

Innovation and the State – Development Strategies for High Technology Industries in a World of Fragmented Production: Israel, Ireland, and Taiwan

By

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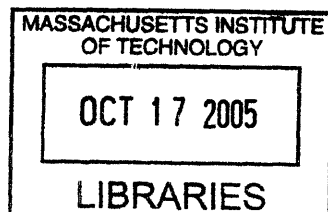
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ABSTRACT

One of the most unexpected changes of the 1990s is that firms in a number of emerging economies not previously known for their high-technology industries have leapfrogged to the forefront in new Information Technologies (IT). Surprisingly, from the perspective of comparative political economy theories, the IT industries of these countries use different business models and have carved out different positions in the global IT production networks. Of these emerging economies, the Taiwanese, Israeli, and Irish have successfully nurtured the growth of their IT industries. This dissertation sets out to establish that emerging economies have more than one option for developing their high technology industries. Moreover, it advances a theoretical framework for analyzing how different choices lead to long-term consequences and to the development of successful *and* radically different industrial systems. Hence, this dissertation strives to give politics – the art and profession of creating alternatives and the social struggles of choosing between, and acting on, them – the importance that it seems to have lost in the social sciences. The research focuses on the role of the state in shaping the structure of the IT industry in Israel, Ireland, and Taiwan. It argues that the developmental path of the IT industry is influenced by four critical decisions by the state. First, decisions about how to acquire the necessary R&D skills influence which organizations – public or private – play a leading role in innovation. Second, state decisions about financing significantly affect both the R&D resources available to the industry and the scope of R&D activity. Third, state efforts to develop local leading companies have long-term consequences for the industry's opportunity structure. Fourth, state decisions regarding foreign firms and investors within and outside national borders affect the resources and the information that the industry receives from its customers, as well as the diffusion and development of specific innovative capabilities. Of particular importance are state decisions that develop specific links between local and foreign companies, investors, and financial markets. Overall, the dissertation utilizes this framework to explain the divergent development of the IT industry in Taiwan, Israel, and Ireland.

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Abbreviations

ASIC – Application Specific Integrated Circuit
BES – Business Expansion Scheme (Ireland)
BIOS – Basic Input-Output System
BIRD – Bi-national Research and Development Foundation (Israel)
BOI – Bank of Israel
CBS – Central Bureau of Statistics (Israel)
CCL – Computer and Communication Lab (Taiwan)
CMOS - Complementary Metal Oxide Semiconductor
CORBA – Common Object Request Broker Architecture
CPU – Central Processing Unit
CRM – Customer Relationship Management
CSIA – Information Service Industry Association (Taiwan)
CSIST – Chungshan Institute of Science and Technology (Taiwan)
DOIT – Department of Industrial Technology (Taiwan)
DRAM – Dynamic Random Access Memory
DSP – Digital Signal Processing
EDIP – Electronic Industry Development Program (Taiwan)
EDP – Enterprise Development Program (Ireland)
EI – Enterprise Ireland
ERSO – Electronic Research and Service Organization (Taiwan)
FDI – Foreign Direct Investment
FRP – Fantasy Role Playing
FT – Financial Times
GDP – Gross Domestic Product
HEA – Higher Education Authority (Ireland)
IAEI – Israel Association of Electronic and Information Industries
IASH – Israeli Association of Software Houses
IC – Integrated Circuit
IDA – Industrial Development Agency (Ireland)
IDB – Industrial Development Bureau (Taiwan)
IDM – Integrated Device Manufacturer
IEP – Irish Punt
III – Institute for Information Industry (Taiwan)
IPO – Initial Public Offering
IPR – Intellectual Property Rights.
IRDA – Israeli R&D Associates

ISA – Irish Software Association (formerly known as ICSA)
ISP – International Services Program (Ireland)
IT – Information Technology
ITRI – Industrial Technology Research Institute (Taiwan)
ITV – Israeli Technology Ventures
IVA – Israel Venture Association
LAN – Local Area Network
LCD – Liquid Crystal Display
LDLP – Leading Product Development Program (Taiwan)
M&A – Merger and Acquisition
MAGNET – Generic Non-Competitive R&D (Hebrew Acronym of)
MBO – Management Buy Out
MCP – Multi-Client Project (Taiwan)
MIC – Market Intelligence Center (Taiwan)
MNC – Multi National Corporation
MoEA – Ministry of Economic Affairs (Taiwan)
MOTI – Ministry of Trade and Industry (Israel)
NESC – National Economic and Social Council (Ireland)
NIC – Newly Industrialized Countries
NID – National Informatics Directorate (Ireland)
NSC – National Science Council (Taiwan)
NSC – National Software Center (Ireland)
NSD – National Software Directorate (Ireland)
NT – New Taiwanese Dollars
NTBF – New Technology Based Firm
OBM – Own Brand Manufacturing
OCR – Optical Character Recognition
OCS – Office of the Chief Scientist (Israel)
ODM – Original Design Manufacturing
OECD – Organization for Economic Co-operation and Development
OEM – Original Equipment Manufacturing
OMG – Object Management Group
PBX – Private Branch Exchange
PRLTI – Program for Research in Third-Level Institutions (Ireland)
R&D – Research and Development
RAD – Rapid Application Development
RIB – Rapid Innovation-Based
RIT – Regional Institute of Technology (Ireland)
RTC – Regional Technical College (Ireland)

S&T – Science and Technology
SBIR – Small Business Innovation Research
SCS – Seed Capital Scheme (Ireland)
SFI – Science Foundation Ireland
SI – Systems of Innovation
SME – Small and Medium size Enterprises
SO – Stationary Office (Ireland)
SoC – System on Chip
STAG – Science and Technology Advisory Group (Taiwan)
TDP – Technology Development Program (Taiwan)
TVCA – Taiwan Venture Capital Association
UCD – University College Dublin
USD – United State Dollar
VC – Venture Capital
VLSI – Very Large Scale Integration
VoIP – Voice over Internet Protocol
WB – World Bank
WLAN – Wireless Local Area Network

Chapter One – Plurality, Choice, and the Politics of Industrial Innovation

*“Action, the only activity that goes on directly between men without the intermediary of things or matter, corresponds to the human condition of plurality, to the fact that men, not Man, live on earth and inhabit the World. While all aspects of the human condition are somehow related to politics, this plurality is specifically the condition – not only the *conditio sine qua non*, but the *conditio per quam* – of all political life”*

Hannah Arendt – *The Human Condition* (Arendt 1958 p. 7).

