical engineering is ranked as twelveth worldwide, according to a benchmarking done based on papers, presentations and citations (Interviewee A5). This high ranking may be due to the fact that "many students in the Technion come from the (IDF computer unit) MAMRAM and from (the elite) 820 (military unit)" (Interviewee A1).

7.4.3 Transfer of technology from academia to industry through informal networking

Some interviewees suggested that there should be more informal networking in Israel, since the energy sector in Israel is small, with hundreds and not thousands of people involved. As expressed by an interviewee, for a company or an entrepreneur to connect with the government official who is the decision maker, "is two phone calls away." For example, "It's a very small environment, everybody knows everybody. You meet in the same conventions, you know everyone, and you can collaborate over coffee"

(Interviewee A7). Therefore it is important as well for industry and entrepreneurs to informally network more often with academia (Interviewee A5).

7.5 TRANSFER OF TECHNOLOGY FROM INDUSTRY TO INDUSTRY

7.5.1 Transfer of Technology through incubators

The Israeli government privatized the incubators it established in the 1990s and today there are competitive processes to establish private incubators, open to local and foreign companies which are often Multinationals (MNCs). Therefore, although all incubators in the country are Israeli, most investors are foreign MNCs (Interviewee A3). For example, one incubator was acquired by Hutchison, the owner of Husky, which established the Hutchison-Kinrot incubator. Hutchison bought the incubator that had been managed by an entrepreneur interviewed for this research, who then became the CEO of a startup within the incubator (Interviewee P12).

A University interviewee indicated that MNCs have their software labs in Israel, such as Intel, because they want to use the cheap labour in Israel, like in India; they can relocate Israelis to US or Europe, or they can use their services in Israel. Nevertheless, many Israelis like to be in Israel (Interviewee A4). Differently, another academic interviewee indicated that Israelis working in the high-tech industry are well paid (Interviewee A5).[50]

In an interview, a Partner of a clean-tech firm with an incubator as a first stage, and a clean-tech VC as a second stage, explained that the VC arm selects the best startups from the incubator, to continue directly to the VC stage under the same umbrella. The incubator invests US$100,000 in a company and the OCS matches this amount with almost US$600,000; sometimes the incubator invests a little more, and the startup raises some more funds as well. The government does not take any equity, and it only gets 3 to 5 percent royalties from sales, until the startup pays the full loan with a small interest. This allows the incubator to significantly reduce its early stage risk and allows it to have

[50] Also, according to the Ministry of Economy and Industry (2014), high-tech salaries are not low, ranging from $72,000 to $170,000 USD, depending on seniority.

more investments. Every week the incubator receives foreign delegations from all over the world, especially from Asia, to meet the companies for potential investments. This incubator is one of the first investors to approach a company, investing in the phase of an idea, a prototype, up to the commercialization stage. In most cases it is the first investor, and sometimes the company has also raised some money from angels, family and friends before the incubator invests. After two years under the incubator the company usually has one or more beta sites in the market or has already started selling, and then the best startups are selected for the second stage under the Venture Capital arm. The company does not have to look for further investments to continue to its commercialization stage, since the VC invests 100 percent in the companies it selected (Interviewee P1). In November 2014 this incubator had six companies under its umbrella, and was hoping to add two more by the end of the year with a goal of building a portfolio of 15 to 20 companies.

Although in 2005 the government imposed a maximum return penalty of six times the funding that the startups receive when they sell the technologies developed in Israel to overseas companies, this has not deterred MNCs from establishing more R&D centres in Israel (Interviewee G6). Furthermore, an incubator that became a holding company gave an example where one of its companies sold one of its technologies for US$100,000 million. The incubator had received 2 million shekels from the government to develop the product and paid the government 12 million shekels in penalty. This was a transaction that the incubator considered as definitely worth while [51] (Interviewee P8).

7.5.2 Transfer of Technology through Startups

An interviewee explained that the Israeli government strongly supports industrial R&D, where technology is developed through startups by first developing the concept demonstrator, then the product, followed by pilots, and after the system proves itself in a pilot project, the last stage is manufacturing and market sales (Interviewee P4), which

[51] This was the only interview conducted in Hebrew; other interviewees would include a word or a sentence in Hebrew, all of which I translated into English if were relevant.

mostly take place overseas. Several issues were identified regarding overseas development including:

7.5.2.1 Israeli technology is exported because Israel is a small country with a small market

Although the Israeli Government does not like when Israeli companies sell their technologies overseas, and some Israeli entrepreneurs do not like it either, sometimes there is no alternative. The reason being, according to an interviewee, that "Israel is a small country (and) it cannot produce everything and sell everything to the whole world, and sometimes you are forced to do this. We try not to sell, but sometimes there is no choice" (Interviewee P8). Furthermore, the government cannot do anything about this because the market rules and the government cannot force the market. "It is a free economy; we do our best so it stays in Israel… sometimes it doesn't happen, but mostly it stays in Israel" (Interviewee P8).

Different explanations were further provided in the interviews. An interviewee pointed out that although Israel is a small country, the Israeli market is not that small with a population twice the size of Alberta (Interviewee P12). Nevertheless, Israelis are not European, who have countries surrounded by customers. Instead, Israel is surrounded by a hostile environment. Therefore "Israel should manufacture where (it) is most economical, and export" (Interviewee P12). Also, manufacturing in developing countries is cheaper, as many developed countries do (Interviewees G1 and P1). When the market and raw materials are not found in Israel, manufacturing must be done overseas (Interviewee A9). Nevertheless, maybe manufacturing could be done locally, but the market must be international and companies must act globally (Interviewee P12). However, two entrepreneurs indicated that if they had the support of the Israeli government, as they received from overseas organizations, to manufacture in Israel and then export, of course they would have done it (Interviewees P12 and P3).

Differently, in the US and other countries the industry is not concentrated geographically as in Israel, where there are about eight million people, of which about

100,000 work in the high-tech industry as a whole [52] (Interviewees P9 and P14). An alternative view considers the small size of Israel as an advantage, where everyone knows everyone, and this facilitates the transfer of technology (Interviewee A5). As an interviewee recounted:

> I can get to basically anybody in the country, I can get to Ehud Barak, Bibi Netanyahu if I want to, it would be hard, you can get to anybody here with the right connections, it is really a matter of just knowing and finding that thing that strikes you as this is the right opportunity, and then cutting everybody in on the action somehow to make the deal happen (Interviewee P11).

7.5.2.2 Manufacturing in Israel is not competitive

Two interviewees discussed that Israel is a good place to have pilot projects (Beta tests), and to initially sell in the Israeli market if there is an opportunity, in order to gain product confidence. But companies do not manufacture in Israel due to a lack of competitiveness, unless the products are very sophisticated chips. This is what most developed countries do. Companies have a very sophisticated production in their country of origin, or their manufacturing is done overseas in order to be competitive (Interviewees P1 and G1).

7.5.2.3 Israelis must focus on their brains which are their strength

Differently from the point of view in the section above, another interviewee indicated that Israelis "are not good at self utilization of the talents, know how and technology of Israel…and therefore it usually goes somewhere else" (Interviewee P11). Per capita Israel is a leading developer of clean-tech technologies, producing a significant number of potentially commercial technologies (Interviewee P2). However, the Israeli model, according to several interviewees, is that Israelis must focus on their brain, which is their strength (Interviewees P1, P2, P3, P8, P11, P13, A8, A9 and G1). The brain, the

[52] Another interviewee indicated that about 50,000 people work in the high-tech industry.

R&D, the know-how, and the entrepreneurs stay in Israel and develop other technologies, but the implementation typically takes place elsewhere **(**Interviewees P11, P2 and P3).

The BIRD foundation, for example, also supports mainly R&D in Israel. There are two parts to BIRD projects. The project development phase that takes 1.5 to 3 years, when both, the Israeli and US companies, work on the technology R&D in their respective countries. After the development of the IP, which belongs to each company, BIRD cannot be, and is not involved anymore in the projects. Once the project ends BIRD is interested in the sales only, and the Israeli company is not required to keep the technology in Israel or in the US. But in most cases, once the companies complete their projects with BIRD, they continue developing and improving the technology and have additional projects, where in most cases the Israeli company will have an R&D operation in Israel. In some cases Israeli companies may also have a small R&D operation in the US and sales in the US. However, usually they will not give up their presence in Israel, because their strength is in the R&D workforce they have in Israel (Interviewee G3).

7.5.2.4 Israeli technology is exported because of the opportunity of Israeli companies to go global

Sometimes exporting the technology is the only opportunity for an Israeli company to go global, as described by an interviewee. If an MNC wants to buy an Israeli company because it has a product of interest, there is no way to stop this. In addition, many innovators return to Israel after a few years, and this is a way to allow Israelis to go global and then bring new ideas back to Israel where they develop them. Avi Hasson, the Chief Scientist of the Ministry of Economy is of the idea that the OCS should not restrain Israelis who wish to go global (Interviewee G1).

7.5.2.5 Israelis can learn how to build and run large corporations by working with MNCs

As an interviewee stated, Israelis are knowledgeable in business, they know how to do business quite well but don’t know everything, and can learn from large companies

how to build and manage large corporations by working with those very same large institutions (Interviewee G7).

7.5.2.6 Israeli Startups have no potential for growth and Israelis do not have the patience to further develop their technologies

An entrepreneur interviewed indicated that he sold its previous startup company to an MNC because there was no potential for his company to grow, and it would take a long time to further develop his technology (Interviewee P4). He sold his company since his technology did not really penetrate the market at the time, and he understood that it would take a long time to develop it to something big. He sold it to Samsung which may not be using the technology, or maybe partially, but he did not care either way. The technology was for TV space, for Sharp Quattron TVs, which is very famous because it has four colours RGB and yellow, a technology invented by this Israeli entrepreneur that he had licensed to Sharp before he sold it to Samsung (Interviewee P4).

Differently, a spinoff startup from the Technion succeeded to stay alive for 10 years, since 2004, and although for the ten years the company was not manufacturing, it managed to survive with no revenues. The company experienced a breakthrough when the CEO and his team connected with a large international strategic company that invested in the startup. However, without its strategic partner, who was willing to take the investment risk, eventually the company would have probably not survived. Until then, the startup team had worked mostly without salaries, and as this CEO recounted, “this is one reason why I joined; because there was a grain of sweat and blood, of entrepreneurship; people who believed in it, and were ready to work for years after putting the hours (inaudible). I call it moonlighting” (Interviewee P12).

7.5.2.7 People want to maximize their own economic benefits

Selling a company to a multinational is very lucrative (Interviewee A7), and people want to maximize their own economic benefits (Interviewee P2). As explained earlier, although the Israeli government does not like Israeli technologies to be sold overseas and

it charges a penalty, it is sometimes worth while to sell a technology for a large sum of money and pay the penalty to the OCS (Interviewee P8).

7.5.2.8 Entrepreneurs need money to further develop their products and their overseas markets, and investors are often foreign MNCs

An interviewee described that in 2008, with the global economic crisis, General Electric (GE) Water suffered strong losses. All GE Water managers left the company, established a consulting firm, and they offered to introduce his spinoff startup from the Technion to the Alberta oil industry. By the end of 2014 this Israeli company was preparing to test the technology in a laboratory in a company in Alberta (Interviewee P12).

The CEO, interviewed, of another startup developed from the Weizmann Institute, with a large foreign investor in the field of green energy, indicated that the team would have liked to grow in Israel, but they were looking for money, and the foreign company was the one that provided an opportunity, and they are working well together. The foreign company invested US$1 million and then raised another US$9 million. Nevertheless, due to the distance and time difference, which are a difficulty for the startup, it would have been easier to have Israeli investors (Interviewee P3). This CEO also indicated that he wished his company could use its product in Israel, but its customers are the heavy industry and there are hardly any in Israel. A challenge to the startup's marketing is that everything is overseas (Interviewee P3).

The problem is also, as indicated by an interviewee, that with internet projects the time to the commercialization stage is much shorter than in green energy, and the amount of money needed is much smaller as well, therefore when companies try to transfer the IT model to energy, it does not work (Interviewee A5). However, one of the startups entrepreneurs interviewed, as seen earlier, had an IT technology that it sold and now he is developing renewable energy technology within an incubator (Interviewee P4). According to another interviewee of a company that helps startups in the biotech industry - medical devices and pharmaceuticals, to get the US Food and Drug Administration's (FDA) approval for their products,

> Israelis are so innovative, it's incredible. Day in day out, we have new companies come to us with incredible incredible ideas for devices, for medication, mainly for devices, medical devices. The thing is that many times they don't have the money to bring it to reality. The Chief Scientist supports, but a lot of times, when they get to the phase 1 stage, that we help them, or phase II, when the trials get bigger, they don't have the money to continue, but as far as innovation, incredible minds (Interviewee P10).

7.5.2.9 An Israeli company that manufactures in Israel and sells its products overseas

Differently, a clean-tech incubator/holding company mentioned earlier indicated that one of its companies that produces biofuel biologically whose inventor and founder is an Israeli Arab, sells the materials worldwide to activate its technology while it manufactures the materials in Israel (Interviewee P8).

7.5.3 Transfer of Technology through Venture Capital Firms (VCs)

VCs' concern is to compete and take the companies globally, as a VC Partner interviewed indicated:

> I am not the government. My concern is about competing globally, in a complex competitive world, where innovation comes from all different angles; we need to be aware of who our competitors are, their strengths and our strengths, and define a strategy to win…The IPOs we're interested on will be international because the Tel Aviv Exchange has not yet matured to the point where it is interesting from the perspective of liquidity, but it could be depending on the case (Interviewee P5*).*

VCs invest mainly in people, also in ideas, but mainly in people. Nevertheless, when a VC firm invests in an idea in an Israeli company, it must have a technology or an idea that can be competitive worldwide, not just in Israel. As further pointed out by a VC

partner, Israel is a good place to have pilot projects, *"to have initial market traction"* (Interviewee P1). Nonetheless, in most cases, startups enter the international market before the Israeli market. In some cases Israeli startups have an opportunity to penetrate the domestic market before going overseas, in order to have more confidence in the product they developed. But every company in which VCs invest must have a clear global opportunity.

> The overall idea every time we invest in a company we consider it to be an international global company. Even if it is small, it has to have a technology or an idea that can be competitive worldwide, not just in Israel (Interviewee P1).

VCs invest 100 percent and significantly in the companies under their umbrellas. Depending on the company, VCs invest about $US 1 to 3 million in each of their companies. They usually raise more money, matching this amount by at least another investor, and then they help the companies to connect with top players in their industries; to raise more money and to expand internationally. The final success for the VC is an exit. In addition, Israeli companies also receive government R&D grants when their technologies reduce CO2 emissions (Interviewee P1).

As a clean-tech VC firm interviewed further pointed out, most of its startups never passed through an incubator, or the firm looks at investing in companies that already exited an incubator. However, in general, it invests in startups that will never go through an incubator. Nevertheless, the VC encourages its startups to apply for OCS money (Interviewee P5).

7.5.3.1 VCs Investments in Energy

As mentioned earlier, one view presented by a university interviewee stated that most VC firms do not invest in green energy because they like to sell quickly with very high returns, while green energy technology development is slow and the returns are not as big as in other technologies such as IT and biomedical developments (Interviewee A2). Furthermore, another academic interviewee discussed that green technologies developed by academic institutions are not a good fit with VCs. Some VCs invested in these

technologies in the past but they did not know what they were getting into. They had no understanding of the difficulties involved. The VC concept sprouted from the development of the IT industry which is based on code, where VCs had been very successful, but they did not understand the difficulty of investing in energy technology (Interviewee A8). In addition, most of the portfolio of clean-tech VC companies (and incubators) is not in the core technology of alternative or renewable energy, but rather in the development of devices or methods for these sectors. For example, VCs do not fund new technologies to develop solar power plants (Interviewee A8).

Differently, a VC Partner interviewed indicated that doing exits by selling the startups or going through IPOs, before the marketing and sales stages is not what this Israeli VC prefers to do, "because then the return would be much limited…… the more the company grows in value the better it will be." In addition, the VC firm is not the only investor, it does not control the company, but rather it invests with other groups; it "supports the decisions of the managers and entrepreneurs when they think it's a good idea to bring the company to liquidity, which it is when it will serve the business interest." The VC has its own need for liquidity at certain points in time, but it can be patient, and it will then obtain a better rate of return (Interviewee P5). This fact is confirmed in a Times of Israel (Shamah, 2016) article, report of the IVC Research Center, where VCs have the right patience and perseverance in managing their portfolio of companies, and many of them have been successful in the past two years. Their average exit time was 9.5 years in 2015, with higher deals and return on equity.

Another VC Partner interviewed whose firm started operations in 2007 provided a unique example of one of its green energy companies that was marketed within months. The VC invested US$150,000 in the company at the end of 2007 in order to develop an energy efficiency technology based on innovative heat pumps that the company retrofits in buildings to be used with hot water, saving from 50 to 70 percent in water heating costs. In addition, the technology also saves almost 90 percent of the fuel used in the buildings, and reduces pollution by 90 percent in the buildings, however, slightly increasing the use of electricity. The company started with an entrepreneur who had the idea, contacted the clean-tech VC, and without developing the technology through an

incubator, one of the VC partners worked long hours with the entrepreneur for about nine months to refine the idea (Interviewee P1).

As explained by this VC partner, the business model for this startup is based on a "shared savings model," where the VC finances the installation of the system; the customer does not take any risk, and it gives 50 to 60 percent of its savings to the VC for 10 years. If the project works it becomes very profitable, with a payback of between one to three years, a very short payback compared with any solar installation (Interviewee P1). More than half of this VCs' projects, and not only those of this startup, follow this business model, which "is a way to significantly reduce the use of energy, save a lot of money, and make a lot of money for us too, (and) for the company" (Interviewee P1). By the end of 2014 this startup had almost broken even. The VC partner pointed out that this was a unique situation, since the VC did not have many technologies that were marketed so fast after having a first customer. In November 2014, during my field trip, this green energy startup already had 100 projects in Israel (Interviewee P1); a few projects in Europe, and the VC was looking at Mexico's Yucatan peninsula, where the cost for fuel is very high (Interviewee P1). This startup company has also received a government R&D grant for reducing CO2 emissions, as well as additional government R&D grants for many of its projects (Interviewee P1).

7.6 TRANSFER OF TECHNOLOGY FROM MILITARY TO INDUSTRY

The IT industry started from military technologies that were commercialized however, military technology is less relevant to energy. In the 1980s and 1990s, large successful Israeli companies that were acquired, such as Check Point (IT Security), Gilead (biopharmaceutical development of new cancer drugs), and Comverse (telecommunications software), were spinouts from military technologies (Interviewee A2). There are many other technologies as well with military roots mainly in the pharmaceutical industry and medicine, but energy has little or no military background. An exception is the company SolarEdge, which originated from military technology, and some technologies from the Grand Technion Energy Program, as mentioned in the previous Research and Development (R&D) Collaboration chapter.

7.7 WEAKNESS OF THE ISRAELI INNOVATION SYSTEM

There are strong arguments that Israelis have become very good at packaging technologies into companies (Interviewee A2). However, as an interviewee explained, today this transfer of innovation process does not benefit the country's economy (Interviewee A5). The current situation is that Israelis are creating a large number of innovations by establishing startups and selling them to MNCs at early stages for very large sums of money, while their implementation does not take place in Israel. If all Israeli entrepreneurs do is create startups, as an interviewee pointed out, Israelis will know only how to develop new ideas, but will not know how to develop these ideas into large companies and industries and Israel will continue "exporting innovation and not products" (Interviewee A5).

Unfortunately, according to two interviewees, Israelis are giving credit to people who are selling startups overseas for huge amounts of money, and today this is a mistake. Instead, Israelis, and the world, should acclaim those Israeli entrepreneurs who successfully build mature companies, since implementation is innovation, not only of technology, but also of new ways of marketing and of creating products:

> I have a different view of how Israel should use the innovation. I don't agree with what is happening today in Israel. I don't agree with the SU Nation concept. That is another question. Innovation is success, but we have a difficulty in Israel because now it is very easy for us to do lots of innovation and startups, and have giant companies buy them at an early stage, but we are giving credit to people who are selling startups for huge amounts of money, and I think this (is) a mistake for us (we are making a mistake). (Instead) We should credit people who are successfully in building full companies; mature companies; not only to have an innovation and sell it before implementing it. Because as we discussed in the beginning... (regarding) implementation… if I had an idea to make an iPhone, let's say, Steve Jobs was not the only one to have the idea, (but) he was the only one who made it and sold it. The innovation is the success at the end of the day (Interviewee A5).

Israel is a small country that is contributing to global innovation, but it is not benefitting economically from all its innovations since these are continuously sold to giant companies (Interviewees A5 and A6). There are several issues that this situation is creating, as described by an academic interviewee. First, the government cannot pursue an R&D based strategy in isolation, since this high-technology R&D market can employ only 20 percent of the population [53] (Interviewee A5). The high-tech industry must develop in a similar way to the pharmaceutical industry, with an ecosystem that includes basic research, development, innovation, manufacturing, marketing and sales, with high salaries and where everyone benefits from this ecosystem. Second, high-tech market salaries are much higher, due to this sector's profits, than those of other industries [54] (Interviewee A5). Third, startups are sold for millions, which are not shared with the economy (Interviewees A5 and A6). Both, the high-tech salaries and sales for enormous sums of money, are creating huge economic gaps and inequality in the Israeli population. In the next decade inequality will be the driving force for decisions made in Israel, and if there is too much inequality, this will create instability in the country.[55] These issues send an important message to the Israeli government "…that small Israeli companies may have….. difficulty reaching global markets, because of their limited finances" (Interviewee A5); and while the Israeli government helps to develop R&D, afterwards "selling companies is the easy way out" (Interviewee A5).

7.8 PROPOSED SOLUTION: INNOVATION OF THE ISRAELI INNOVATION SYSTEM

This section reflects mainly the view of a significant academic researcher interviewed. As he describes:

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[53] Different numbers were given by different interviewees. For example, Interviewee G1 indicated that 10 percent of the workforce in Israel is employed by the high tech industry.

[54] According to Interviewee G2, the high-tech sector in Israel, which is at the forefront of the economic transition to capitalism through private investors, does not offer secure long-term work, which other sectors with lower paying jobs usually provide.

[55] This point brought up in my interview is further strengthened by JNI Media (2015).

> Innovation is success…Innovation is, from our point of view, doing things differently and achieving new targets in new ways, continuously. By the end of the day you're measured by success, so it's not invention; invention has more to do with research. Innovation has to do with implementation. So you have to see implementation by the end of the day, but you can see also failures; failure is part of the innovation process (Interviewee A5).

As further stated by this interviewee, Israel has done very well during the last 20 years, but it is time for the OCS and for the Israeli Innovation System to change. The *Start-up Nation* book, published in 2009, helped Israel by exposing its technological developments, but:

> We have to be careful not to be so happy with ourselves, and satisfied. We have to leverage this correctly and move to the next stage in an innovative way. This is also innovation, changing the process, changing the rules of the game, defining the target again, that's innovation...What I'm looking for now is innovation, how to manage the innovation in Israel, in the long run, economically for the country. We are innovative, we are a startup country, we have an ecosystem, and we have done many things that happened correctly; but innovation should be done differently now. You cannot continue doing what you did (for) 20 years…Now it's easy to say 'yeah it's not so bad with (the) MNCs, it's working'… We need the next move and (it) is being done right now in Israel (Interviewee A5).

The suggested innovation steps to be taken include the following:

7.8.1 The OCS must become an independent agency

Israeli policy makers are aware of the weaknesses described above and are taking action. The Chief Scientist is becoming independent in order to make changes faster. This move is modeled on the Yozma fund which was initially government owned but independent in its decision making (Interviewee A5). The present situation is that VCs

invest, for example, in 10 energy companies; of these nine fail, and the VCs expects the 10th company to provide a profit that they lost with the other nine companies, and are very eager to have a big sale. Therefore, the government should look for other kinds of funds that are not so pressed for results and sales:

> We have to structure a little differently. Look at Israel in the beginning, with the Yozma fund, which when they started was 100 percent government (funded). So nobody cared if they got their money back, they cared if you built an (VC) industry; so Yozma was a very successful story (Interviewee A5).

Today Yozma is a private firm and its owners, the Ofer brothers, are business oriented, need to make money and the benefit to the economy is not their concern [56] (Interviewee A5). Researchers at the Samuel Neaman Institute (SNI) are talking about these new strategies with the OCS, and Mr. Avi Hasson, the Chief Scientist is listening and understands that there is a need for change. The SNI acts as a bridge between industry and government, including in the area of renewable energy and its implementation in Israel (Interviewees A5 and A7).[57]

Other government interviewees mentioned that the OCS will become independent in order to be more flexible due to the global R&D environment which is becoming more complex, with more competition and multinational collaboration. Today, when Mr. Hasson needs to change a program or employ people, he must go through a bureaucratic government process, while he needs to be more dynamic and make decisions faster (Interviewees G6 and G1). As well, he mist be more flexible in his collaboration with VC

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[56] According to the Ofer Group (2013), it is "Israel's leading industrial and technology conglomerate with global assets valued in excess of $6 billion. The Group has a majority shareholding in Israel Corp. (TASE: ILCO), one of Israel's major holding companies focusing on semiconductors, telecommunications, chemicals, shipping, oil, and energy, whose aggregate annual revenues are over $5 billion. The Ofer Group is a major shareholder in Israel's fourth-largest commercial bank, United Mizrahi Bank, and has extensive interests in the high technology, shipping, construction, energy, and hotel industries worldwide."

[57] The Samuel Neaman Institute (2015) Website indicates that the Institute was established in 1978, is located within the Technion, and it "is an independent multi-disciplinary national policy research institute," (para. 1).

firms and with other financial institutions in order to find more resources to address companies' needs (Interviewee G1).

7.8.2 The OCS must invest in startups after their R&D stage

In a similar way to Yozma, the Israeli government should fund Israeli companies once these are ready to implement their technologies in order to help develop them into productive companies. It is the relationship between research, development, marketing, and production that can create success. When a company comes out of an incubator the government should take the majority of the risk; the government would take equity in the project, but not in the company itself; being this is the best way to promote risky innovation. If the government is the first one to take the risk, then it works, and if there is a small risk or a loss, the government should take the loss (Interviewees A5 and A7).

When Israeli companies are not interested in selling in the Israeli market, but in entering global markets from day one, they would be much better off if they received government support. The Israeli government should set-up a fund which would be a mix of institutional investors with some VCs, backed by government, and this fund should financially support the implementation of new technologies. This support would be further strengthened by related policy measures.

> You build a multinational company, you buy some worldwide subsidiaries for marketing purpose; you also do some manufacturing in the target countries, in order to give work to the local population. I don't care so much about the know-how, but what you do with know-how… If you have a unique technology, like the water companies, and you buy subsidiaries, you can still sell to the governments abroad through subsidiaries (Interviewee A5).

In this way, instead of Israelis selling their technologies to MNCs they would be able to grow; own their own technologies; establish their headquarters in Israel and have global subsidiaries [58] (Interviewee A5). Another example is the global pharmaceutical

[58] MATIMOP - Israeli Industry Centre for R&D (2015) indicates that the Israeli government is moving towards establishing such policies: "Israel's Chief Scientist Avi Hasson Introduces Israel's

Teva, and most Americans would not know that Teva is an Israeli company because there is also Teva USA, managed by Americans.

With regards to government support for green energy, the Israeli government has had large investment funds used for implementing and keeping big traditional industries which relied strongly on tax shelters, and which are not competitive enough since competition takes place only if companies have competition. Some of that money could be used to help green energy companies in their implementation phase. Another way to raise money for the death-valley, the gap between R&D and commercialization, is through royalties that the government receives from those companies that reach maturity and that become public through IPOs (Interviewee A5).

7.8.3 IPOs instead of acquisitions

An alternative to acquisitions are IPOs, where Israelis keep control of the companies, and the companies remain Israeli. The companies return the money to their investors and give them the option to invest further and make more money. Such an example is the successful Israeli company Solar Edge, from Herzliya, that had a recent IPO and its head office is in Israel. Maturity is represented with an IPO (Interviewee A5).

7.8.4 Enhance the Tel Aviv Stock Exchange (TASE)

Israeli companies have had IPOs in international stock exchanges, but there is an effort to enhance the TASE by having pension funds invest in Israeli startups. This is

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First Annual Innovation Report in April 2015, identifying four significant measures that should be taken to meet these challenges: 1) Creating new sources of funding for industry 2) Turning more high-tech companies into major companies 3) Implementing and developing technologies in traditional industries and in the public sector 4) smarter and more efficient government involvement, Growing More Hi-tech Startups into Major Companies. Israel has been blessed with a plethora of startups but many of them are quickly sold to larger companies and never grow to become major companies within Israel. Some claim that these ‘speed boats’ - startups with quick exits - are where our market's competitive edge lies, but the OCS believes that growth of local ‘large ships’ - i.e. mature companies - is crucial. Large companies employ a higher number and wider variety of employees and develop know-how within Israel. It is also more difficult to move their activities abroad. The challenge of company growth is not purely technological but also requires identifying market trends, grasping foreign cultures and understanding different markets - with the business development this entails,” (p.1).

risky but it would create another growth engine, since more Israeli startups would go through IPOs in the TASE (Interviewee A5).

7.8.5 Establish applied research institutions

Germany is very successful and profitable in technology implementation through its many private applied research institutions that transfer innovation from academia to industry. Israel could adopt this model and close the gap from implementation to production. However, since Germany lacks the basic innovation component that Israelis have, Israel and Germany would make the best unbeatable match. Israel already has two applied research institutions, the Volcani Institute of Agriculture, one of the biggest in Israel that is still operating, while many others closed; and Migal, a research institute privately owned by several kibbutzim (Interviewee A5).

7.9 CONCLUSION

In the 1950s, Prime Minister David Ben-Gurion set-up a laboratory for the research and development of renewable energy technology, and from this laboratory came out some technologies, one of them the solar power for water heating installed on most of Israel's building since the 1970s. Later on, Israeli Universities, such as Weizmann and the Technion, all had renewable and alternative energy R&D also since the 1970s. Notwithstanding the fact that Israel is a pioneer in renewable energy technology and a leader in clean-tech technology, most of these technologies are implemented overseas.

One of the main issues that stands-out in this chapter is that Israel is a small country that has been contributing significantly to global innovation, but today the country does not benefit economically from all it innovations since these are sold for millions of dollars to MNCs, and these gains are not shared by Israel's economy; a situation that is creating economic gaps and inequality in its society. In addition, a problem with having large MNCs as investors is that they may have control over the smaller Israeli companies in their decisions.

There are two viewpoints related to Israel's small size. A first one is related to the barriers and difficulties in implementing renewable energy in the country. A second view

is regarding the selling to MNCs of Israeli technology in general, such as IT, clean-tech, biotechnology and others.

First, Israel's small geographical area and its small market size - although twice the size of the Alberta market, are barriers mentioned by most of the interviewees when it comes to the implementation of large solar energy fields. Therefore, Israeli companies such as Luz and Solel found it easier to get their licenses to build large solar power projects in California and Spain, where there were larger markets and more money from their projects, although the area of the Negev desert is over half of that of Israel's.