Explaining Rapid-Innovation-Based Development

One of the most unexpected developments of the 1990s is that firms in a number of emerging states not known for their high-technology industries in the past, moved to the forefront in new Information Technologies (IT). Even more surprising from the point of view of comparative political economy theories, the IT industries of these countries seem to embody different business models and to carve out different positions in the global production network of the US dominated IT industry. Of these emerging economies, the Taiwanese, Israeli, and Irish indigenous IT industries, riding what seems to be one of the greatest waves of industrial innovation ever, have become hotbeds of New Technology Based Firms (NTBF). Some of these firms have become global players over the last ten years.

That very different IT industries working in the same sectors and markets have grown in emerging economies challenges two central ideas in the comparative political economy literature. First, it suggests that there is a way for less developed countries to become successful players in rapid innovation-based (RIB) industries, something that was not considered plausible in the past. Second, it suggests that there are multiple choices for industrial development. The cases of Ireland, Israel, and Taiwan demonstrate that states and societies, even under conditions of intense globalization in one of the most globalized industries, can pursue different strategies of economic growth.

Contemporary political economy literature cannot satisfactorily explain many of the changes in industrial systems in the last few decades. This is especially true in the case of RIB industries in emerging economies. First, contemporary political economy has a dismal view of the prospects for RIB industrial leapfrogging by backward societies. While each of the standard theories has a particular approach, they all unite in pessimism about the possibility of using government policies to leapfrog in RIB industries, i.e., to transform a relatively backward society to a front-rank competitor in technological innovation in a time-span of one generation.¹ Second, none of the theories can accommodate a situation in which a few different emerging countries, each employing very different industrial policies, planned and implemented by very different bureaucracies, as well as having very different labor market regulations, financial institutions, and educational/training systems, achieve success at the same time in the same R&D-intensive sectors.

Against these bleak predictions, the stories of Israel, Ireland, and Taiwan present cases of successful RIB industrial growth in the time span of one generation in countries with very different political and institutional systems. Thus, the stories of IT industrial development in Taiwan, Ireland, and Israel, offer us multiple puzzles, the answers to which are intimately linked to important debates in comparative political economy. First, comparing the three stories provides us with insights into a highly contested issue of

¹ For the purpose of this dissertation, success in RIB industrial growth is defined as the development of an industry based around NTBFs, which contribute a significant amount of GDP growth, exports, and employment, making the industry a critical sector of the national economy. I use the common definition of NTBF from the literature: companies whose products are new technologies, are based on their own and others' R&D effort to commercialize applications of new technology, or, companies whose main revenue stream is based on R&D efforts to develop new technologies. I further elaborate on it by defining IT NTBF as a company whose main product/s are either a new technology or a new application of new technology that its main function is the gathering, transferring, possessing, or presenting of information, and where the company is conducting the R&D that leads to the product itself, either with or without cooperation with other organizations.

economic growth – the role of the state in the development of high-technology industries in less developed economies. Second, comparing the three very different paths of science and technology industrial policy regimes and development, bears upon the question of whether states and societies have choices in their economic development strategies. Finally, comparing the three different positions and relationships of the local IT industry with the global IT production networks offers us an understanding of how globalization, and especially the radical transformation of production, influences development opportunities of peripheral economies.

Politics are about crafting and picking alternatives. Politics matters, therefore, only if choices can be made and if making them has real consequences. In the last three decades, students of politics have done their best to convince us that choosing between alternatives, even if choices exist, no longer truly matters. Nowhere is this more evident than in comparative political economy, particularly in the study of industrial development. Both the neo-classical economists in their belief that the only choice is to let the market rule, and the developmental statist, arguing that only specific structures of states bring forth industrial success, have marginalized the importance of picking between true alternatives.

The aim of this dissertation is to show that choices still exist, that states and societies, through the political process of crafting and picking alternative modes of action, can follow diverse paths and still achieve industrial success. Furthermore, this dissertation aims to prove that the outcome of each path is a different socio-industrial system with different strengths, different weaknesses, and a different distribution of the fruits of success. I argue that choices have real consequences. This dissertation sets out to

confirm that emerging economies have different options in regard to their industrial development. Moreover, it advances a framework of thinking about how different choices lead to long-term consequences and the development of successful *and* radically different industrial systems. Hence, this dissertation strives to give politics – the art and profession of creating alternatives and the social struggles of choosing between, and acting on, them – the importance that they seem to have lost in social science.

The goals of this dissertation are twofold: first, to expand our understanding of the role of the state in the development of the rapid-innovation-based industries. The dissertation aims to clarify not only what options less developed states have or do not have to spur the creation of, and sustain, IT industrial growth, but also to analyze and map the limits of state actions and the dynamics of state-industry interactions. To do so, the analysis focuses on the ways in which the three states influenced the skills and capabilities acquired and developed by the private IT industry.

The second goal of the dissertation is to explain how the different approaches of the three states shaped the IT industries, and influenced the particular development path of, and the particular capabilities developed by, each industry. I seek to move beyond the question of whether or not the state has a role in industrial development. I propose a theory concerning the influence of particular policies on the development of RIB industries in emerging economies. Much of the literature in comparative political economy takes the existence of different industrial and capitalistic systems as given and explains their influence on the behavior of firms and economies under the same global conditions. This dissertation seeks to understand how different industrial systems are created in the first place. It argues that state actions give rise to different high technology

industries. These industries not only utilize different business models, position themselves differently in the global production network, and acquire different skills and capabilities, but also have very different strengths and weaknesses and distribute the fruits of their success very differently within their host societies. In short, this dissertation argues that choices are made, actions are taken, and these choices and actions have consequences.

A Brief Historical Description of the Three Cases

Ireland, Israel, and Taiwan were poor, peripheral, and technologically backward societies in 1950. They all had mixed histories of success in more traditional industries. At the end of the 1960s, state-led initiatives to develop indigenous high-tech industries appeared in all three societies. At that point, all three were very similar along most of the important economic dimensions, including size and population. All three had low skill intensity in their labor force (defined as the number and percentage of scientists and engineers in the population), a relatively low percentage of high school graduates, poor communication and physical infrastructures, and a high dependence upon agriculture.

All three states followed similar infrastructure policies. Each improved its education system, leading to high rates of skill formation between 1960 and the 1980s. All three improved their physical infrastructures, and, after failed attempts at direct bureaucratic control, created public telecommunication companies that vastly improved their line subscription penetration rates. Deregulation and privatization of the telecommunication market followed, leading to high rates of wireless and Internet

penetration. Finally, unlike Japan and South Korea, all three based their growth on small and medium size enterprises rather than on big corporations.²

Despite the similarities of their macro level and infrastructure policies, however, their micro, i.e., industry and firm level, policies were distinctly different. For most of the period since the late 1960s, Ireland has focused mainly on inward investment policies. Israel has focused on inducing industrial R&D activities through government grants, with project ideas originating solely from private industry. In Taiwan, the ruling party, the KMT, mistrusted big private industry and feared the rise of competing powers. Hence, it prevented the creation of overarching conglomerates, controlled the inflows and outflows of investment, and relied on public research agencies such as ITRI and III to lead R&D efforts and diffuse the results throughout private industry.