Notwithstanding the issues above, there are new solar energy companies operating in Israel such as the Arava Power Company, a pioneer and the first to build a solar field in Israel with investors such as the Eilat-Eilot Renewable Energy Ltd. in southern Israel, planning to be energy independent by 2020. However, the fact that Siemens, a well known MNC, was a strong investor in Arava Power, may have influenced the bureaucratic system in Israel to move forward faster, and to allow Arava Power to build several solar fields in Israel. Nevertheless, Arava Power's success opened the doors to other companies. Consequently, as indicated in this chapter, although the Israeli government places barriers on the implementation of large projects, these eventually happen. However, by 2014 Israel had only one percent energy production from renewable energy sources, instead of its five percent goal, and therefore it may not achieve its target of 10 percent by 2020 which, as an academic researcher interviewed stated, "is not that high, nor an inspiring target" (Interviewee A5).

Some interviewees indicated that Israel is not a great producer of renewable energy, and especially not its industry sector, while universities are the ones that produce a significant amount of green technology. For example, the Renewable Energy (research) Centre in the Arava is developing technology with spinoffs from the Technion; while interviewees from the Weizmann Institute mentioned that their green energy projects are very large, and these can only be commercialized by large foreign companies.

Nevertheless, all entrepreneurs interviewed who were developing university technologies mentioned that they would have preferred Israeli investors, but they were looking for financing and foreign MNCs were the ones that came forward with the money. A second stance points out that since Israel is a small country and cannot produce and sell

everything within the country, most technologies developed in Israel are sold to and developed by foreign MNCS such as IT, biotechnology, clean-tech and others; and even if these are not large projects, most of the technology is sold and developed overseas.

On the other hand, some interviewees mentioned that there is an advantage to a small country and market since everyone knows everyone and this situation facilitates the transfer of technology. To increase this process there should be more informal networking especially between industry and academia, where there is a large amount of applied research with the intention of being commercialized.

Another reason given for the early sale of technology to large MNCs, was that Israeli entrepreneurs lack the patience and funding to commercialize their products, whether in Israel or overseas. However, lack of patience may not be true for all companies while funding is. For example, the Arava Power entrepreneurs were tenacious and patient from the establishment of the company in 2006 and until 2009, when Siemens invested in the company. Another example is the spinoff startup from the Technion that survived for 10 years until it found a strategic investor.

Two different views were also provided regarding VCs. One stated that VCs do not like to invest in green energy since VCs want quick exists, and green energy takes much longer to develop and also requires higher investments than in other technologies, such as IT. An entrepreneur interviewed mentioned as well, that he could not find any VCs ready to invest in his technology because of the green energy crisis and its resulting losses. Differently, however, two clean-tech VCs pointed out that they do invest in green energy projects, although not on large projects, and they do wait until the companies have had marketing and sales stages to have an exit, in order to get higher returns on their investments, a process that can take up to nine and a half years. These two different views are a proof that there should be increased informal networking between academia and industry to improve communication and mutual understanding.

My research shows, nonetheless, that Israel has been very successful in its transfer of technology with its many well known global innovations, such as the USB stick mentioned in this chapter, even though these don’t take place in Israel. My research also shows that startups approach VCs first, and if unsuccessful then they approach incubators, since VCs invest much more money in them through different investors. Although the

government invests heavily in incubated companies, the startups can find themselves without an investor after the incubation period. Alternatively, through VCs the technology follows a more direct commercialization path, since Israeli VCs invest in the early stages of the technologies up to their commercialization stages. Furthermore, Israel has the second largest number of VC firms in the world, after the US, and therefore maybe a large number of startups achieve the direct commercialization stage. A unique example given was the green energy company started by an entrepreneur, which from its first VC investment in 2007 to its sales in 2014 had almost broken even (Interviewee P1). As well, the large number of foreign MNCs that invest in Israel may contribute to the direct commercialization process of Israeli technologies. As well, VCs and University TTOs work with networks of entrepreneurs who are willing to take risks, being another innovation engine, and strongly contributing to Israel's innovation and transfer of technology process.

Another mechanism that promotes the transfer of technology among institutions is the movement of key people across institutions that would also facilitate knowledge exchange. For example, researchers who worked for the Israeli defense industry, such as RAFAEL, move around the Israeli Innovation ecosystem working for instance with the OCS as evaluators (Interviewee G1), or in academic research institutions, such as with the Samuel Neaman Institute (Interviewee A5). They may be creating in this way informal and formal networks, where transfer of knowledge and technology from military to industry and to academia is conducted in informal and formal ways through conversations and information exchanges, passing on their knowledge and experience. Nevertheless, as discussed in my interviews, energy innovation has very little or no military background except for the company SolarEdge, as mentioned in this chapter, which originated from military technology, and for some technologies from the Grand Technion Energy Program.

Israel has been very successful in technology development for the last 20 years, and now the Office of the Chief Scientist is being proactive and getting ready to address the issues described above - dealing with the death-valley of Israeli startups, and is ready to implement changes. These changes include the independent operation of the OCS, modelled on the Yozma VC fund, where the government will be the main risk taker and

invest in startups after their R&D incubation stage, when ready to commercialize their technologies, and turn the startups into productive Israeli companies. Similar to Yozma, the OCS will establish a fund of institutional investors, such as VCs, that will support the commercialization and implementation of new technologies modelled on the Israeli water companies. If the changes brought forward by the OCS are implemented, they could propel Israel to becoming a global innovation and economic powerhouse.

CHAPTER 8: DEVELOPMENT OF GREEN ENERGY IN ISRAEL

8.1 INTRODUCTION

This chapter examines Israel's development and implementation of green energy. It begins by studying some reasons for this development as identified by interviewees. The main reasons are that Israel is interested in being a global player in alternative and renewable power supply, and these efforts will also have a positive impact on Israel's security. On the other hand, the municipalities in southern Israel are focused on implementing renewable energy with the goal of becoming completely independent from fossil fuels by 2020. A secondary reason for developing green energy is to create technologies that will improve the environment both, in Israel and worldwide.

Next, the chapter addresses two main views, as presented by interviewees, on the impact of green energy on Israel's economy - a low impact and a positive but not strong impact nevertheless. For example the low impact is due to the fact that interest in green energy fluctuates depending on the price of oil, and it is also more costly than fossil fuel. Nonetheless, green energy has had some positive impact as well. For example, the solar energy water heaters that are widely used across the country have had a vast impact on the Israeli economy; as well as the development of the southern Israeli region through clean energy.

The last section presents two views on the impact of the gas discoveries on green energy development - a negative impact, by slowing down even more the implementation of renewable energy in Israel; and the uncertainty in achieving its 10 percent renewable energy implementation target by 2020. A more neutral impact viewpoint was that although it will be difficult for green energy to compete with gas, it will continue to grow, since the price of solar energy has almost reached grid parity; there is interest in energy diversification and in clean energy; and natural gas and green energy complement each other.

8.2 REASONS ISRAEL HAS FOR SELECTING TO DEVELOP GREEN ENERGY

8.2.1 Interest in being a global player and ensuring the power supply in the country

Different institutions have different reasons and goals for selecting to develop green energy as explained below, but some of the common reasons to all were the global opportunities in green energy and ensuring Israel's power supply and security.

8.2.1.1 Government support

According to two interviewees, the Office of the Chief Scientist (OCS) is in theory sector independent, but in reality this office and its agencies have pressure from the Prime Minister's office to support alternative fuels R&D, mainly through the Fuel Choices Initiative (Interviewee G6 and G2). The Fuel Choices Initiative is a program implemented by the Office of the Prime Minister that targets alternative transportation fuels, and assigns its funding through the OCS programs that already exist. For example the government's MAGNET program has a project called TEPS[59] funded by both, Fuel Choices and MAGNET. The TEPS project is a technology for future batteries that supply energy for fully electric cars, not hybrid cars. Differently from the Renault and Nissan batteries that get emptied after 150 km, this Israeli battery is being developed to last 500 km before it needs to be recharged (Interviewee G5).

The Government implemented the Fuel Choices Initiative program for two reasons. First, to reduce world oil consumption, of which transportation uses a 60 percent, and to find solutions to reduce Israel's and the world's dependence on oil, since it will also have a positive impact on Israel's security even if these technologies are implemented outside of Israel (Interviewee G6, G2 and G4); and second, to contribute to the reduction of greenhouse emissions (Interviewee G1).

[59] According to the TEPS-OCS Magnet Consortium (2014) "TEPS is an acronym for Transportation Electric Power Solutions. It is an Israeli consortium of industries and academia, initiated and sponsored by the Magnet Directorate of the Office of the Chief Scientist (Ministry of Economy) and by the Alternative Fuels Administration (Prime Minister Office)." One of its participating members is the defense company Elbit Systems, (para. 1).

Another green energy government program, under the Canada-Israel Research and Development Foundation (CIIRDF) partnership, is "with Natural Resources Canada; they want the projects to be in energy and 75 percent to be on oil sands. If that's what the partner wants, OK, we will go there" (Interviewee G6). If it were not for this request, as an interviewee stated, the Israeli partners would prefer to have calls for proposals general in nature, but CIIRDF focuses on the requests from the Canadian partners (Interviewee G6).

At the Municipalities' level, of the 250 Municipalities in Israel, as Udi Gat (personal communication, August 6, 2014) described, the Eilat and Eilot municipalities in the sunny region of southern Israel are implementing renewable energy projects through a joint renewable energy initiative, branding themselves as the Silicon Valley/Sun Valley of Renewable Energy. As also presented by Udi Gat, due to Israel's need to be energy independent, the Eilat and Eilot municipalities in southern Israel established an organization called Eilat-Eilot Renewable Energy Ltd. with the mission and vision of finding solutions to global environmental problems to climate change and to populate this southern region with people who "are interested in living in an environmentally friendly region" (Udi Gat, personal communication, August 6, 2014). [60] During his presentation, he also explained that the Eilat-Eilot Renewable Energy Ltd. was planning to export its renewable energy knowledge to developing countries.[61] The Mission of the Eilat-Eilot Region is:

> To develop vertically integrated renewable energy projects in the Eilat Eilot region that will generate sustainable regional development and promote Israel's renewable industry. (Its vision is) Turning disadvantages into advantages on the way to Regional Energy Independence, setting an example and becoming a model for

[60] The Arava Institute (n.d.) points out that one of its research centers is the Center for Renewable Energy and Energy Conservation (CREEC), established in August 2008 which is the leading center for research, development, and technology on renewable energy and energy conservation in the region, partnering with renowned academic institutions in Israel and around the world.

[61] Moreover, I found that Eilat-Eilot Renewable Energy Ltd. (n.d.a) is already doing this.

solving the global energy crisis and regional development (Udi Gat, August 6, 2014).

8.2.1.2 Private industry sector

The industry sector provided an alternative view, where the CEO of a green energy startup pointed out that Israeli entrepreneurs innovate in the area of green energy not because Israel has some specific needs, since due to its oil and gas discoveries the country now has no energy problems, and the cost of gas energy is lower than that of renewable energy, but because there is a large international market for green energy, while the Israeli market is very small. Therefore, even before Israel's large gas discoveries, there was no development of green energy in the country because there was not a strong demand from international markets. It is also known today that renewable energy will create a huge global change, shifting from fossil fuels to renewable energy (Interviewee P4).

Several interviewees pointed out that although renewable energy is important for the planet, there must be a good business opportunity as well (Interviewee P3, P11 and P4). People cannot be interested in the environment by itself,

> It has to be a business. You cannot go around caring about the environment by itself. There has to be real business, otherwise you don't accomplish anything. So first and foremost we try to make it into a business and the underlying effect on the world, so we are happy about that (Interviewee P11).

An example was provided by an interviewee in the Arava Power Company in southern Israel, as seen in previous chapters, which has built several solar power projects in Israel with profitable business goals and Zionist as well, in order to help the country, and with plans to export the company's expertise to Europe (Interviewee P7).

8.2.1.3 Defense industry sector

The Israeli defense industry companies, Rafael Advance Defense Systems and Elbit Systems have expanded with many civilian projects including green energy, due to their interest in energy storage for the military and to diversify into the private sector. In this role they are part owners of Capital Nature Venture, the only purely renewable energy incubator in Israel, located in the Eilat-Eilot region in southern Israel (Interviewees P1, and G2). In addition, as indicated in the Transfer of Technology chapter, Elbit Systems, an Aerospace company, opened its own incubator, Incubit Ventures in 2013, which also supports green energy projects (Interviewee P1).

8.2.2 Energy crisis and desire to improve the environment

"Israel is a country of endless sun, an independent source to develop Israel's economy in a sustainable way" (Interviewee G2).

8.2.2.1 Government support

There has been a global surge in protecting the environment against greenhouse warming which was initiated by the Kyoto Protocol (in December 1997). Before this, the environmental market demand was very small, with very little general interest. Since Europe and the rest of the world became interested in environmental issues in 2007, there have been many opportunities, even to the point of saturation (Interviewee P11). In 2009 due to global discussions on climate change, the Israeli government declared that it would reduce greenhouse emissions by implementing five percent renewable energy by 2014 and 10 percent by 2020. The government requested from the EU to implement renewable energy regulations in order to move towards these goals (Interviewee P7). However, as seen in previous chapters, this five percent goal was not achieved by the end of 2014.

8.2.2.2 Academic sector

A professor interviewed at the Weizmann Institute looks at both, global power supply and environmental factors. He indicated that energy conversion for different applications is an important field since there is an energy crisis that started in the 1970s

and it is accelerating today, since the world is running out of cheap oil and oil is becoming harder to mine. These issues "coupled with the environmental crisis came together…burning (fossil) fuel has become an environmental hazard, and I thought this was…an important challenge, with the opportunity offered by (the) Weizmann" Institute to conduct energy research (Interviewee A8).

8.2.2.3 Industry sector

With the global surge in green energy in 2007, even IT companies moved towards the green energy sector (Interviewee P13). An example was an interview conducted with the CEO of an incubator established in 1993 that had projects in different sectors including medicine. Around 2007 the incubators' owners decided to change it into a clean-tech incubator, although there were very few green incubators in Israel, since it was difficult to make profits similar to and be as secure as in the medical sector. Nevertheless the owners thought that this sector was important (Interviewee P8).

Similarly, a partner in another clean-tech incubator and VC indicated that he became interested in energy because he has a PhD in plasma-physics and he wanted to solve the fusion problem, the world energy problem. When he arrived to Israel, after working for another VC and a startup, he then decided to create his own fund, finding an opportunity in the new clean-tech sector. Although there was plenty of know-how and expertise in this field in 2005/2006, while conceptualizing his idea, no one was investing in it although there were big opportunities if developed (Interviewee P1). Furthermore, as an entrepreneur in renewable energy pointed out, in the end, caring about the environment is a basic life issue, and engineers are aware of the "industrial effects" on the planet (Interviewee P13).

8.3 IMPACT OF GREEN ENERGY DEVELOPMENT ON ISRAEL'S ECONOMY

Two views were provided in the interviews. One view supports the low impact of green energy on the Israeli economy, and a second one mentions a positive impact, but not a strong one, at least not yet.

8.3.1 Low impact

As stated by an interviewee, "in Israel the percentage of solar energy is very low when compared to Europe, and the country has a long way to go" (Interviewee P1). There were several reasons provided for the low impact of renewable energy on the Israeli economy as described below:

8.3.1.1 Government support

According to an interviewee, the government brands Israel as a green country, but in reality the impact is minimal (Interviewee P2), with only between 700 and 900 megawatts of renewable energy on the grid. Another interviewee explained that Professor Eugene Kandel (Globe's Israel's Business Arena, 2013), from the Ministry of Economy, drafted a report outlining the benefits of renewable energy to Israel. [62] The report was approved by the government in October 2014, and was supposed to be included in the government's work plan for 2015, "but there is no work plan that shows this route; it is miserable to say that in the land of sun the government stops the development of renewable energy…." (Interviewee G2). A government interviewee further discussed that the government's MAGNET program has sporadic activities in energy and mostly for batteries, such as the TEPS project mentioned earlier, and in the last three years it had only about five projects in green energy (Interviewee G5).

[62] Frenkel (2012) stated that other reports written by Eugene Kandel are: "National Economic Council Chief Eugene Kandel says Israeli economy's smart use of energy has yet to reduce the pollution it causes,"; According to Business Wire (2012), Professor Eugene Kandel, Head of the National Economic Council, also gave a presentation on "governmental policies to encourage grid parity and the viability of renewable and alternative energies in Israel," (para. 1).

8.3.1.2 Academic sector

An interviewee indicated that there is very little renewable energy research in Israeli universities, and only in alternative fuels, which are also a product of gas. The reason being that renewable energy changes the industry's infrastructure, while alternative fuels use the same infrastructure (Interviewee G2).

The low impact of green energy on the Israeli economy is also reflected on the percentage of green energy spinoff companies from the Technion at 10 to 15 percent, while its top commercialization successes are in life sciences, medical devices and pharma, while energy is an area lagging behind. In addition, the level of funding to academia, for green energy, from Israeli, US and other sources is not even close to that of medical devices and pharma (Interviewee A2).

8.3.1.3 Industry sector

According to a government interviewee, the green energy market is not clear-cut, and its development depends on the price of oil (Interviewee G5). This situation is also reflected in the experience of an engineer and CEO of a renewable energy startup who explained, as also seen in Chapter Seven, that he was a former employee of Solel Solar Systems, an Israeli solar company that Siemens acquired in 2009, working for Siemens until it closed its operations in 2012 with the collapse of the green energy sector. He then spent a year fundraising to develop his own idea until he received a grant from the OCS to join an incubator.

> It was a very tough year to find investors, 2012/2013, because our initiative is tagged with the name solar; difficult to find investors to invest in the solar sector in those years, because of the crisis, the negative opinion on the solar market (Interviewee P13).

This was the case with many investors who liked his technology but were afraid to invest in solar energy. As explained above, in 2007/2008, there were many Israelis working in the IT high-tech industry who moved to the green energy sector, in which

there were several companies operating. However, with the 2011 green energy crisis, those companies reduced their workforce and the IT professionals moved back to the high-tech sector (Interviewee P13).

Another reason provided for the low impact of green energy, pointed out by two interviewees, is that renewable energy is more costly than fossil fuel energy; it can make the energy mix much more expensive; become a burden to the country, and hinder its industrial competitiveness and economic growth (Interviewee G3 and P2).

Furthermore, most interviewees' stance, as also covered in the Transfer of Technology chapter, was that Israel is too small to play a full role as a supplier of energy technology since renewable technology needs large land areas. Notwithstanding Israel's large desert, renewable energy is not easy to develop. However, if it would be possible to connect it with energy, then there would be very little negative impact on the general population (Interviewee P1).

Regarding the current situation, according to an interviewee, Israel can play some role in fossil fuel replacement or in reducing dependency on oil, but it cannot be a world leader as it is in other fields, such as cyber, telecommunications and medical technologies. Israel does not manufacture cars or airplanes either and it cannot be a full player in energy. However, the country can play a role in a consortium in order to provide solutions to energy problems (Interviewee G7).

Differently, as mentioned in previous chapters, green energy is not a leading activity in Israel because although there are several academic research groups with good results, the technologies they produce are too big to be transferred to the Israeli industry, since Israel does not have many large companies but mainly startups and it is difficult for them to develop core technologies in green energy (Interviewees A8 and G5). Industrial green energy R&D in Israel does not focus on core technology. Core technologies in green energy are rather produced through basic research in academia and then licensed to MNCs. There are many small companies producing innovation in energy, such as special turbines, PV panels, but they do not deal with the full energy system, only with its parts (InterviweeS G7 and A8).

8.3.2 Positive Impact

As mentioned by an interviewee of a clean-tech VC, the clean-tech sector is not an easy one. It requires a high degree of knowledge in many fields, not only in energy; it is slow and very conservative; and has a slow global market with very little innovation. However, in the last ten years, due to the environmental impact, the clean-tech market, such as renewable energy and energy efficiency, has become more dynamic, although it could be even more active. For example, solar energy worldwide is a US$1 billion dollar market and clean-tech is a US$100 billion market (Interviewee P1).

Also, as pointed out earlier, renewable energy is growing in southern Israel. The Eilat and Eilot municipalities are building solar energy in the desert with the goal of developing the region and creating a technology cluster that will supply 70 percent of the Town of Eilat's energy, and as explained by Udi Gat (personal communication, August 6, 2014), with the aim of providing, in the near future "a surplus of clean energy to the rest of the country."

The Photovoltaic (PV) technology has also improved during the last 10 years to such a level, that in Israel "banking institutions consider it a safe and proven technology," and the banks are willing to finance a percentage of the project (Interviewee P7). Therefore, in the past Israel had incentives for solar energy "and now they are pretty much gone, which is probably good because we don't need incentives anymore" (Interviewee P1).

Furthermore, as mentioned in previous chapters, throughout the country and not only in the south, solar energy for water heaters has been widely used in Israel since the 1970s, where all apartment buildings have water heating solar panels installed with a huge impact on the country's economy. Also, in some parts of the country such as Beth Shemesh (the House of the Sun in Hebrew), there are traffic cameras powered by solar panels (Interviewee P1 and P11). In addition, there are some companies in the country that employ a high number of people such as Bright Source Energy, that has R&D centres and one solar field in Israel; Panoramic Power (Interviewee P5), and Ormat, a successful company that focuses on geothermal energy (Interviewee A8).

In the academic field, with the global surge in green energy in 2007, the Grand Technion Energy Program (GTEP) was created by upgrading the Technion's laboratory equipment and implementing a more coordinated and interdisciplinary collaboration

through central laboratories. Previously, although working on energy issues, researchers worked on their own projects and the Technion did not have well equipped central laboratories, due to lack of funding. In 2007 the Technion raised funds to create the GETP Program, in order to advance the field of energy, and mainly in renewable energy, with its central labs around the campus. The Technion also has a graduate program in energy engineering, with 40 to 50 professors from eight faculties and disciplines, and some students have Advisors from two different faculties. As an interviewee at the GTEP indicated, all these innovations will help not only Israel, but other countries as well (Interviewee A9).

8.4 IMPACT OF GAS DISCOVERIES ON GREEN ENERGY DEVELOPMENT

Two views are presented in this section. One view supports the negative impact and a second one explains why the gas discoveries do not have a negative impact yet, and why green energy will continue developing together with natural gas exploitation.

8.4.1 Negative Impact

Israel has discovered some large offshore gas and onshore shale oil deposits. While the offshore gas reservoirs will be exploited soon, environmentalists have been fighting the oil companies planning onshore drilling, as an interviewee recounted, “We fight them very hard. I live in a Moshav, in Shfelat Yehuda, they wanted to drill and we fought them hard and we won” (Interviewee P9).

Two interviewees further described that the offshore discoveries of natural gas five years ago have had a huge impact on Israel and have reshuffled priorities within the government, making renewable energy less attractive. An example is that the Fuel Choices Initiative is counting on using natural gas for transportation since one cannot ignore this energy source. However, there is also a growing understanding of the importance of supporting renewable energy, but there is a high level of bureaucracy and changing policies is a lengthy government process. Furthermore, the gas discoveries may

have a negative impact on the government's implementation target of 10 percent renewable energy by 2020; and as two interviewees pointed out, the government is skeptical that it will reach this target (Interviewees A5 and A7). Another interviewee mentioned that Israel is busy developing its gas fields and is

> Not so interested in renewable energy. They speak about renewable energy but the real story is the gas. But the reason is not related to Israel, is related to the world, and I think energy should be totally green, non-polluting (Interviewee P4).

8.4.2 No negative impact

A more positive view was expressed by a clean-tech VC partner interviewed, indicating that Israel's gas discoveries have had no impact yet on green energy since the country has started to extract it only recently. In the meantime the gas will be used only to produce energy in large factories, which now use coal, to significantly reduce their environmental impact, and it will also significantly reduce the cost of electricity (Interviewee P1). However, this will have some negative impact on renewable energy and energy efficiency which will find it difficult to compete against natural gas (Interviewee P1; Udi Gat, personal communication, August 6, 2014). Nonetheless, green energy will continue to grow parallel to gas energy because it will take time for the gas to be exploited. Also, according to two cleantech VC partners interviewed, it is difficult to solve the energy problem with just one source; the price of gas has up and down cycles, and in the long term there is an interest in diversification and in clean energy (Interviewees P1 and P5). Moreover, since Israeli companies target global markets, and because there is a need for cleaner and diverse sources of energy, entrepreneurs will not stop developing their green energy projects. In addition,

> The prices of solar have been dropped so low, that it's almost a crime not to implement it especially off grid, and in the south of the country that has so much sun; it will develop in parallel. Natural gas will come in strong and solar will continue to grow. We almost reached grid parity. There is no reason why not to do

more solar in Israel In Israel the percentage of solar energy is very low compared to Europe, we still have a long way to go (Interviewee P1).

As these interviewees further explained, natural gas and solar energy complement each other, and therefore both will have a positive impact on the Israeli economy. For example, Udi Gat (personal communication, August 6, 2014) described that the gas discoveries are positive for solar energy, since gas and solar turbines work well together. When the sun sets, gas turbines are turned on, and these work faster than coal fired power plants. In this way, as expressed by a cleantech VC partner interviewed, the energy mix will be much cleaner; will still include the benefits from renewables; and natural gas will allow the country to have much more cogeneration, especially in industry which already takes place on a small scale (Interviewee P1). Another issue to consider is that Israel may have enough gas for one generation only, while energy from the sun is good for many future generations (Interviewee P7).

As indicated by an interviewee, in a 2017 personal communication, it seems that the renewables technology is experiencing a downturn, with VCs stopping their investments in this sector, due to the global decline. However, on July 25th a law passed in the Kenesset (Israeli Parliament), "enforcing the Ministry of Energy to prepare a long term plan to meet the set governmental resolution for renewables penetration targets, but I expect this will only affect installation companies, not tech developers" (Interviewee A7, personal communication, July 26, 2017).

8.5 CONCLUSION

An issue that stands-out in this chapter is the year 2007, as mentioned by several interviewees, as the year when there was a surge in the green energy and clean-tech sectors worldwide and therefore in Israel as well, which lasted until around 2012/2013, when this sector experienced a crisis. During this time Israeli companies, investors and engineers switched from sectors such as IT, to green energy and clean-tech; and it was in 2007 as well that the Technion opened the Grand Technion Energy Program (GTEP).

Nevertheless, after the green energy crisis, this sector continues to be developed, although at a slower pace, where the main goal of the Israeli government, academia and

industry is to become global players in green energy power supply. All institutions, including academia, respond to the needs of global markets with “positive (side) effects,” on Israel, according to the view of several interviewees. An exception to this strategy are the Eilat and Eilot municipalities and the region in southern Israel, where renewable energy is implemented with the goal of achieving renewable energy independence and security by 2020, and to attain a surplus in clean energy to supply the rest of the country.

As addressed in this chapter, before the discoveries of gas fields in Israel, there was little or no green energy development in Israel, as there was little global demand. In order for academia, with applied technologies, and industry to develop and implement a product, there must be business opportunities with positive global impacts. In this case as well, according to some interviewees, there will also be positive impacts on Israel. Therefore, we see that although national energy independence and security are important, green energy technology is developed with the intention of being exported, with the exception of the Eilat-Eilot Region, as mentioned above.

Another important point in this chapter is that although the OCS is in theory sector independent when it comes to R&D, it strongly supports alternative transportation fuels through all of its agencies and programs. This further corroborates the viewpoint that clean energy has a strong role to play in global markets, and (hopefully) with positive effects on Israel as well.

Again, as explained in previous chapters, technology developed in Israel and sold overseas does not benefit the Israeli economy. In order to solve this problem, Israel must increase its number of large companies which would also increase the possibilities - by the time Israel’s offshore gas fields are depleted and estimated to last for one generation only, for Israel to achieve energy independence and security.

CHAPTER 9: ANALYSIS AND DISCUSSION

9.1 INTRODUCTION

Israel has been described as a young 69 year old nation since its independence, in 1948, that has achieved the economic status of a developed country, mainly due to its high technical and unique entrepreneurial culture (Chorev and Anderson, 2006). Although Israel is producing important innovation in areas such as information technology (IT) and biotechnology, there is a knowledge gap in the academic literature with regards to the Israeli System of Innovation in general, and concerning the emerging field of green energy in particular.

In 2010 Israel had approximately 2000 start-up companies set-up by universities, government research institutions, and private entrepreneurs (Buchwald, 2009). According to Senor and Singer (2009), about two thirds of the TTOs inventions at the Hebrew University are in biotechnology, a tenth in agriculture, and a tenth in computer science and engineering (p.212). Furthermore, Israeli universities and government institutions have also been very successful in licensing their discoveries with large royalty profits, mainly from drugs. Israel also produces a high number of patents. For example, between 1980 and 2000 Israel registered 7,625 patents (p.209).

On May 10, 2010, due to Israel's economic standing and its implementation of economic liberalization policies, the country was invited to join the Organization for Economic Cooperation and Development (OECD, 2010). The research looks at two main questions:

3. How has the Israeli Innovation System evolved since its inception in 1948 and what events shaped it?
4. How is this system responding to the new technological area of green energy?

In accordance with the interdisciplinary approach described in Chapter One, this discussion chapter outlines key observations drawn from documentary research based on the Israeli academic literature and institutional sources about the Israeli innovation system, and from high-level in-depth interviews. These are compared and contrasted with

key theories drawn from the academic literature on Systems of Innovation theory and on the business literature related to green energy.

9.2 HOW HAS THE ISRAELI INNOVATION SYSTEM EVOLVED SINCE ITS INCEPTION IN 1948 AND WHAT EVENTS SHAPED IT?

9.2.1 Jewish values and "intellectual capital"

As covered in Chapter Three, each country has its own national innovation system based on its history, which in turn influences its economic development. A common thread that pervades all of the materials contributing to this study is how Jewish values and Israeli culture shaped the Israeli innovation system within and across its different institutions.

Nelson (1981) posits that for the NIS approach the quality of capital accumulation, achieved through the skills of the labour force and entrepreneurs are the important economic growth factors of a country. Pavitt (1993) indicates that economic growth through innovation is achieved by having capability and education in basic science.

In the Israeli academic literature, Fortuna (2012) proposes that Israel's sources of innovation are a result of its history and culture, starting during the British Mandate between 1918 and 1948. According to Teubal (1983), the Israeli Innovation System was born during this time through the establishment of its three universities. Almost from the beginning, these institutions conducted applied research and commercial R&D, a practice that continues today. Thus, Israel began to achieve economic growth early on by exploiting its "intellectual capital" in science and technology. Teubal (1983) noted that research and development has been "deeply rooted in the history of Israel" (p. 172) and that the country's high quality universities have given Israel a competitive R&D edge.

These observations are confirmed by Breznitz (2007b) and Fortuna (2012). Breznitz (2007b) explains that the goal of Israel's 'National Ideology,' during its first twenty years of existence, was to develop a knowledge based economy and society based on intellectual capital, emphasizing that the prominence given to science and technology is founded on Jewish values of education, a point also stressed by Getz and Segal (2008).

In addition, Stone (1999) discusses that this trend continued in the following decades and was boosted by the wave of highly skilled Russian Jewish immigrants who further increased the country's absorptive capacity and adaptive efficiency.