Moreover, the structure of the state in all three countries varies significantly. Ireland is a model of an English-style Weberian bureaucracy with its separation between engineering and management, i.e., between industrial domain knowledge and high-level bureaucrats and politicians. Taiwan is a model example of a technocratic Weberian bureaucracy. All high and mid-level bureaucrats, as well as their Ministers, have graduate education in engineering, and thus, are quite versed in their industrial domain knowledge. Israel has a much more chaotically structured bureaucracy. The key principle behind its establishment was to balance bureaucratic professionalism and the ability of politicians to implement their will. The result is similar to the American bureaucracy: elected politicians bring in many of the top executives, including all the director generals of state ministries, from outside the state structure. These differences significantly influence the

² On Japan's and South Korea's conglomerate-based industrial development, see, for example Amsden 1989; Anchordoguy 1989; Calder 1993; Evans 1995; Fields 1997; Johnson 1982; Okimoto 1987.

politics of industrial development in each country. Moreover, their existence severely weakens arguments that focus all their explanatory power on specific state structure.

It is important to underscore the critical role of the state in all three cases. For many years, the private market did not possess the necessary skills and capabilities to successfully create and manage R&D-based IT companies. Private actors, in particular investors, shied away from even attempting to do so. Moreover, even after more than a few successes, such as the spin-off of UMC from ITRI in Taiwan, or the several IPOs of Israeli firms on the New York stock exchanges by 1989, private financial institutions were unwilling to invest in the IT industry. Thus, the state was the only actor able and willing to start the process of skills and capabilities development in an attempt to spur the growth of the industry.

Today, the IT industries of all three countries are undoubtedly successful.³ But the three IT industries are markedly different in the way they work, the business models they use, and the way they relate to the global IT production network.

³ In Israel annual overall sales in the high-tech electronic industry, excluding software, more than quadrupled from 1986 to 2000 from \$2.003 billion to \$12.5 billion. Exports rose even faster from \$1.135 billion to \$11 billion. Software sales had the highest growth rates, rising from overall sales of \$380 million in 1989 to over \$3.7 billion in 2000. Software exports grew from \$5 million in 1984 to over \$2.6 billion in 1998. Ireland, a country that lost 1.1% of its total population in 1989 due to economic immigration, has seen its IT industry achieve remarkable growth. Software was the main sector where indigenous companies, and not only Irish subsidiaries of MNCs, achieved worldwide success. The number of indigenous software companies in Ireland rose from 291 in 1991 to 630 in 1998, while the total number of firms rose from 365 to 760. Revenues reached a total of \$6.6 billion, out of which exports were around \$6 billion. The total sales of Irish-owned companies were \$950 million, a marked improvement from 1991 when total revenues were \$2.7 billion, out of which only \$234 million came from the Irish-owned sector. In 1998, the IT exports of Taiwan, a country in which the first IC chip was fabricated in a demonstration fabrication facility of a public research institution only in 1977, reached more than \$40 billion, out of which over 80% were hardware, with a large and growing percentage of the world's chips being fabricated by Taiwanese companies. Sources: Israel, CBS 2001; IAEI 2002; IASH 2003; MOTI 1998. As the SEC filing of the leading Israeli software firms were higher than the reported sale figures of the Israeli Association of Software Houses, there is a reason to believe that the figures above are underestimated; Ireland, IDA 2000; NID 2003; Taiwan, ITRI 2003; MoEA various years.

Israeli firms have succeeded in both the software and the hardware subsectors. The industry's role in the global IT production networks is one of a supplier of high-end new technologies (or of new products based on new technologies). Thus, Israel's success is almost solely based on intensive R&D. In Taiwan, the software industry development has stagnated, and the IT hardware industry is embedded within the global IT production network in a very different way than Israel's. Taiwan's industry bases its success on innovation in product design and manufacturing, and focuses on second-generation innovation R&D. In Ireland, even after more than forty years of industrial policies that brought MNCs to open manufacturing facilities in Ireland, the indigenous IT hardware sector growth has not been significant, and it is the local software industry that rose to prominence.

Politics play a very important role in these stories. In a similar way to Japan in the late 19th century and Germany before it, these three young societies faced a harsh reality, in which the result of a failure to build successful national industries would have meant destruction of their societies as independent social units. Israel, Ireland, and Taiwan were all societies that had only recently gained their right to independent existence after long, bitter, and bloody struggles. The leaders who directed the three societies to their current success – politicians, civil servants, and businessmen and entrepreneurs – were all of a generation keenly aware of the price of failure.

Thus, the ways in which Ireland, Israel, and Taiwan have been building their national IT industries, and shaping the relations of these with the global markets, can only be understood as part of national efforts. These have been endeavors in which Ireland, Israel, and Taiwan strived not only to stay independent, but also to continuously win

legitimacy as a coherent national unit, both internally and externally. Economic and industrial growth has been an important part of the national and international process with which these societies have been defining and redefining themselves. Analyzing the roles of the state in the growth of the IT industry, therefore, gives us another mirror in which to see how national socio-political identity is shaped both inwardly and outwardly in a globalizing world – a continuation of the constant socio-political struggle to define what it is to be Irish, Israeli, and Taiwanese.

The bulk of the dissertation aims to show that politics – creating, picking between, and acting on, different alternatives – have consequences. Accordingly, it analyzes how different policies are structured and shape different national industrial systems in turn. However, throughout this dissertation I will also analyze how specific critical decisions were shaped, in part, as an element in this nation-building political process. I will briefly explore how Ireland’s economic policy was shaped within the context of its long dependency on Britain and its struggle to shape itself anew; how science and technology policies were formed by both the Israeli-Arab conflict and the ongoing quest for a national Jewish identity; and how the Taiwanese IT industry has been shaped by its formal international political isolation and the need to craft and present a new and better model of “a China.”

The dissertation utilizes the comparative case-study method in an inductive-iterative theory building effort (Eisenhardt 1989; King et al. 1994; Lin 1987; Ragin 1987; Ragin 1994; Van Evera 1997; Yin 1994). Hence, the theoretical and research traditions that this dissertation arises from, firmly believe that only intimate connection with

empirical reality allows the researcher to develop a relevant and valid theory (Glaser and Strauss 1967).