As Fortuna (2012) explains "Israeli success in leveraging scientific and technological R&D into economic growth is the result of special circumstances and the massive public investments in research and higher education in decades past" (p.15). Fortuna (2012) further indicates that such measures are consistent with a positive cultural attitude towards change. As an interviewee proposed, Jews like to complain that things are never good enough: "that permanent dissatisfaction, (a) yearning for more, to fix and improve, is part of the (Jewish) heritage, and it passes from one (generation) to the next" (Interviewee A3). Another interviewee noted similarly that for 2000 years the Jewish people only had their intellect to compensate for shortages of resources (Interviewee A1).

9.2.2 Comparing the Israeli System to those of Britain and the US

Freeman (2002) explains that national innovation systems succeed when these are in synchronicity with their social sub-systems such as "science, technology, economy, politics and culture" (p.193). As Edquist (1997a,b) describes, this was the case of Britain during its exceptional economic growth in the eighteenth and nineteenth centuries. The United States (US) as well, Freeman (1995) explains, exceeded Britain's economic development through education and its waves of immigrants.

Fortuna (2012) describes that since its foundation as a State, and even before, Israel's national innovation system and its policies have been aligned and consistent with its culture and institutions, a situation that, according to the NIS literature is similar to that of Britain in the eighteenth and nineteenth centuries. Similarly to the US as well, Israel has been a country of immigrants. But as stressed by several interviewees, Israeli immigrants, differently from both Britain and the US, are "one people," As stated by Levi-Faur (1998), one of the unique domestic conditions in which the Israeli economy developed was that Israel is home of ancient people with a strong national identity: the official designation of a "national sociopolitical identity" became a nation-building trait (p.10).

This view was widely shared by the interviewees who said that although Israel is home to Jews from many different countries who immigrated because of Zionist or persecution reasons, they are 'still one people' (Interviewee P3), while immigration to other countries is highly pluralistic in terms of religions and backgrounds (Interviewee I1). Some interviewees who had immigrated to Israel saw themselves as 'arriving home;' as building the country and its economy by living in a Jewish state and not as a minority in another country (Interviewees G1 and I1). However, as a young interviewee stated, Israelis see themselves more as Israelis than Jewish (Interviewee I1); while another interviewee stressed that Israeli Jews celebrate and keep the Jewish holidays even those who are not religious, who are secular (Interviewee A3). My interviews also noted that building the State of Israel was supported through investments in Israeli technologies by international Jewish corporations, such as the large foreign MNC that invested in the Weizmann Institute's renewable energy technology. Also, in a similar way to Britain, as Senor and Singer (2009) illustrate, Israeli companies have developed agricultural technologies since the British Mandate when Jewish immigrants arrived to what was then Palestine, developing technologies such as drip irrigation, greenhouses, and desalination for agricultural irrigation and human consumption (pp. 63-64, 108-113, 226).

The NIS literature also addresses the fact that the economic development of Britain and the US was achieved mainly through their manufacturing, economies of scale, and accumulation of capital, which was not the case of Israel. Differently, Israel has focused mainly on high-tech R&D and not on manufacturing, achieving economic growth mostly through institutional change, technology development, and strong foreign direct investment in the country. Also, while Britain and the US had abundant natural resources, differently as well, Israel has scarce natural resources whilst intellectual capital is its main resource. Israel's institutional change took place by moving from a socialist to a liberal economy; by opening its doors to foreign direct investment which poured into Israel through VC firms and MNCs establishing R&D centres in the country; through the Office of the Chief Scientist (OCS) programs, and by strengthening the R&D relationship between the private and defense industry, academia and government.

Documentary and interview sources all confirmed that due to the small domestic market for R&D intensive high-technology products and distance from friendly nations,

global business opportunities rank high in strategic importance for Israeli companies. Most of the technologies developed in Israel are implemented in overseas markets mainly by foreign MNCs.

9.2.3 Culture of Israeli Institutions

9.2.3.1 Military Culture

A subject not covered by the NIS literature and which is highly pervasive in, and unique to the Israeli Innovation System is the social component of the country's military service obligation. As explained by the Israeli academic literature and confirmed by my interviews, since military service is compulsory, the military culture has a strong influence on the Israeli population which spills over to government, academia and industry. For example, de Fontenay and Carmel (2004) and Chorev and Anderson (2006) argue that the military allows and encourages soldiers to question and challenge orders from, and decisions by their superiors. This behaviour spills over to the business sector, where Israelis learn to challenge collective wisdom and to question the status quo, while showing initiative and being daring, as confirmed by several interviewees (Interviewees P6, P3, I1). Although not specifically mentioned in the Israeli academic literature, due to these cultural traits we may add that Israel possibly has one of the lowest military and business hierarchical cultural distances, if not the lowest, in the world.

According to the GEM Israel Report 2013 (Global Entrepreneurship Monitor, n.d.), Israelis form strong social networks that promote entrepreneurial activity. Breznitz (2005), de Fontenay and Carmel (2004), and Chorev and Anderson (2006), and confirmed by my interviews, describe that these networks are formed through the strong bonds, camaraderie, trust, teamwork and loyalty to the group developed during military service and adopted by the business sector as well (Interviewees I1, P4).

Interviews indicated that bonding during military service was the basis of many business partnerships, especially those involving graduates of the elite 8200 Military Unit, which is also confirmed by institutional sources (Forbes, 2016). As an interviewee and graduate of this elite unit described, together with two friends who had served with him

in the military many years before, he developed a renewable energy technology (Interviewee P4). Because of these social networks, an interviewee pointed out that Israelis consider themselves to be more open than Americans as a society and culture, and which allows for a more fluid transfer of technology (Interviewee A5).

Fortuna (2012) discusses that stubborn persistence is another Israeli cultural entrepreneurial trait. As confirmed by an interviewee, persistence and perseverance are learned in the military which teaches soldiers to reach their goals and to not give up (Interviewee P12). A view also supported by another interviewee, pointing out that through military training Israelis also learn to cope with change by thinking quickly before taking action, while having a long-term vision of their decisions (Interviewee P9). Differently however, two interviewees mentioned that Israelis do not have the money or the patience to develop their technologies into products (Interviewees A4 and P11).

While not addressed by the Israeli academic literature, an interviewee indicated that Israel is a country in crisis where Israelis live under constant uncertainty and risk; where life is more difficult in general with more obstacles and challenges than in Western countries; being obliged to think outside the box, and therefore their success (Interviewee P11). Thus we can say that Israelis face risks during their military service, and they also face constant uncertainty and risk during their daily lives. On the other hand, although Israel is a country in crisis, it has a democratic and stable government, which his different from other countries in crises that are not innovative and do not think outside the box. In addition, other countries in crisis may not value education as Israel does.

9.2.3.2 Government Culture

Teubal (1993) talks about the role of Israeli bureaucratic champions during the history of the State, from the 1950s to the1960s, and in the 1990s referring to them as heroes. As Breznitz (2007b), indicates, Israel's leaders who directed the country's success "politicians, civil servants, and businessmen and entrepreneurs-were all of a generation keenly aware of the price of failure" (p.10), and therefore acted within a national development effort. However, today it seems that this ideology may be changing. As an interviewee explained (Interviewee A5), today Yozma (the VC industry founding

program) is a private firm owned by the Ofer brothers who are business oriented, need to make money and the benefit to the economy is not their concern (Interviewee A5); a statement also expressed by a VC regarding its business position (Interviewee P5). Also, as indicated by another interviewee, today Israel is an established nation with different priorities than in the past when it was a nation in the making (Interviewee I1).

We can also say that improvisation, mentioned by Maital et al. (2008), also exists at a government level. For example, Breznitz (2007b) posits that Israeli R&D policy, such as the BIRD foundation, was developed on a trial and error basis. Differently, other countries, such as Ireland and Taiwan, developed their policies in a more organized and strategic way. Two interviewees described the Israeli culture and the government as being action oriented, which is not described as such in the Israeli academic literature, but that may fall under the improvisation characteristic due to the country's history of moving fast, of doing things first and then evaluating the consequences (Interviewees A5 and I1); as expressed by an interviewee, a culture "that is hands on and the analysis comes later," (Interviewees A5) as seen with the Russian immigration in the 1990s.

Another important fact not addressed by the Israeli academic literature and mentioned by two government interviewees is that the OCS has highly experienced evaluators who visit the bidding companies in order to conduct in-depth evaluations through face-to-face interactions. As explained by both interviewees, this is a procedure that does not take place during the selection process in Canada (Interviewee G1 and G6), which may also reflect the different interaction levels of two different cultures, Israeli and Canadian, where the Israeli one is more open.

9.2.3.3 Entrepreneurial and risk taking business culture

According to the NIS literature, innovation is highly risky, since entrepreneurs do not have accurate information of their R&D results. Getz and Segal (2008) discuss that at the same time that the Israeli economy was liberalized the Israeli culture became more individualistic, which may be more related to entrepreneurs and risk taking. Culturally, Israelis have practically all the characteristics of an innovative society, which is also described by the NIS literature, one of them being no fear of risk or a "risk-favouring entrepreneurial culture" (Maital et al., 2008, p. 4), acquired through the military service.

Similarly, the 2001 GEM report, which placed Israel as 2nd in entrepreneurial motivation and skills, after the US and tied with Canada, explains that there had been a cultural and ideology change in Israel where Israelis had become more individualistic and materialistic, and entrepreneurship drove the market development.

Getz and Segal (2008) and Avidor (2011) also explain that the Israeli culture has a high tolerance for entrepreneurial failure and therefore a high individual risk tolerance, as a result of military experience as well. However, an interviewee mentioned that the government does not fund companies that have been funded several times and did not reach the commercialization stage, which is expected of every project (Interviewee G6).

In the NIS literature, Jacob (1988) explains that Britain's government strongly supported science, and in the country there was admiration and respect towards Newton. Avidor (2011) posits that in Israel entrepreneurs are considered heroes and role models. However, in response to the Israeli entrepreneurial role model, an interviewee suggested that instead Israelis should admire successful entrepreneurs who grow their startups into mature companies, since implementation is innovation while invention is more related to research (Interviewee A5). As he further voiced, Israel, as a small country, is contributing to global innovation but this is not benefitting its economy since its innovations are sold to large MNCs. In addition, this approach is creating economic gaps, inequality in its society and a double economy, which could create economic instability in the country (Interviewee A5).

My interviews identified different views regarding this issue mentioned above, such as short-term thinking by entrepreneurs when selling their technologies to MNCs. However, several interviewees mentioned other non-cultural factors involved as well, such as startups running out of funding; a high level of bureaucracy and red tape; and notwithstanding the penalty of six times the funding provided to startups by the government, the fact is that selling a company to an MNC is worth while and very lucrative (Interviewees A7, P2, and P8).

In the NIS literature, Baumol (2013) points out that some companies are better at inventing while others perform better by licensing and improving products, while R&D involves high investments. Similarly to this view, additional reasons given by several interviewees were that Israelis must focus on their brain, which is their strength; in their

R&D workforce and their know-how, which stay in Israel while the implementation takes place somewhere else (Interviewees A8, A9, G1, G3, P1, P2, P3, P8, P11, P12 and P13). For example a startup interviewed has its main R&D centre in Israel, although in this case the IP belongs to the company and its manufacturing takes place overseas (Interviewee P12). The downside to this situation is that even if the company is Israeli and the main investor is a foreign MNC, probably the company will follow the decisions of the major investor. Therefore, although not addressed by the Israeli academic literature, an interviewee suggested that the best route for companies to remain Israeli is to go through an Initial Public Offering (IPO) (Interviewee A5). Nonetheless, in the NIS literature, Utterback and Suárez, (1993) indicate that foreign acquisitions of startups is a common situation (not only in Israel) since it is costly to develop new technologies; and as indicated above as well, selling a startup for millions of dollars is very lucrative.

Freeman (2002) suggests, which is also the case of Israel, that the future of innovation in the twenty first century will be oriented mainly towards ICT with the dominance of the service sectors, while agriculture will continue to be important. Manufacturing will continue to be located outside of the industrialized countries, thus further reducing employment in this industry. Innovation will centre on managing global networks with main activities in research, design and development of software and hardware mainly in the home country by MNCs. However, the author indicates that this approach increases the social inequality within developed national social systems, a situation that is also happening in Israel, as confirmed by an interviewee (Interviewee A5).

Levi-Faur (1998) discusses that although culture may be important for economic development, policies are more important. Nevertheless, as covered in the NIS literature, the Israeli academic literature and my interviews, we can deduce that both, culture and policies, are equally important and one cannot be successful without the other.

9.2.4 Israeli Institutions that promote innovation and transfer of technology

In the NIS literature, Malecki (1981a,b), Malecki and Tootle (1996) explain that national innovation systems are created through technology and knowledge transfer by a country's institutions and within its boundaries. In addition, Lundvall (1988) proposes

that within a national innovation system, the relations among institutions (industry, government, universities) involve learning and technology transfer process that occur between universities and industries, where universities produce basic research and industries are their users. On the other hand, university applied researchers also learn the needs of industry.

As seen in the Israeli academic literature and confirmed by my interviews, there is a high flow of information and knowledge across Israel's institutions due to the movement of scientists, engineers and entrepreneurs across government, academia, the defense and private industries, and the military. For example my interviewees included successful entrepreneurs and also PhDs who worked for many years with the defense industry and who now work with government programs supporting international R&D, and as academic researchers.

9.2.4.1 Military and defense Industry

Freeman (2004) explains that the development of a country's defense technology enhances national morale, political power and encourages indirect economic progress. Ruttan (2006) notes that historically, military institutions have contributed significantly to technology R&D and in the US developing civilian commercial technology as well. Freeman (2004) also indicates that each country has its own technological infrastructure which influences its international competitiveness, and technological leadership gives international advantage to a country.

According to Breznitz (2005) and de Fontenay and Carmel, (2004), military graduates from Israeli high-tech elite units have had a strong role in the development of the civilian IT industry, which the military has also encouraged. In this way IT became Israel's technological strength, becoming an international leader in this sector. However, as stated by an interviewee this trend may be changing since today about five percent of Israeli entrepreneurs come from the military (Interviewee G1), which may mean that through Israel's accumulation of knowledge and adaptive efficiency, more technology is being developed that does not originate directly from the military. Nevertheless, we can infer that this may happen indirectly.

9.2.4.2 Government

While the military had a primordial role in the development of IT technologies as part of its defense programs, as Breznitz (2007b) discusses, Israel's long-term and coordinated government support strategy also played a most important role. For example, we can say that the Israeli government has been proactive in adapting to global changes, such as implementing the liberalization reforms of its economy in the 1980s, which facilitated the country's move towards innovation in the 1990s.

Utterback (1974) identified the external environmental characteristics that drive innovation of firms which are: a firm's economic, social and political environments, such as government programs, incentives, and regulations, and "the state of development of technology, and information about technology" (p.621). Lundvall (1992) further discusses that some important features of the British national system were the strong ties between scientists and entrepreneurs; the ability of inventors to raise funds and collaborate with entrepreneurs; and government support for science, becoming a national institution. These traits are also described in the Israeli academic literature and by my interviews, where university researchers have strong ties with entrepreneurs (Interviewees A3 and A8) who are able to raise funds due to the policies implemented by the government.

Hospers (2005) also suggests that economic change should happen from a country's existing resources, which the Israeli government did by taking advantage of the country's high-skilled labour force, since the late 1960s, which were the country's existing resources. However differently from Hosper's (2005) suggestion indicating that policy makers should not chase after programs that were successful in other countries, Yigal Erlich, who successfully established the VC industry in Israel and is considered a bureaucratic champion, did adopt and adapt the VC model from the Silicon Valley developing an early phase VC industry in Israel.

Furthermore, as seen in the NIS literature, Cohen et al. (2002) and Feller et al. (2002) explain that the involvement and support of government institutions, through public-funded research, has been essential for technological innovation and the economic development of societies. Similar to the NIS literature and Freeman's (2004) suggestions, the Israeli government has supported the Five Cs - coupling, creating, clustering,

comprehending and coping, also supporting and developing Israel's position as a technological leader.

Also, the increase by the Israeli government in industrial R&D funding, as well as the boost in defense R&D funding, resulted in a significant increase in the number of scientists and engineers over the years, not withstanding the cuts by the Office of the Chief Scientist (OCS) to universities starting in the late 1960s. However, as presented by the Israeli academic literature and confirmed by my interviews, this trend is changing and currently there is a shortage of engineers which could jeopardize Israel's high-technological leadership. According to a recent article in the Times of Israel (January 16, 2017), Israel will hire foreign high-tech workers due to a lack of manpower in the country, and they will be paid double the salary of Israeli employees.

Different views were provided by my interviews regarding the shortage of engineers. The 2013 Israel GEM Summary Report indicates that the incentive of entrepreneurs to increase their income and independence is stronger than not having the opportunity for work. In support of this statement, as stated by an interviewee, engineers in their 30s and 40s leave good jobs to establish startups (Interviewee G1); and since Israel is a small country, large companies in Israel have problems finding engineers and business managers (Interviewee P1). Alternatively, another interviewee proposed that the Israeli market is not that small, since it is larger than the Alberta market (Interviewee P12). Another explanation provided by an interviewee (Interviewee A5), and supported by Israeli institutional sources is that of a shortage of local manufacturing causing "the constraint on the supply side" (Israel Innovation Authority, 2016 report), and a shortage of engineers.

Additional reasons for this shortage of engineers may be found in the Israeli academic literature, although not stated as such. Getz and Segal (2008) and Trajtenberg (2005) indicate that Israel does not follow an explicit innovation policy, but its goal is to promote R&D while commercialization is expected in all its funding programs with the objective of creating manufacturing, employment and export, and of producing spillovers as well. Nevertheless, as widely stressed by my interviews and the Israeli institutional sources, very little of these have taken place in Israel, which may have resulted in a shortage of engineers as predicted by Trajtenberg (2005) and as voiced by Teubal and

Kuznetsov (2012), together with a slow growth in the rest of the economy. Kalman (2008) also explains that in 2006 there were cuts in government funding to universities which could affect Israel's leadership in high-tech. Also, as mentioned in my interviews, currently there is a decrease in R&D capital from the government (Interviewee A5); and little collaboration between the high-technology sectors and the traditional/conventional industries. However, as described in an interview, the MAGNET consortium program supports more engineering or mid-tech companies than high-tech companies, which means that the government is aware of and working on this issue (Interviewee G5); being this also a MAGNET selection criterion not mentioned in the Israeli academic literature.

As well, an important selection criterion of the MAGNET program is the export probability of the products resulting from the R&D for the benefit of the Israeli economy, which is higher in importance than the benefits to the companies themselves (Interviewee G5). While not mentioned by the Israeli academic literature, perhaps we can assume from my interview that there is a higher probability for local production by mid-tech companies than by high-tech companies, which tend to sell their technologies and are mostly manufactured overseas. Therefore the MAGNET program tends to support mainly mid-tech firms.

The NIS literature explains that external indirect innovation includes formal collaboration between industry and universities to create generic technologies, supported by government programs. My interview indicated that the MAGNET program that develops generic technologies, and the MAGNETON program that develops applied academic research, have strengthened the R&D relationships between industry and academia (Interviewee G5), although there is still room for improvement, by establishing applied research institutions such as those in Germany, that transfer technology from academia to industry (Interviewee A5).

Lundvall (1992) indicates that Britain's economic growth in the eighteenth century is attributable in part to the nation's cultural connection with science, technology invention, and its industrial processes, which created the industrial revolution; and to its government policies that integrated science, technology, culture and entrepreneurship, which became the features of the British national innovation system. Similarly to Britain, the Israeli government has implemented policies that have integrated science, technology,

culture and entrepreneurship, which have also become the staple of Israel's national innovation system. Furthermore, Israel also has a cultural connection with science and technology invention that began even before the foundation of the State.

Hospers (2005) proposes that a country's institutions shape its economic process, and in turn, the economy shapes the country's democracy and its political institutions. Following this view, a particularly highly placed interviewee suggested several strategies to deal with the issues the Israeli innovation system is facing, as mentioned above, and to innovate the Israeli Innovation System (Interviewee A5): First, the Israeli government should continue implementing R&D policies and programs, and include manufacturing with its full supply chain in Israel and with high salaries that would benefit the whole country's ecosystem and its economy. Differently, other interviewees indicated that manufacturing in Israel is already not competitive except for sophisticated chips, and manufacturing in developing countries is an approach used by corporations with headquarters in developed countries as well (Interviewees G1 and P1). However, as described by the NIS literature and an interviewee this approach is already creating social inequality (Interviewee A5). Second, the government should also invest in startups after their incubation R&D stage and take most of the risk, as it did with the Yozma program and with no equity in the companies, as it does with its present programs (The Times of Israel, July 11, 2017). The goal would be that instead of selling their technologies, Israeli companies would be able to grow, own their technologies and have their headquarters in Israel with global subsidiaries, following the business model of the Israeli water corporations.

As confirmed by two interviewees, the Chief Scientist is consulting with academic researchers, is aware of these issues and is taking action by becoming a flexible and independent agency to implement the related changes faster (Interviewees A5 and G1). The approaches above will not end all MNCs' acquisitions of Israeli technology but will probably help to create larger and more global Israeli companies (Interviewee A5). According to The Times of Israel (July 13, 2017), the Israel Innovation Authority (IIA), former OCS, is implementing a new program to achieve this by providing R&D grants to large Israeli companies in order to help them to grow further and to enter new markets, to strengthen the Israeli economy.

9.2.4.3 Universities to industry

Meseri and Maital (2001) found in their study of TTOs, that Israeli Universities conduct a significant amount of basic research, which was their main challenge when it came to their transfer of technology to industry, and therefore concluding that Universities have a problem in their transfer of technology to the private sector. However, the authors further propose that in order to understand all phases of the transfer of technology process it is necessary to study the interactions among all related institutions.

Differently, my interviewees explained that today, 13 years since Meseri and Maital (2001) published their article, at least 50 percent of the research at the Weizmann Institute, which is a science based university, is applied (Interviewees A3, A4 and A8). As the NIS literature indicates, basic research is changing towards more collaboration with industry and therefore more application oriented as well.

Freeman (1994) proposes that external indirect sources of innovation also include informal networking between firms; and Bozeman (2000) states that many of the skills involved to produce scientific and technical knowledge are rather social, through networks between scientists and firms, and more tacit than intellectual. In support of this view, two interviewees also described how human socialization and networking are crucial during the transfer of technology between academia and industry (Interviewee A1 and A8). For example, MAGNET projects are complicated because of their human component which requires not only the research in itself but also a high level of socialization, which plays an important role for the transfer of knowledge to take place. Another example is the Technion Transfer of Technology (T3) office that encourages the mutual transfer of technology between industry and academia, where networking and chemistry between people of both institutions is very important in order to be successful (Interviewee A1). Another example of the importance of networking identified in my interviews, and not addressed by the Israeli academic literature but suggested by the NIS literature, by Fini et al. (2010), is between university researchers who have a network of entrepreneurs and companies with whom they have worked in the past and contact them when there is a technology development opportunity (Interviewees P3, A8 and P1). Similar to this view, VC firms in Israel also contact academic scientists on an ongoing basis to identify potential projects in which to invest (Interviewee A3).

In the NIS theory, Stankiewicz (1994) proposes that scientists are not good entrepreneurs. My interviews also identified that during the transfer of technology and the licensing process from university TTOs to industry, scientists are strongly involved in the decision making process of the technology development only; and as Jaffe (2000) adds, this assistance of university inventors is crucial during the development stage, and patent royalties play a strong incentive. According to an interviewee, this approach is different from US universities where scientists establish companies and run them, while Israeli researchers can only help to set-up a company and act as consultants (Interviewee A8).

a) Patenting

Regarding the filing of patents, as identified in my interviews and not covered by the Israeli academic literature, there seem to be different approaches between the Technion and the Weizmann Institute in their patent filings. The Technion encourages researchers to write patents and files them "very liberally" (Interviewee A1), while the Weizmann Institute is more selective due to the high costs of patents (Interviewee A3). My interviews indicate that Israeli universities have a large number of patents, but according to an interviewee very few get successfully commercialized, except for their very successful drugs (Interviewee A4). According to the Israeli academic literature and confirmed by my interviews, drugs produced by Israeli universities and sold worldwide are their highest source of royalties, which as an interviewee stated, allowing TTOs to be very active in the licensing of new discoveries (Interviewee A4). Nevertheless, other interviews indicated that the Weizmann and the Technion had several successful spinoffs, including in green energy (Interviewees A1 and A8). In addition, an interviewee indicated that for startups to join incubators their technologies must be patented, otherwise they cannot join an incubator (Interviewee G2).

The NIS literature offers different views regarding the role of patents. Archibugi and Pianta (1992) and Patel and Pavitt posit that countries record their specialized technological skills in their scientific publications and patenting, thus developing specific skills within their national innovation systems. Feldman and Florida (1994) and Hicks and Olivastro (1998) point out that patents usually refer to papers published by local

public institutions; while Salter and Martin (2001) add that in this way tacit knowledge becomes codified and the collective property of the country.

Differently, Macdonald (2002) argues that average patents never had much value with regards to innovation, and that studies conducted in the US in the 1990s show that only one in 100 patents (one percent) produce royalty revenues. Differently, as identified in my interviews, the Technion Transfer of Technology (T3) files close to 100 patents every year; it also has 60 spinoff companies in its portfolio in which it holds equity or a license agreement, or both, equity and royalties, and these companies have raised close to US$300 million in the last three to four years. The T3 spends US$3 million per year in patents and other activities, and it generates over US$30 million per year in commercialization revenues only (Interviewee A2). The patents include: Healthcare, Drug Discovery, Engineering and Physical Sciences, Computer Science, Food and Nutrition, Clean-tech - energy, environment and water (Technion Technology Transfer (T3), n.d.).

Cohen et al. (2002) discuss that commercialization through patenting and licensing has had a low influence and importance on industrial R&D, with technology transfer taking place mainly in the pharmaceutical industry, and with average results in high-technology sectors including aerospace. Differently however, according to the Israeli academic literature (Vekstein, 1999) and my interviews, Israel's strength is in industrial high-tech R&D, and the country also has a powerful aerospace industry (Reuters, November 2010).

Macdonald (2002) further discusses that the patent system is based on the linear myth of innovation. However, the Israeli academic literature and my interviews identified several examples of linear innovation models, such as the former Technion Entrepreneurial Incubator Company (TEIC), described by Rothschild and Darr (2005) as a successful linear innovation model with successful commercial projects. As well, a VC firm interviewed selects its investments from its incubated companies, moving them directly from their research to the development and commercialization stages (Interviewee P5). A third example from my interviews is that of the green energy startup, under the umbrella of a cleantech VC (Interviewee P1), and of the biofuel company, under an incubator that is becoming a holding company (Interviewee P8). Both, after 7 years

are selling their products worldwide. Although, these startups seem to be exceptions to the norm, there may be more of them in the country.

Differently from the linear innovation model, according to the technology push/market pull concepts (Rothwell, 1994), and as described in my interviews, when the Technion Liaison Office connects with industry, the transfer of knowledge can sometimes be both ways, from university to industry and from industry to academia. The Liaison Office, for example, identifies a liaison person inside industry with whom to work and to mutually transfer information (Interviewee A1). In this way we can say that innovation takes place through technology push and market pull.

Differently from Macdonald (2002) as well, and in support of Jaffe (2003), Israeli companies are mostly small and they do tend to patent their discoveries. However, differently from what Jaffe states, these startups file their patents mainly in the NASDAQ, located in the US.

In addition, differently from Macdonald (2002), and what may be unique to Israel, is that the innovation and strong patenting implementation by the Israeli government, and the technologies and startups created, have indeed resulted in the almost immediate wealth of Israeli companies, of the country's industry, and in the economic prosperity of Israel.

9.2.4.4 Private Industry

In the NIS literature, Pavitt (1984) and Utterback and Suárez, (1993) found that small firms are increasingly contributing to invention and innovation mainly in a few industries such as software and biotechnology, and mostly during the early phases of new generic technologies. Similarly, Israel is known as the Startup Nation (Senor and Singer, 2009), with 2000 startups in 2010 mainly in software and biotechnology.

Teubal (2013) indicates that between 1993 and 2001 more than 50 percent of VC investments were allocated to early startup stages - with a higher risk than the more mature startups, versus 25 percent in the US and about eight percent average in all other OECD countries. My research confirmed that this is still a trend, since the cleantech VCs interviewed invest mostly in early startup stages, while also in some incubated companies, which supports Israel's high risk entrepreneurial trend.

In the NIS literature, Smith (2000) states that government R&D subsidies are related to the linear model of innovation, which has limitations. However, my interviews show that incubators have an average success rate of 20 percent, and the BIRD foundation has a success rate of 20 to 30 percent, both subsidized by the government. Similarly according to the IVC company with its startups' database, 34 percent of startups continue operating every year. These numbers are also higher than the one percent proposed above by Macdonald (2002).

Breznitz (2007b) explains that between the 2000 and 2003 economic crisis, the incubator program produced more than one hundred startups per year, proving to be independent of VCs; and as of 2003 a few VCs only acquired and managed a small number of incubators. Nonetheless, four interviewees, related to green energy, indicated that startups prefer investors from large companies and VCs to incubators because they get higher financing and may have a higher success rate as well (Interviewees, G2, P3, P4, P13). Furthermore, we can deduce that since Israeli VCs are early stage they would not have many investments in incubated technologies (Interviewee P1).

Breznitz (2007b), and Chorev and Anderson (2006) present the negative effects of the VC industry such as quick financial exits within five to seven years. However, according to my interviews, VCs are not in a hurry to have financial exits and these take as long as needed.

As identified in this section, the NIS literature does not address at all the military culture influence across institutions, including that of government which tends to improvise and be action oriented; an entrepreneurial culture that favours risk; and a business culture that tends to be daring and to challenge the status quo, and therefore embrace change.

9.3 HOW IS THE ISRAELI INNOVATION SYSTEM RESPONDING TO THE NEW TECHNOLOGICAL AREA OF GREEN ENERGY?

9.3.1 Role of military and defense industry

My research found that defense companies have a strong role in renewable energy generation, which is not addressed by the Israeli academic literature, in their role as partners in cleantech and in renewable energy incubators (Interviewees P1, P8 and G2), promoting the country's economic growth. However, as my interviews stressed, none of the technologies developed in these incubators had direct military origins (Interviewees P1 and P8); while two interviewees mentioned the company Solar Edge as having a military background as an exception (Interviewees A2 and G2). Instead, as a cleantech organization mentioned, most ideas come from entrepreneurs and mostly from their work experience (Interviewee P8). As also described in my research, the defense industry collaborates with universities, such as the Grand Technion Energy Program (GTEP) (Interviewee A9), and with smaller renewable startups from other energy Technion programs, to develop both military and civilian technologies.

9.3.2 Role of Government

In the NIS theory, Mowery and Rosenberg (1979) suggest that government must promote the development of alternative energy technologies, through incentives and information, since companies may not have the knowledge to develop this technology and there may not be a market demand. The office of the Israeli Prime Minister established the Fuel Choices Initiative that supports R&D and the further development of technology of alternative fuels for the transportation sector through a co-investment program. Two interviewees as well indicated that Israel's R&D in alternative fuel transportation will have a positive impact on Israel's security even if these technologies are implemented overseas and not in Israel (Interviewees G4 and G6).