The data analyzed in this dissertation comes from a database of 482 interviews conducted between December 1999 and December 2003, as well as from official and industrial statistical sources.⁴ The interviews were conducted with founders and executives of IT companies, top civil servants in all the developmental and science and technology industrial agencies, academics, and venture capitalists. All developmental agencies were visited at least once and their top officials interviewed. In addition, interviews with the specific labs and departments within each agency were conducted. For both the hardware and software sectors, a list of companies was compiled from public and official records. All the major Irish, Israeli, and Taiwanese companies in the two sectors were interviewed, together with a large sample of smaller companies chosen from companies that were not doing only bespoke development or consultancy.⁵ Lastly, a snowball technique was used to tease out companies that were not included in the original lists but were deemed innovative by their peers. Thus, our sample was intentionally biased toward the more successful and R&D-based companies, giving us, if anything, an overly optimistic view. In all company visits we tried to interview the top management, preferably the CEO/President and/or the firm's founders.⁶

⁴ Of the 482 interviews (not counting repeats), 137 were conducted in Ireland or with Irish companies and officials in the US, 110 were conducted in Israel or with Israeli companies and official in the US, and 235 were conducted in Taiwan or with Taiwanese companies and officials in the US. Unless otherwise stated data on company profiles and information was gathered through interviews, SEC filings, Hoover on-line database, and companies' websites.

⁵ Because many interviewees from private companies have not only asked to stay anonymous but asked that no mention be made that their firm was interviewed, unless I needed to refer directly to an interview, a decision was made that when possible not to specify which of the companies described, were interviewed. This was done in order to better mask the identity of the interviewees who wished to stay anonymous.

⁶ While the interviews were open-ended, an interview theme consisting of forty questions organized around eight sub-themes, was adhered to, with all questions touched upon during the 1-2 hour long interview. The

The State of the Literature

No single strand of political economy literature offers a comprehensive answer to the puzzles that motivate this dissertation. The first puzzle is to understand the role of the state in the development of high-technology industries in less developed economies, under the conditions of intensified globalization and fragmented production. The second puzzle is to understand how such different development paths of the high technology industry appeared, and whether they suggest that multiple developmental choices are available to emerging economies.

It is therefore necessary to develop a theoretical approach using the arguments of several theories. For each question our puzzles present we will need to borrow insights from a different body of literature. The developmental state and late development theories give us an understanding of the role of the state in economic growth in emerging economies. Globalization theories, specifically global production network and industrial fragmentation, offer us a way to understand development in the radical new conditions caused by the rise of global production networks. Finally, systems of innovation theories, which seek to explain how different institutional systems affect the innovative capacity of industrial systems, offer some explanations of how different decisions about resources, industrial R&D, and industrial relations affect the dynamic creation of firms' capabilities. Systems of innovation theories also present a theory of how the co-evolution of state-industry interactions influences different development paths. The following section explores these theories and the answers they provide to the two puzzles of R&D-based

interviews' transcripts were then uploaded onto a server running custom-made software that allows access to the extended database through a web portal with enhanced research engine capabilities.

industrial development of emerging economies. I then use elements of these theories in my approach, which is presented in the concluding part of this chapter.

Late Development and Developmental State Theories

One prominent school of thought that aims to explain the role of the state in emerging countries' economic growth is late development. This paradigm originates in the work of Alexander Gerschenkron on the industrialization of the "late developing" European countries, e.g., France, Germany, and Italy (Gerschenkron 1962). In *Economic Backwardness in Historical Perspective*, Gerschenkron presents an institution-based view of how a backward state's leadership can use the advantages of relative backwardness to attain rapid economic growth. He argues that the more economically backward a nation, the more state intervention is needed if it is to grow. An economic historian of Europe, Gerschenkron acknowledges that the task of economic growth should be positioned within the process of modern nation-state building. Late developing states needed a more rapid industrialization than the pioneering nations, as economic backwardness equals political and military weakness.

One of Gerschenkron's main arguments is that states have different paths of industrial development, built around different institutions, depending on the *timing* of industrialization. Gerschenkron points to the appearance of a new model of industrial banks in France and Germany and the transfer of this model to Italy and Russia as they reached their rapid industrializing phase.

Advancing a linear theory of economic development that sees it as a process with specific stages, Gerschenkron contends that among the advantages of backward countries is the fact that product markets are already developed and defined by the pioneering

countries, which have already invested in the R&D to develop the manufacturing technologies.⁷ A backward country, unlike a pioneering country, has the double advantages of knowing the market, and accordingly being able to predict needs fairly accurately, as well as of having a clean slate in regards to manufacturing infrastructure so that its industry can invest in the latest technologies. This allows backward countries to reach a scale and scope that the pioneering countries cannot match, as they have already invested in an array of smaller and older manufacturing facilities.

To use these advantages, backward economies need two institutional capabilities: planning capability (i.e., a professional and capable bureaucracy) and access to large amounts of patient investment capital, i.e., financiers willing to invest large sums for long periods of time. If it manages to put these two together, a relatively backward economy can invest in large-scale factories with the latest manufacturing technology. It can achieve economies of scale and outdo the leader in manufacturing capacity and global market share. Gerschenkron stipulates the development of specific and new institutional systems, different from the institutional system of early developing countries.

The idea that backward economies have a specific path of development that depends on the *timing* of their industrialization, is still very prominent in the literature.

For example, Alice Amsden argues that

“If industrialization first occurred in England on the basis of invention, and if it occurred in Germany and the United States on the basis of innovation, then it occurs now among ‘backward’ countries on the basis of learning. The paradigm of late industrialization through learning generalizes to a diverse

⁷ Together with Rostow, Gerschenkron gave a paradigmatic all-powerful stature in economic development studies to the notion that economic development should be seen almost as an organic process that must pass through certain specific stages before achieving full blossom, and with it the ability to innovate on the scientific edge (Rostow 1960). A more recent proponent of the linear model in regards to innovation and the IT industry in Asia was Linsu Kim with his influential model of innovational catch-up progression (Kim 1997). For an argument that changes in the 1990s made this linear model of sequential innovational progression less compelling in Asia, see Ernst 2004b.

assortment of countries... but in all cases industrialization has come about as a process of learning rather than of generation of inventions or innovations. *Learning moreover, has been based on a similar set of institutions*" (Amsden 1989. P. 4. Italics added.)

Even the most recent proponents of the developmental state theories bow to the notion that common timing necessarily means a common model of development.⁸

Gerschenkron's model provides the basis for a more recent version of the late development theories, the developmental state theory. Most writers in this tradition focus on the rapid growth of Japan after WWII and on the rise of the Asian Newly Industrialized Countries (NIC), also known as the Tigers or the Dragons. The latter group of states has been described as late-late-developers. One of the pioneers of this approach was Chalmers Johnson (Johnson 1982). Johnson situated the industrial and economic growth of Japan as a part its national-political struggle and development process.⁹ In *MITI and the Japanese Miracle*, Johnson uses Gerschenkronian logic to argue that what enabled Japan to attain such rapid growth after its devastation in the Second World War was a unique developmental agency called the Ministry of International Trade and Industry (MITI). MITI, argues Johnson, acted as a pilot agency. It not only strategically planned the development of Japan, relying on the fact that both the technologies and the major markets for its final products were already well developed, but also used control over foreign exchange to encourage the entrance and growth of a few large conglomerates to compete in each of the strategic industries chosen.