The government is also supportive of R&D only in renewable energy, but less supportive of its implementation due to the standardization of the energy production and distribution technology, as indicated by an interviewee (Interviewee G2). However, according to an interviewee, on July 25, 2017, a law passed in the Knesset (the Israeli

Parliament) where the Ministry of Energy must prepare a long-term plan to achieve the government's renewable energy goal, which as expressed by this interviewee, will probably only support the installation companies and not the technology developers (Interviewee A7, personal communication, July 25, 2017).

9.3.3 Role of Universities

Bozeman (2000) and Cohen et al. (2002) found that firm size is important as well when it comes to the impact of basic research on industry, since more than half of technology transfers initiated by universities are to large firms. My interviews indicate that the Weizmann Institute and the Grand Technion Energy Program produce green core technologies, which are too big for Israeli companies to develop and implement, and therefore the TTOs license these technologies to large foreign MNCs (Interviewees G5 and A8). Nevertheless, some of the renewable energy technologies from the Technion energy programs are licensed and developed by the Capital Nature Venture incubator in its research centre in southern Israel, which are smaller in scale (Interviewees A5, A7 and G2). However, it seems that this situation is not unique to green energy. Getz et al. (2014) point out that there is an increase in collaboration between Israeli universities and MNCs, creating an unequal transfer of know-how and technology from these universities to MNCs, versus to Israeli companies. The authors suggest expanding OCS programs, such as the MAGNET consortia to include MNCs, which would benefit all participants – universities, local firms and MNCs due to the spillovers these programs create. Tax incentives to MNCs should be provided on the condition that MNCs acquire products and services from local companies.

Therefore, as suggested by an interviewee, Israel needs more large companies that can develop big projects and manufacture in Israel or overseas, while remaining Israeli, following the model of the very successful Israeli multinational desalination plants (Interviewee A5); and as Teubal (1983) adds, that of the global Israeli chemical and petrochemical companies that manufacture in Israel and sell most of their products overseas. With regards to support for green energy companies, as proposed by an interviewee, some of the government funds invested in large traditional industries that rely heavily on tax shelters and are not competitive, should be invested instead on the

implementation stages of green energy companies using the same royalty models of the OCS programs (Interviewee A5).

9.3.4 Role of private industry

Private industry interviewees provided different points of view regarding Israel's renewable energy. Some sources pointed out to the green energy market dependence on the price of oil and gas causing ups and downs in the renewable energy sector (Interviewees G5 and P4). However, an interviewee established a renewable energy startup even after experiencing such a renewable energy crisis (Interviewee P13), while another indicated that renewable energy has reached grid parity (Interviewee P1); and another interviewee explained that Israel can play some role in green energy, but it cannot be a world leader as it is in other fields such as ICT and biotechnology, but it can provide solutions to energy problems (Interviewee G7). Differently one of the green energy startups under a VC interviewed is exporting its technology already to Europe, and the Arava Power Company plans to export its expertise to Europe as well (Interviewee P7). An interviewee also discussed that Israel is too small to have solar fields (Interviewee P1), although some companies have built them in southern Israel, for example the Arava Power Company, but on a smaller scale than in bigger countries such as in the United States.

The Arava Power Company had built eight solar fields in southern Israel by 2015 and had additional future projects planned, despite the country's offshore gas discoveries (Interviewee P7). Also, the Eilat-Eilot and the Arava regions in southern Israel plan to be solar energy independent by 2025, notwithstanding the country's large gas discoveries (Interviewee G2).

The Israeli academic literature does not mention the direct impact of Israel's large offshore gas discoveries on the development of green energy. According to my interviews, there are also different views regarding the impact of these discoveries on green energy development. Some are negative, such as slowing down the implementation of the government's 10 percent renewable energy by 2020 (Interviewees G2, A2, A5, A7, A9 and P2); while another interviewee presented rather non-negative impacts on the development of green energy, since there is a global need for cleaner and varied sources

of energy (Interviewee P1). However, as I found through my interviews, by the end of 2014 Israel had not achieved the implementation of its five percent renewable energy goal. A reason for the renewable implementation slowdown is that it is more costly than natural gas and makes the energy mix much more expensive and onerous on the country since it changes the whole electrical structure, while this is not the case with the use of natural gas (Interviewees G2, G3 and P2). Nevertheless, as mentioned above, the Israeli government is speeding up solar installations.

In the business literature, Hart and Christensen (2002) suggest that entering developing markets with green technologies offers a higher degree of success than in saturated developed markets. However, according to the Israeli academic literature and my interviews, the US market is very important because every Israeli technological company that can commercialize a product looks at the US as its first market, where Israeli companies have built large solar fields. Europe and the US are larger markets with more money to develop renewable energy, as mentioned by an interviewee (Interviewee A8). However, as Fortuna et al. (2015) discuss, most of the increase in solar energy installations takes place in the developing countries which have already become target markets for the Israeli renewable energy sector. In support of this view, a VC interviewed is looking at Yucatan in Mexico as a highly prospective market for its green energy startup, but it already sells in Europe (Interviewee P1). Also, the Eilat-Eilot region is planning to market the technologies developed in its research centre to Africa, Asia, some parts of Israel and northern Canada, where people are not connected to the grid (Udi Gat, personal communication, August 6, 2014).[63] It seems that some Israeli companies, as described by my interviews, access the US and European markets first and then the developing countries. However, further research in this area would be needed.

Espinoza and Vredenburg (2010a; 2010b) identified different reasons for countries to develop renewable energy. According to my interviews, Israel's power supply and national security are the main reason for the country's interest in reducing its dependence on foreign oil and on dealing with energy crises, while the desire to improve the

[63] For example, the Israeli organizations: Innovation: Africa, and Gigawatt Global. See Footnote 23, p. 128.

environment ranks second. For example, it was the Canadian government who requested that R&D be conducted in green energy under the CIIRDF program with Israel.

In addition, as identified in my interviews and not mentioned in the Israeli academic literature as such, global business opportunities rank high in importance for Israeli companies with prospects in promoting and identifying potential investors in alternative and renewable technology and which are a driver for Israeli green energy R&D, but most of them to be developed overseas (Interviewee P4). Nonetheless, this trend is not only followed by green energy technologies, but by the high-tech industry as well, where most of Israel's technologies are developed overseas by foreign MNCs. However, as explained by several participants, renewable energy requires much higher investments, longer development time, and more challenges to be developed and commercialized than IT (Interviewees A5 and A9). Therefore, as an interviewee noted, most IT entrepreneurs who moved to develop renewable energy during its peak period returned to the high-tech sector during its crisis (Interviewee P13); and another added that some VCs also invested in green energy, but were not successful since they did not understand its challenges (Interviewee A8). As pointed out by a renewable energy startup interviewee, he could not find a VC that would invest in his technology (Interviewee p13). Another interviewee recently indicated that the renewable energy technology is going through a strong crisis:

> Severe downturn with VC deal flows grinding to a halt, no significant activity on sight, and (a) general lack of enthusiasm by most actors. This might be result of (the) global trend, but also I believe that some entrepreneurs were 'flushed out' by lack of funding (Interviewee A7, personal communication, July 26, 2017).

Day and Schoemaker (2011), in the business literature, suggest 10 strategic lessons for companies to survive and win the difficult battle of green energy markets. Israeli firms seem to have some of the attributes suggested by these lessons, acquired mainly through the military training of their personnel and which they bring to the business sector. However, since Israeli green energy companies depend on global markets, the global crisis affected the Israeli companies as well. On the other hand, as indicated by a

cleantech VC partner, green energy will continue to be important and in high demand (Interviewee P5).

CHAPTER 10: CONCLUSION

10.1 WHY THE ISRAELI INNOVATION SYSTEM?

As a young country, Israel has become a developed nation through technology innovation and entrepreneurship, and a leader in Information Technology and Biotechnology. My research investigated the Israeli Innovation System, how it works and why and where it is successful or unsuccessful. This Chapter summarizes what I learned, which capabilities can be transferred to other countries and their implications; and what other countries can learn from Israel's successes and weaknesses. I also examine lessons learned, including those in the green energy sector.

10.2 MAIN POINTS AND LESSONS LEARNED

1) Role of Israeli culture, education and Jewish values:

As identified in this dissertation some facts are unique to Israel's Innovation System. These include Jewish values and the Israeli culture which play an important role in the innovation and economic growth of the country. The country's compulsory military service has created a culture of risk takers and entrepreneurs, while also playing a significant role in shaping its informal networks that are an important component of Israeli society. As well, there is an ongoing movement of scientists and engineers across the country's institutions creating spillovers from university innovations, from military elite units, and from private industry experience.

The in-depth interviews provided many new insights that were not well recorded in the published documents. For example, the people interviewed, who shaped and are shaping the Israeli Innovation System, all agree with Israel's National Spirit 'of one people,' with many immigrants arriving in Israel for Zionist reasons, such as to participate in the building of the country. Therefore we can conclude that culture and policies are equally important in innovation and transfer of technology, and one cannot be successful without the other, as seen throughout this dissertation.

Also, some interviewees described Israel as a country in crisis. However, other countries experiencing crises similar to those of Israel are not innovative and probably do not value education as Israel does. In addition, such countries may not have democratic and stable governments as Israel has. This point can be a lesson to other countries.

2) Government support:

Some differences were also identified between the Israel Innovation System and some Systems of Innovation theories, such as Israel benefiting from massive government industrial R&D support, patenting, licensing and the creation of startups. As well, early stage technologies under Israeli VCs probably follow a more direct commercialization path, resulting in the almost immediate wealth of Israeli high-tech companies, its industry, and in the prosperity of the nation. Also, the large number of VCs, second to the US, and the large number of entrepreneurs as well, probably result in a higher number of startups reaching the commercialization stages.

However, as Fortuna (2012) explains "Israeli success in leveraging scientific and technological R&D into economic growth is the result of special circumstances and the massive public investments in research and higher education in decades past" (p.15). The author further indicates that such measures are consistent with a positive cultural attitude towards change. Therefore, developing and developed countries need the long-term commitment of their governments and of bureaucratic champions.

In addition, governments should implement liberalization policies to increase foreign direct investment which creates economic growth, but also implement policies for MNCs to manufacture locally in order to create jobs and support local supply chains. As well, the Israeli government is listening to academic findings and suggestions regarding the need for the government to invest in the growth of startups, responding proactively and quickly by moving the innovation of the Israeli Innovation System forward through the recently established Israel Innovation Authority (IIA) and other Ministries.

3) Weakness of the Israeli Innovation System - R&D only:

As a high level interviewee explained, having a narrow focus on R&D creates a situation that is not sustainable, a fact that is also supported by the NIS literature.

Although industrial R&D is important, it is not enough for sustained economic growth. The Israeli companies that do both, R&D and manufacturing are the most successful which may be true as well in other countries. Also, manufacturing with good salaries creates a more egalitarian society. Therefore, government intervention through funding is important in helping to grow startups out of the Valley of Death.

However, there were disagreements in my interview findings regarding this issue. For example, some interviewees indicated that Israelis do not have the patience to develop their technologies into products; or that Israelis must focus on their brains by having only R&D centres in the country and overseas manufacturing; while others said that Israelis do not have the money to develop their technologies.

Regarding the last point above, instead of selling technologies to large foreign MNCs, it was suggested that Israeli startups have IPO exits instead, needing funding to get to this stage. It was suggested that government funding was needed after startups leave the incubation phase, and that government take most of the development risk, with no equity in the startups, as it already does with its programs, and helping companies to grow with their headquarters in Israel. The government has such a program with the Fuel Choices Initiative, through a co-investment fund offering an option to the investors, a similar strategy it had with the Yozma (VC) program. Being 'action oriented,' the Israel Innovation Authority (IIA), former Office of the Chief Scientist, is taking action and extending its funding by implementing new programs to help companies grow after their incubation stage, and helping large companies to become multinational, however for now supporting only IT and biotechnology companies.

4) Response of the Israeli Innovation System to the new technological area of green energy:

The development and implementation of alternative energy technologies, through the different government programs, take place overseas as well, although one of the most important goals is to assure Israel's power supply and national security. It is difficult to understand this rationale when such technologies are developed overseas and not in Israel, the exception being the Eilat-Eilot region in southern Israel.

There were also disagreements in my interview findings regarding this issue in the area of green energy. Some interviewees stated that Israel is too small to install solar fields, although several have been built in southern Israel, and the government is planning to support the installation of more solar fields. Other disagreements mentioned included that renewable energy is more costly than fossil fuel; and other views indicated that renewable energy has reached grid parity, meaning, at the same price from the electricity grid, and without subsidies. Other points of view were that Israel cannot be a leader in green energy as it is in IT and biotechnology; while others have already exported their expertise in this field or are planning to do so.

The same as with IT, defense companies such as RAFAEL and Elbit Systems are investing in renewable energy startups with technologies produced by universities, for both military and civilian applications. In addition, Elbit also has its own Incubit Ventures incubator, which supports green energy as well. In this way we can say that transfer of technology takes place both ways, from academia to private industry, then to the defense and military industry, and back to the civilian sector.

On July 2017, a law passed in the Knesset (the Israeli Parliament), under which the Ministry of Energy will prepare a long term plan to build and install renewable energy systems. This move probably has the intention of getting closer to the country's renewable energy target, and possibly in response to the solar energy recommendations by Prof. Eugene Kandel's report, commissioned in 2014 by the Ministry of Economy.

However, differently from IT, green energy needs longer developing times and therefore higher investments from larger companies, especially regarding installation of renewable energy. Therefore innovation strategies must be linked to longer term strategies for energy supply.

5) Can the Israeli Innovation System be transferred to other countries?

The Israeli Innovation System has been shaped by its history since 1948 in a unique way, through its 'mental capital' and its strong national identity as a Jewish nation. We can also state that Israel became an IT and biotechnology innovative leader in the 1990s due to the technological developments by its elite military units, the commitment of its governments since the foundation of the State, and its military and business cultures that

embrace risk and entrepreneurship. More recently the country's Innovation System was also shaped by the Russian Jewish immigration and its large human capital, complemented by the strong role of its universities. All of these are unique to Israel, and therefore difficult to transfer or not transferable. In addition, Israel's economic development was supported by very large investments in applied R&D through its three top universities since the 1920s, having an advantage of 70 to 80 years of basic research development, and achieving an accumulation of knowledge over other developing countries who wish to catch up.

6) Establishing successful national innovation systems

As explained by Fortuna (2012), governments must implement policies that accord with a country's culture, institutions (including policy), infrastructure (scientific, educational and physical), and resources (human and physical capital). As my interviews show as well, the NIS literature does not address enough important issues outside the areas of technology, such as the human dynamics of innovations systems, which are also an important component of a country's economy.

10.3 KEY FINDINGS AND CONTRIBUTION TO KNOWLEDGE

Based on the points presented above the original contribution of my thesis falls into the following four categories:

1) The Israeli Innovation System has been successful in the last 20 years through its highly developed scientific research system and exceptional technology transfer to the market. However, in order to continue being successful, this is not sufficient, since it needs to develop an industry and large companies as well, and as its industrial piece is missing. My findings show that a national innovation system cannot focus mostly on front end investments and not invest enough on building and sustaining an industrial sector.

2) My findings also show that the Israeli government is proactive and responds quickly to changes, for example through the Israeli Innovation Authority (IIA), former OCS, established to support the growth of an industry sector in Israel. In this way I also found that a main characteristic of the Israeli Innovation System is that it is not a fixed system based on a set of institutions, policies and programs. Instead, this system is in a continuous process of experimentation with different institutional structures and arrangements. We can see this flexibility by the government terminating institutions and programs that do not deliver, such as the Inbal program that supported Public VC funds (footnote 38). This is an important finding since it indicates that the issue in implementing policies is not the efficiency of specific institutional arrangements, but rather the connection among specific national economic, social and cultural goals and the results achieved.

3) Although a large number of people from different countries travel to Israel to copy its model, my research confirms that the transferability of its Innovation System is limited or non-transferable to other countries. Moreover, my findings on green energy show the challenges involved in transferring the system to a new technological sector even within the same country.

4) Taking into account all the three points above which stress the importance of non-technological factors such as culture, national security, a cohesive national 'project,' and others, my studies suggest that the NIS literature tends to marginalize these issues, and it needs to increase the coverage of historical and human dimensions of the national innovation systems it examines.

10.4 FUTURE RESEARCH

1) As confirmed by two interviewees and as seen in the Israeli institutional literature, the Office of the Chief Scientist (OCS) has taken action by becoming a flexible and independent agency, arms-length from the government, in order to faster implement decisions needed for the Israeli Innovation System. The OCS has also changed its name

to the ‘Israel Innovation Authority’ (IIA) and is implementing new programs to help companies grow after their incubation stage; and helping large companies to become multinational. A proposed future research is to investigate the policies and programs implemented by the IIA, the type of companies it supports, the resulting changes to the Israeli economy, and what other countries can learn from this approach.

2) Israel was founded on a “National Ideology” based on developing a knowledge based economy in support of Science and Technology and of the country, that does not seems to exist anymore. If so, how and why did this happen? What was the process?

3) Compare the Israeli Innovation System with other countries in addition to Taiwan and Ireland, as done by Breznitz (2007b), and to South Korea, as done by Levi-Faur (1998).

4) Analyze the Israeli culture under Geert’s Hofstede’s theoretical cultural model. Identify what is unique about the Israeli culture that does and does not fit within this model.

5) The Ministry of Energy has been given the responsibility of preparing a long-term plan for the implementation and installation of renewable energy. Future research in this area, as well as on the advances in renewable energy implemented in Israel by the Eilat-Eilot municipalities, and the export of its off-the-grid technologies to Africa and developed countries, such as northern Canada, are also suggested as a follow up to this dissertation.

6) The business literature (Day and Schoemaker, 2011) suggests that less saturated developing markets are the best ones for green energy development. However, according to the Israeli literature and to most of my interviews, Israelis have installed their first solar fields in the U.S. and Spain, and look at the European market also as a first target, while entering developing markets as second targets. Nevertheless one interviewee mentioned that Israeli companies are already entering developing markets which have the most opportunities. Research into this area would also provide a clearer picture of how successful is the export of green energy technologies to developing and developed markets.

The significance of this dissertation is in that it brings together the work of several Israeli authors and adds new insights obtained from significant interviews, adding knowledge to the Israeli Innovation System literature, and to the Israeli System in general which is studied in Canada and other countries. This dissertation also adds to the System Innovation theories' body of knowledge by challenging some of its concepts and theories. Moreover, although the Israeli System is quite unique, there may be other countries with distinctive national innovation systems worth studying at the deeper level of their human dynamics, possibly discovering some fascinating facts and new perspectives in their Systems, as I discovered through this research.

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APPENDIX 1: HYPOTHESES

IF	THEN
1A. ISRAEL IS HOME OF ANCIENT PEOPLE: According to an author Israel is home of ancient people with a strong national identity, being this trait different from other developing countries that do not have a shared identity to build a nation (Levi-Faur, 1998, pp.67-69). Israel followed its economic development under a national ideology (ideas and principles) expressed by Prime Minister's David Ben Gurion in his concept of 'Mamlachtiut' or etatism. As Breznitz (2007) further explains, this *"National Ideology"* gave a very high rank to Science and Technology and allowed scientists to have an easy access to political leaders (p.44). It seems that this ideology is not followed anymore by university TTOs and VCs. In their study, Meseri and Maital (2001) found that for Transfer of Technology Offices (TTOs) and VCs, the question on the projects' potential contribution to Israel's national economy ranked low on importance, while their focus on market was high (Meseri and Maital, 2001, p.118).	
If Israel's strong national identity and ideology of 'Mamlachtiut' or etatism created its economic growth in the 1950s/1960s, but if this ideology is not followed anymore by Israeli institutions, and ranks low on importance,	Then this lack of ideology could have a negative impact on the national development of Israel's energy industry and not have a positive impact on the Israeli economy.
If Israel's strong national identity and ideology of 'Mamlachtiut' or etatism, did not create an economic growth in Israel in the 1970s/1980s, when Israel experienced an economic stagnation; and if this ideology is not followed anymore by Israeli institutions, and ranks low on importance,[64]	Then this lack of ideology will not have a negative impact on the national development of Israel's energy industry, or a negative impact on the Israeli economy.
If there is a lack of this National Ideology,	Then Science and Technology would not be ranked high, and scientists would not have an easy access to political leaders (Breznitz, 2007, p.44).
If this National Ideology is strong,	Then Science and Technology would be ranked high and scientists would still have an easy access to political leaders (Breznitz, 20017, p.44)
1B. CULTURE HYPOTHESIS: Some authors argue that Israel's economic growth and success is in part due to Israel's culture (Getz and Segal, 2008, pp.13, -36). Israeli culture has a high risk tolerance due to military experience as well as acceptance of entrepreneurial failure. However, according to one Israeli author, culture could not have played a role in Israel's economic development. He poses that although culture may be important for development, how can culture influence economic growth if the same culture changed the economic performance in Israel from excellent in the 1950s/1960s to poor in the 1970s/1980s? He argues that although culture may play a role in economic development, policies are more important and essential (Levi-Faur, 1998, pp. 83-84).	
If Israel has a high risk tolerance culture due in part to military experience, and also acceptance of entrepreneurial failure,	Then Israel's culture played a very important role in the country's economic growth and technological success.
If Israel's culture did not play an important role in the country's economic performance, since if the same culture changed the economic	Then Israel's policies, played a major role in the country's economic development in the 1990s/2000s

[64] In the 1970s and 1980s Israel's Prime Ministers were: Yitzhak Rabin, Menachem Begin, Shimon Peres, Yitzhak Shamir. *Prime Ministers of Israel from 1948 until the Present* (n.d.)

performance in Israel from excellent in the 1950s/1960s to poor in the 1970s/1980s,	
2. DEVELOPMENT OF GREEN ENERGY IN ISRAEL: Espinoza and Vredenburg (2010b, p.218) indicate that the development of energy renewables partially depends on how the countries react to energy crises. For example, the most important issue for developing a wind power industry for Costa Rica and Ecuador is to ensure the power supply in their countries with additional sources, while a secondary reason is the improvement of the environment (Espinoza and Vredenburg, 2010a, pp. 264-265). Differently, Alberta and Denmark consider environmental issues as important as economic factors, and both see climate change as a global threat that could weaken their business, which is also a global concern addressed by oil and gas multinationals (MNCs). Another study also found that a well established oil industry in Ecuador and Alberta is a significant barrier to the growth of wind energy in both jurisdictions (Espinoza and Vredenburg, 2010b pp.223-224). Similarly, Day and Schoemaker (2011, p.38) found that some countries and cultures are willing to move to a low-carbon economy, while others, as oil and gas producers, establish barriers against such initiatives.	
If Israel has continued to foster R&D in energy through government programs such as the Canada-Israel Industrial Research and Development Foundation (CIIRDF),[65] the BIRD Energy program, the Fuel Choices Initiative by the Prime Minister's office; and University energy programs such as the Grand Technion Energy Program (GTEP) among others,	Then it will consider environmental issues as important as economic factors, notwithstanding its discoveries of large fossil fuel fields.
If the Office of the Chief Scientist (OCS) has strongly promoted R&D in different green energy technologies; and if there have been and there are programs newly established specifically for R&D in green energy, such as incubators and venture capital (VC) firms focused on green and clean energy,	Then the OCS strategy has been to strongly promote R&D in energy, notwithstanding its discoveries of large fossil fuel fields.
3. COLLABORATION HYPOTHESIS: Day and Schoemacker (2011, p.38) indicate that the global market for green energy technologies, such as wind, solar energy and biofuels, is expected to reach $315 billion by 2018. However, the green technology market faces many uncertainties that are beyond the control of any entrepreneur and investor. The authors suggest 10 strategic lessons based on past experiences, to help companies succeed in their development of green energy technologies in order to survive long-term uncertainty and setbacks such as recessions, and to stay ahead of the competition (p.38). One of these strategic lessons is: collaborate and share for joint gain by establishing strategic alliances between companies, in order to share the risks and rewards of investments.	
If Israeli government policies foster innovation through R&D collaboration between academia and industry, such as the Magnet and Magneton programs; and international R&D collaboration, such as the BIRD and CIIRDF foundations,	Then Israel will indeed seek to collaborate internationally in R&D to develop green energy technologies
If Israeli companies tend to collaborate and share for joint gain by establishing strategic alliances with other companies,	Then they will be more successful by sharing the risks and rewards of investments.
4. TRANSFER OF TECHNOLOGY: Meseri and Maital (2001:115) argue that although Israel is a world leader in the productivity and intensity of its basic research in science and technology, it lags	

[65] With the Canada-Israel Energy S&T Fund - CIEST Fund, within the CIIRDF.

behind in its ability to transfer technology and commercialize it. An example was its trade deficit *"in recent years"* (p.115). Also, as per the 2000 IMD (World Competitiveness) report, Israel ranked 41st in *"company-university cooperation"* and 40th in development and application of technology (p.115). A significant amount of basic research was conducted by Israeli universities while only 10 percent of that research was funded by industry (p.115). However, according to more recent studies, "*During the past decade it (Israel's trade deficit) diminished considerably, down to zero, and since 2002… it (has become) growingly positive - namely, Israel is a creditor - with "the world" owing it more than Israel owes the world, with a net difference of $50 billion in 2010*" (Israel Ministry of Foreign Affairs, 2013b), while in 2013 Israel had a trade surplus (Central Bureau of Statistics, 2014).	
If Israel is a world leader in productivity and intensity of its basic research in science and technology and has a trade surplus,	Then it is also a leader in its ability to transfer technology, commercialize and export it.
If Israel is a leader in its ability to transfer technology, commercialize and export it,	Then it has strong "company-university cooperation;" a high percent of research is funded by industry; and it is a leader in application of technology. Then its government policies on developing industrial R&D have been successful.

APPENDIX 2: INTRODUCTION LETTER TO ISRAELI KEY PLAYERS

Dear ___,

My name is Alice Fischer and I am PhD Candidate with the University of Calgary. I am investigating the factors that have contributed to Israel's scientific and technological innovation. As part of this study I intend to conduct interviews in Israel with several key players in government, academia and industry. Due to your position as _____, your input would be very valuable in this research. I would be grateful if I could have an hour of your time for an interview.

I am planning to be in _____ between _____ and _____, and if you suggest a day and time, I will do my best to keep your schedule.

The interviews will be focused on innovation within the energy sector, in, alternative and renewable energy, an area that has been studied less and which is getting a new thrust in Israel. The questions will be open ended in order to get your view on the subject. For example:

- Factors underpinning the Israeli innovation and technology transfer system
- How the system works
- How is this system being applied to the innovation area in energy

I will be thankful if you include or suggest other professionals whose involvement would be beneficial to the study.

Thank you for your kind attention to my request. If you have any questions please feel free to contact me at ab.fischer@shaw.ca; or for any questions regarding my study you can also contact my Supervisor, Dr. Richard Hawkins at rhawkins@ucalgary.ca.

Sincerely,
Alice Fischer

APPENDIX 3: RESEARCH DESCRIPTION FOR ISRAELI KEY PLAYERS

Alice Fischer, PhD Candidate University of Calgary, Canada.

Israel Research Visit November 2014

Title: Israeli Innovation and Transfer of Technology, Innovation in Energy

Purpose of research:

Studies have found that although Research and Development (R&D), knowledge, government institutions' support, patents and commercialization of technologies, should result in economic development, there is no evidence that these effects are strong enough on their own to drive an economy. However, Israel, as a young country has achieved the economic status of a developed country mainly through its progress in high technology. The purpose of my research is to find out how the production, flow and application of knowledge is organized by Israeli public and private institutions, mainly through interactions between universities, industry and government institutions, and how it is applied in the energy sector.

Methodology:

The interviews will be focused on innovation within the energy sector, in alternative and renewable energy, and in environmental technology for fossil fuels extraction, an area that has been studied less and which is getting a new thrust in Israel. The questions will be open ended in order to get your view on the subject. For example:

- Factors underpinning the Israeli innovation and technology transfer system
- How the system works
- How is this system being applied to the innovation area in energy

Purpose of this trip:

During this visit to Israel, I am seeking to meet with key players in government, academia and industry involved in the energy sector, to get a greater understanding of how the innovation and transfer of technology system is applied in this sector.

Research Contribution:

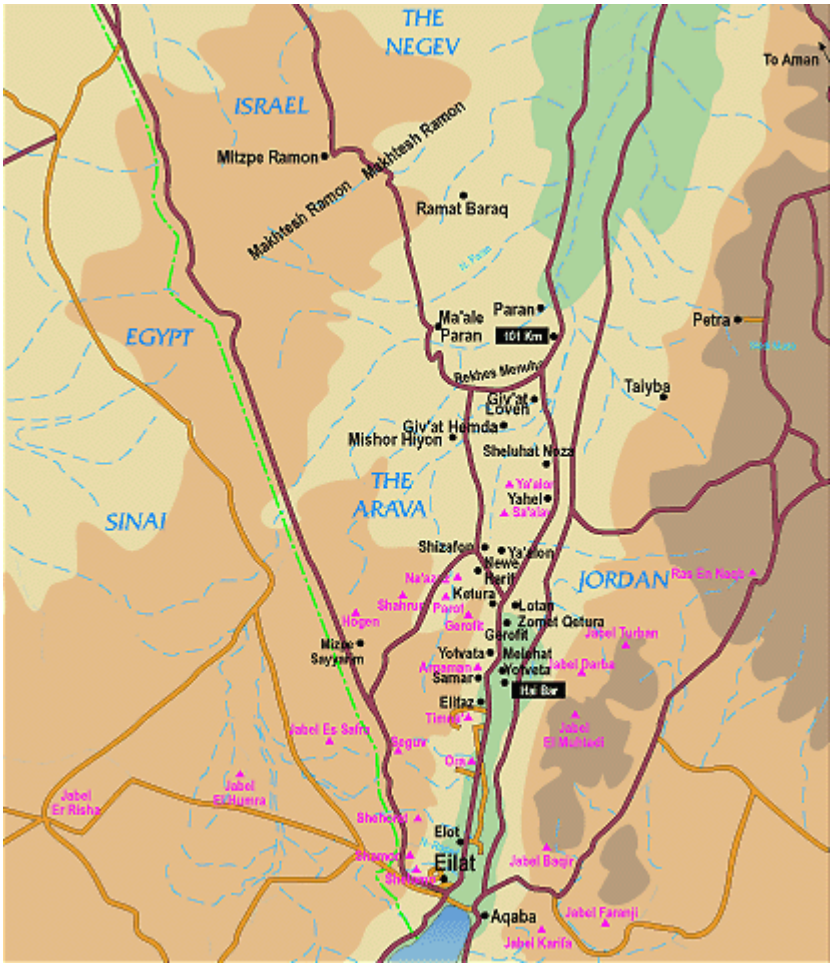
The expected outcomes of my research will clarify whether Israel's innovation and commercialization system indicates a new practice in technology transfer and whether it can be adopted by other countries; or whether this success is a sole product of Israel's industrial history. The Israeli innovation and technology transfer system is being monitored closely as a potential model by other countries, including Canada. However, there are no comprehensive studies specifically about the Israeli Innovation System, from which we could learn, and that other countries could consult.

APPENDIX 4: MAPS OF ISRAEL

Map of Israel

Weizmann Institute of Science. (n.d). *Map of Israel.* [online image].

Southern part of Israel (Eilat Region)



Weizmann Institute of Science. (n.d). *Southern part of Israel (Eilat region).* [online image].