Hence, Johnson argues, the fact that the Japanese state had internal cohesiveness, a capable bureaucracy, and *a specific structure* with a pilot developmental agency,

⁸ See, for example, O'Riain 2004. Pp. 6-8, or Amsden proposing the same theoretical argument in her recent works (Amsden 2001. P 2.)

⁹ Woo-Cumings elaborates to great lengths on the intimate connection between the developmental state and its growth as part of the socio-political efforts of nationalism and state building (Woo-Cumings 1999).

allowed Japan to become a plan-rational-economy, enabling it to generate an export-oriented catch-up industrialization that has been the basis for its “economic miracle” after World War II.¹⁰ Some writers have applied Johnson’s arguments to South Korea. Others claim that Taiwan also used a similar strategy even if in a less state-controlled way (Amsden 1989; Amsden 2001; Amsden and Chu 2003; Cheng 1990; Cheng 1993; Fields 1997; Kohli 1994; Park 2000; Wade 1990; Woo-Cumings 1991).

In sum, the developmental state theories have built on Gerschenkron’s theory of relative backwardness to present a model of development that emphasizes the role of the state in a national effort of creating an export-based industrial system and facilitating industries that excel in technology transfer-based catching-up. Thus, they advance an argument about the need for *specific state structure* that enables emerging economies to utilize *a particular strategy* of development. This is a strategy of state-led development based on long-term industrial planning, and the nurturing of a few big industrial conglomerates operating across a broad array of industries with some managed competition. This creates a system that tends toward large investment in the latest manufacturing technologies to reach scope and scale. Its underlying assumption is that industrial development is achieved by the growth of a few big vertically integrated firms that manufacture complete products and are not only competing among themselves, but are also able to directly compete with foreign companies in the world markets.¹¹

The industrial systems that are built as a result of these policies are systems that foster industrial research that focuses on: (1) improvement in process and manufacturing

¹⁰ For a recent article that also argues that the development agency needs to be a “pilot” agency, contending that in order for developmental policy to succeed there is a need for a “nodal” development agency with power over other agencies, see Chibber 2002.

¹¹ Parts of this version of this economic growth theory have been sanctified by the World Bank (WB 1993).

technologies; and (2) incremental changes to products and technologies originally innovated and designed elsewhere. Moreover, this model of development is based on the assumption that advanced economies are willing to grant the emerging economies access to their market and to their technologies, even when their trade balances with the same emerging economies are deteriorating. In addition, a key element in all these theories is a particular model of professional elite bureaucracy, as was idealized by Weber (Weber 1952; Weber 1958; Weber 1999).¹²

None of the assumptions of this model hold in the case of R&D intensive and RIB industries. First, looking at the industrial landscape, the market is not already well developed. Therefore, strategic planning by the state, based on the fact that both the products and their markets are defined, is not as useful. Second, the rate of technological innovation is so fast that industrial systems based on incremental innovations on technologies and products developed elsewhere find it difficult to compete and develop comparable products quickly enough. Third, products are no longer being manufactured by vertically integrated firms. Many of the leading MNCs in all industries, American as well as European, are shedding most of their manufacturing capacities and moving to manage a global production network where products are manufactured by stages in geographically distant locations. Finally, when the industry itself becomes the creation and rapid application of new technologies, a strategy that is based on catching-up and

¹² Among Japanese specialists a disagreement with Johnson's assessment of the state's extreme power and importance evolved. For examples of studies that strongly disagree with Johnson, see Calder 1993; Freeman 1987; Samuels 1994; Samuels 1988; for examples of studies that only slightly disagree, or even agree with Johnson, see Anchordoguy 1989; Chinworth 1992. Nonetheless, all these studies agree with the basic Gerschenkronian model of industrial growth and all agree that the state was highly important in the development of the industry in Japan.

massive long-term investment in large-scale manufacturing facilities does not grant such a big advantage. Chalmers Johnson noted this in *MITI and the Japanese Miracle*:

“When there is confusion or conflict over the overarching goal in a plan-rational economy <developmental state>, it will appear quite adrift, incapable of coming to grips with basic problems and unable to place responsibility for failures... Generally speaking the great strength of the plan-rational system lies in its effectiveness in dealing with routine problems” (Ibid. pp. 22).

The relative economic stagnation of many of the Asian NICs and Japan toward the end of the 1990s, their difficulties to succeed in more innovative industries, and even more importantly the realization that under the new international conditions and the rise of China it would be difficult for other nations to emulate their growth strategies, brought a new version of the development state theories to the fore. Proponents of the neo-developmental state theories, building on earlier research by critics of the strong developmental state theory like Richard Samuels, or on the revised theories offered by some of the developmental statist themselves like Peter Evans, proposed a restructured theory of state-industry interaction in industrial development (Amsden and Chu 2003; Ansell 2000; Calder 1993; Chibber 2002; Chibber 2003; Evans 1995; O’Riain 2004; Samuels 1994; Samuels 1988). The adjectives describing this newly found category of developmental state proliferated. However, be it “the flexible developmental state,” “the neo-developmental state,” “the developmental networked state,” or “the embedded autonomy industrial bureaucracy,” the same broad model is advanced.

This model suggests that for a state to initiate successful industrial development, especially in a technologically intensive industry, it must cultivate interaction and a dynamic division of labor with the local industry. The state needs to: (a) have and retain ability to make and implement decisions in the national interest; (b) be informed about the needs, abilities, and difficulties of the industry so it can tailor its policies accordingly

and refrain from policy initiatives that limit the ability of the industry to develop capabilities on which it can base long-term growth; and (c) change its policies in tandem with the changing needs of the industry. Rather than long-term planning, the state needs a flexible structure that enables it to quickly change and implement different policies as quickly as possible when industrial conditions change.¹³ In addition, the neo-development argument implicitly calls for the state to manage a process in which its let the industry gain more and more power to decide its own future as it finds its feet and grows. Hence, the state needs to be able to change its role from that of initiator and leader to that of a supporting actor.¹⁴

However, neo-developmental arguments are all structural, contending that if a state manages to have the *specific necessary state structure* economic development will follow. The main difference between the various neo-developmental statist lies in the specification of the necessary structure, not in the theoretical argument or causal mechanisms.

The neo-developmental statist argue that in order to succeed in the developmental efforts in high technology industries, the bureaucracy needs, first, to have

¹³ There are some differences among the neo-developmental state theorists, in particular between those who argue that the state should continue to advance national champions, and those who argue for a strategy based around SMEs. It is unclear whether these differences arise because of the different context of location, timing, and industries that the different writers researched. However, in the critical part of theorizing about the optimal role and behavior of the state in its attempt to spur the growth of high-technology industries and in their treatment of the state for all practical purposes as a unitary actor, the authors are similar enough to be treated as advancing one model.

¹⁴ The reason why I argue that this point is implicit and not explicit in the neo-developmental state theories is that while some writers, for example Peter Evans, present a typology of the different roles of the state, none of the neo-development statist pay enough attention to the political process of the state initiating the creation of the industry and then managing its own retreat from a commanding and planning position to a more supporting and less controlling role. Nonetheless, these exact political processes determine both whether sustained success is achieved, and how different models of industrial systems are shaped.

multiple ties with, and embeddedness within, industry and finance.¹⁵ Indeed, recent writers in this line argue that the main attribute of a successful developmental-state in the 1990s was its network structure. They argue that the ability of the state to successfully motivate industrial development stems from a structure where different agencies are embedded into different social-industrial-capital networks (Ansell 2000; O'Riain 2004). Second, the bureaucracy needs skills that enable it to understand the complex and changing needs of a highly technological industry. These two requirements means that we can no longer view the developmental bureaucracy as an ideal-type Weberian bureaucracy with long stable career patterns and skills and capabilities that are taught solely within the organization. In addition, if the arguments are that: (a) the developmental agencies need to be able act independently from other state agencies; and (b) that the developmental agencies need to be flexible and dynamic, constantly changing their policies in step with the needs of the *specific and different industries* each agency aims to nurture, we must also change our view of the state.

No longer can we view the state as a unitary actor. The neo-developmental theories lead us to focus on specific parts within the organization of the state and analyze each one in line with the specific policy domains and industrial sectors we study. If we are to follow the neo-development arguments to their ultimate conclusion, the state itself is to be viewed as multiple groups of development bureaucracies each with unique capabilities, structures, powers, and embeddedness within society. Indeed, even a cursory

¹⁵ As such the neo-developmental state theorists are different from the earlier critics of the strong developmental state argument, such as Samuels' model of the politics of reciprocal consent. These earlier critics' main aim was to re-inquire into the exact roles of the state and the nature of state-business relations in the development of industries that are not based on rapid innovation, at a period before the advent of globalized fragmented production, not to propose a new model of the developmental state suitable for RIB industries (Samuels 1988).

look at Ireland, Israel, and Taiwan reveals three very different bureaucratic structure and cultures, therefore, very different politics of industrial development.¹⁶

Nonetheless, the new developmental state theorists, in much the same way as the old development statist, still portray the state as a unitary and under-defined variable: the state is portrayed either as a success, and therefore a flexible/networked/embedded developmental state, or as a failure, and hence not a neo-developmental state. An example is Sean O’Riain’s recent study of the Irish software industry, where he defines a flexible development state:

“The flexible developmental state (FDS) is defined by its ability to nurture post-Fordist networks of production and innovation, to attract international investment, and to link these local and global technology and business networks together in ways that promote development.” (O’Riain 2000, my italics)

The tendency toward a success or failure definition of states is the result of two common traits of recent studies. The first is the use of either a macro level of analysis of industrial development, or the use of partial sectoral analysis looking at one specific industry or region and generalizing to the national level. The second trait is the tendency to focus on either successes or failures without an attempt to analyze these at the micro level. This tendency can be attributed to the under-defined nature of the neo-developmental state concept and the need to classify the cases studied using the

¹⁶ Just using the simple Evans-Ruach measurement of “Weberianism” in the structure of the bureaucracy in regards to meritocratic recruitment and career patterns reveals some surprises. While Taiwan and Ireland score very high (12 and 12.5 respectively on a 14 point scale), Israel’s score is relatively low 7 (Evans and Rauch 1999; O’Riain 2004. Pp. 145-146.) Israel’s score equals that of Morocco and Turkey, and is below that of Mexico, Brazil, Sri-Lanka, and Egypt (Ireland’s score was evaluated by a different study using the Evans-Ruach measurement, an evaluation which is strengthened by our own analysis, see Chapter Four of this dissertation). This result suggests that the strong coherent Weberian bureaucracy hypothesis does not hold a lot of generalizable explanatory power over the three cases. This is before we even noted the fact that the three bureaucracies are very different in their tradition and social role, as well as the social origin, educational background, and the influence on the political decision making process that their members possess.

dependent variable. This is true even in studies that urge us to look at the different bureaucratic constellations of agencies and power.

Thus, for example, Vivek Chibber, comparing the development efforts of India and South Korea, argues that the Korean state was successful and that the Indian state was a failure. He does so even when arguing that the Korean development efforts were successful because the Korean state had a “nodal” development agency with power not only over the industry but also over other agencies. Thus, even with an argument locating the reason for success at the level of industrial agencies and constellation of power within the state, Chibber still treats the state as a unitary actor and industrial success as a binary success or failure variable (Chibber 2002).

This is surprising because the neo-developmental statist arguments strongly suggest that the same state, having a structure where different agencies are embedded into different social-industrial-capital networks during their attempts to nurture different industries, can both succeed and fail in different sectors. It is quite possible that it is no longer the “state” that is neo-developmental or not, but different parts of it. If indeed there are many ways to organize the ties between the state and the industry, many ways in which to organize R&D efforts, and no way in which to fully and strategically plan the industrialization process, then industrial systems that grow out of these diverse efforts will be different. The neo-developmental statist, however, still propose one “best” model of development and focus their explanations around specific state structures. Therefore, their argument marginalizes the importance of politics. They do so even when their own arguments, suggesting the possibility of many different ways of organizing and managing

the industrial development effort, undermine the one best practice argument in the case of R&D intensive industrialization.¹⁷

Another way in which the neo-developmental statist diminish the role of politics in their theories is by not accounting for the dynamic process of co-evolution within which the state builds its “networked structure” and embeddedness. Even if the argument is that there is only “one” best way to be embedded, then it is important to explain how this embeddedness is taking place. It becomes crucial to explain this once the assumption is that there is more than one way to be “networked” and that the different ways in which the state get embedded with industry have long-term consequences. Ignoring the politics of state-industry co-evolution is a significant oversight in the case of emerging economies. Since private industry lacks the skills, the capital, and sometimes the will to enter new high-technology industries, many times the first and foremost role of the state is to directly intervene and create the industry. Hence, it is imperative for sustained industrial growth that the state manages the dynamic political process of moving from a position of hierarchical power into a position where it acts more as the supporting actor. These processes are critical in molding the final shape of each particular industrial system, and as such they need to be accounted for.

Since the old and neo-developmental state theories are not focused on explaining the various outcomes of diverse industrial policy regimes, they do not supply tools to understand and predict these differences and to gauge their influence and importance. Instead, their main efforts are devoted to showing the importance of the state in industrial

¹⁷ For example, Sean O’Riain, a neo-developmental statist who specifically looks at the growth of SMEs in the software industry of Ireland, still argues for one specific model of development and state behavior that he terms either as Flexible Developmental State or as Developmental Networked State, which is different than the old developmental state model that he terms Bureaucratic Developmental State (O’Riain 2000; O’Riain 2004).

development and to distinguishing their model of state-industry interactions from that of the old development state theories. Indeed, “The State” might have been brought back “in,” but only at the price of throwing politics “out” (Evans et al. 1985).

Finally, the neo-developmental state argument proceeds without attention to the radical ways in which industrial production has changed since WWII, although these writers claim to explain growth in post-Fordist industries. Recall that the old developmental school was built around the coherent Gerschenkronian institutional theory of industrial development in relatively backward societies, and was built on an understanding of industrial technology and production management. Thus, the old developmental-state school not only explained but also predicted a whole set of complementary institutions seen in many successful NICs, such as high saving rates and the strategy of industrial conglomerates-based growth. In contrast, the neo-developmental statisticians do not propose or integrate a theory of economic and industrial development. This explains why writers in the developmental state tradition can not account for a particular set of institutions arising in a specific society or industry, nor for how certain institutions influence economic growth trajectories and behavior in global markets.¹⁸

This is a major lapse in the neo-developmental state arguments as it also denies them one of the mainstays of the developmental state theories - the intricate explanation of the specific ways in which developmental states’ control over finance allowed them to influence industrial development (Zysman 1983). Many developmental state writers have gone as far as to call control over finance the “nerves” of the developmental state; others have argued that answers to questions about financial resources and policies provide the

¹⁸ For example, high saving ratios, industrial banks, conglomerates-based industrial development, and employment regimes.

best indicators for states' ability to realize industrial goals (Evans et al. 1985; Woo-Cumings 1991; Woo-Cumings 1999). It is a glaring omission that the neo-developmental school does not have a coherent theory of how states' different financial initiatives shape the growth of different high technology industries.

As a tradition of research that grows from an institutional theory of national industrial and economic growth, the neo-developmental-state theorists lack a systematic understanding of how recent and radical changes in industrial production change industrial growth. Without such a theory, it is not possible to explain how policies interact with the markets and with private industry to produce specific institutional systems that foster the growth of technological industries with specific capabilities.

Globalization as Fragmentation – Global Production Network Theory

The intensified movement of capital, trade, services, and, to some degree, people across national borders, starting in the 1970s, gave rise to a multitude of studies. Of these, a specific line of research that tries to understand the international reconfiguration of industrial activities is of particular interest. Pioneered by economic geographers, these studies highlight two interlinked novel features of the latest globalization: the growth of worldwide production networks, and the growing fragmentation or 'deverticalization' of the production process. Interestingly, this process is accompanied by a new pattern of geographical industrial clustering, that of similar activities of the production process (Arndt and Kierzkowski 2001a; Feenstra 1998; Gereffi 1994; Gereffi 1996; Sturgeon 2000; Sturgeon 2002).

Today we see rising spatial specialization in particular stages of the product manufacturing chain and a rising international inter-firm (not just intra-firm) trade in

components (not only in final products). Within the electronics industry, for example, there has been a major transformation in the way final products are manufactured and sold. In the US, new leading companies such as Dell, Sun, Cisco, or Microsoft's Xbox division do not even have their own manufacturing facilities but concentrate on R&D, high-level product design, sales, marketing, and, at most, final assembly. Old companies such as HP (and Compaq before their merger), 3Com, and IBM have been shedding a large percentage of manufacturing capabilities and opting for manufacturing outsourcing. Even components such as hard-drives are now manufactured in discrete stages in different locations globally (Gourevitch 2000; Kenney and Florida 2004; McKendrick et al. 2000; Sturgeon 2000; Sturgeon 2003). In addition, a whole new class of high-technology companies – the fabless IC design houses – rose to prominence without ever having a manufacturing facility for their own chips.

Many writers use the term product chain to describe this growing 'de-verticalization'. However, product chain may imply linear manufacturing processes of specific products from basic inputs to final assembly. The reality, however, is of manufacturing processes built from multiple relationships between suppliers, each with different power structures between actors involved in the production of numerous products. These products may be the final products and/or components for other products. For these reasons I prefer to use the term production networks which implies many suppliers with different relationships producing multiple products. Especially in the case of the IT industry, the term global production networks describes reality much better than product(s) chain with its linear implications.¹⁹

¹⁹ For papers outlining the different terminology used in the literature, see Henderson et al. 2002; Sturgeon 2001.

There are many causes of the growing fragmentation of production: lower transportation costs, lower telecommunication and information costs that in turn decrease the cost of off-site coordination and control, technological advances that enable the codification of component manufacturing and allow off-site manufacturing, and the de- and re-regulation of trade. This fragmentation process has also been the cause, and in turn is further expanded by, the de-linking of the innovation, design, and marketing and sales processes from the production process. The de-linking of production stages is now evident in almost every industry in the world, from textile to auto manufacturing, and from tool making to electronics (Fuller et al. 2003; Gereffi 1999; Gereffi and Korzeniewicz 1994; Herrigel and Wittke 2004; Sturgeon 2000; Sturgeon 2003; Sturgeon and Lester 2004; Yeats 2001).

The growth of the global production network raises questions about its effects on developmental strategies of nations and regions (Arndt and Kierzkowski 2001b; Bathlet et al. 2002; Gereffi 1999; Gereffi et al. 2004; Henderson et al. 2002; Ruane and Gorg 2001; Sturgeon and Lester 2004). It is becoming more and more apparent that what is moving from country to country are specific phases of production, rather than the production of complete products, but of. Thus, product-cycle theories, which predict that as products and industries become old and commoditized they will move from the more advanced economies to the less developed, are becoming less relevant (Akamatsu 1962; Cumings 1984; Vernon 1966).

This fragmentation not only occurs in production, but also in R&D (Dunning 1994; Gassmann and von Zedtwitz 1999; Gerybadze and Reger 1999; Pearce 1999; Reddy 2000). A study by the MIT Industrial Performance Center analyzing the results of

two surveys conducted in 1991 and 1999 on all the companies in Western Europe, Japan, and the US, with R&D expenditures topping \$100 Million in 1991 current dollars (totaling 244), found a remarkable growth in the tendency of big companies to rely on external sources of R&D. While in 1991 less than 10% of American firms, 20% of European, and 40% of Japanese reported a high reliance on external sources for R&D, by 1999 the figure was above 80% for *all surveyed firms*. Moreover, the geographical range and distance of firms' sources of R&D had also grown tremendously. If the average of the percentage of total R&D activity outside the home region was 26.8% for European companies, 24.3% for American, and 4.6% for Japanese, in 1999 European and American companies reported estimates of over 33% of total R&D done outside the home region and Japanese companies reported over 10% (Roberts 1999).

There has been no study that systematically examines how product fragmentation shapes the development of emerging industrial countries. Such an account would need to explain why some activities occur in specific locations, as well as to clarify whether particular development strategies resonate better with specific stages in the global product chain. There are many calls for research on the effects of global production networks on economic development. Nevertheless, what the literature offers are only suggestions for research frameworks on the governance and power relations in different types of product chains, or case studies about particular industries in specific locations.

A promising point of departure is to look at the two dynamic processes that reinforce fragmentation: production stage specialization and capability building, and production stage economies of scope and scale. These are the main reasons for the rapid diffusion of fragmentation and the growth of global production networks. If we can

analyze them to gain understanding of how different emerging countries' industrial policies give these countries advantage in specific stages of production, we will have the beginning of an answer.

“Production stage economies of scale and scope” is the term I use to describe the process by which, once a specific production chain fragments into discrete stages, suppliers in each stage, by pooling the demand of many customers, create economies of scope and scale that in-house manufacturing divisions cannot. These economies of scope and scale enable suppliers to become more efficient and allow them to operate on levels of profit margins that are significantly lower than those achieved by in-house manufacturing divisions.²⁰ This in turn allows them to further lower their prices while offering the same or even higher quality, further speeding the trend toward outsourcing of this stage's manufacturing activities (Sturgeon 2000; Sturgeon 2002).

“Production stage specialization” is the term I use to describe the process by which product fragmentation leads companies to develop superior capabilities in particular stages or components of the product network. A recent example of this in the IT industry are the pureplay foundries. Pureplay foundries, such as the Taiwanese TSMC and UMC, are semiconductor companies that specialize solely in chip fabrication, and whose revenues come from fabricating chips according to the designs of their customers. Such specialization enables companies to become better and more efficient in this narrow set of activities.²¹ It also helps them to acquire specialized capabilities and knowledge

²⁰ One should differentiate between higher overall profits and profits margins. As these specialized suppliers sell vastly large quantities, they can lower the margin of their profits per item sold, while still having overall profits that are higher in-house manufacturing divisions. The best scenario from the point of view of the specialized supplier is becoming so efficient that they can continuously lower their prices per item and still have a profit margin that is as high, or higher, in-house manufacturing divisions.

²¹ In effect this process takes Adam Smith's argument about the division of labor, specialization, efficiency, and the size of the market one step further (Smith 1937, in particular book I chapters 1 and 3).

that more vertically integrated firms could not. These capabilities, once acquired, enable these firms to excel in innovation around the particular production stages and set of components they focus on, using their superior skills and unique knowledge. Over time these two related advantages, in skills and innovation capabilities, grant these companies even more advantages vis-à-vis in-house division of vertically integrated companies. We observe this process both in high-technology areas, for example in the manufacturing of specialized cards or chips for the PC, such as graphic cards or memory chips, and in more traditional industries such as the bicycle where the product chain fragmentation allowed one company, Shimano, to become the innovator and market leader in drive-train components (Galvin and Morkel 2001).

The fragmentation of production and the growth of global product chains suggest that there are multiple entry points and ways to succeed, even in the same industry and even during the same time period. Global production networks allow emerging economies as many different innovation-based entry points to the global IT industry as there are stages in the global IT industry production network. The decisive factors that influence the entry point of each national industry are: (a) the relationship of the industry with global markets, specifically with the MNCs that build, manage, and to a large degree control these product chains; and, (b) the development of capabilities that enable the industry to excel in specific activities that are more or less suitable to specific stages of production. Thus, focusing on the development and growth of global production networks, theories of product fragmentation enable us to formulate arguments as to how different states' science and technology policies build national industries that do better in different production stages. However, we still need to account for how state-business

interaction and the implementation of specific policy regimes translate into institutional systems that, through time, facilitate the development of particular capabilities and skills by private firms and motivate them to employ specific business models. We need to understand how different industrial innovational capabilities are created, maintained, and employed.

Systems of Innovation Theories

From the point of view of the comparative political economy literature, the systems of innovation theories are seen as part of the varieties of capitalism theories. Those theories assume many different models of national economies, each with distinct institutional systems. These systems confer different economic and industrial advantages and disadvantages on companies operating within them. As a result, these companies, in turn, behave differently even when operating in the same product markets and under the same international conditions.

Systems of innovation (SI) theories aim to explain how systematic differences in industrial as well as science and technology institutional systems give rise to industries with specific industrial technological innovation capabilities. SI theories were first developed in the 1980s by evolutionary economists (Carlsson et al. 2002; Edquist 1997; Freeman 1987; Lundvall 1992; Nelson 1993). The writers in this tradition build on Schumpeterian economics and on institutional economic theories. They argue that not only is innovation the main source of long term economic growth, but also that there is a major role for policy in R&D and science. Government has such a major role, they argue, for two reasons: first, the innovation process itself is iterative and cooperative in nature; hence, there is a significant role for public actors (Braczyk et al. 1998; Cooke and Morgan 1998; Lester and Piore 2004; Morgan 1997; Piore et al. 1994; Piore and Sabel 1984; Teubal 1996; Teubal 2002). Second, scientific research, especially industrial R&D, represents a clear case of market failure. The indivisibility, inappropriability, and high uncertainties of R&D lead private investors to allocate sub-optimal amounts of finance to

research under conditions of perfect free competitive market – a clear case of market failure (Arrow 1962; Schumpeter 1961 (1934)).²²

Starting from the national system and later moving to the sectoral, regional, and industrial systems, researchers in this tradition have argued that the different relationships between government, firms, research institutions, suppliers, and customers influence the ways in which new technologies are created and/or diffused throughout the industrial system. The relationships also affect the rates at which new generations of products using the latest technology are produced (Braczyk et al. 1998; Breschi and Malerba 1997; Lundvall et al. 2002).

The main mechanisms by which these constellations influence firm behaviors are, first, by shaping firm capabilities, especially their dynamic economic capabilities and innovation production/absorption capacities, i.e. capabilities to produce new products and technologies or to infuse new technologies into their existing products and manufacturing systems (Carlsson and Eliason 1994; Carlsson et al. 2002; Cohen and Levinthal 1989; Cohen and Levinthal 1990). Second, institutional structures influence firm behavior by offering different opportunity structures and different resources which influence the profitability of certain activities (Carlsson 1995; Carlsson and Eliason 1994; Giuliani 2002; Morgan 1997; Teubal 2002; Teubal et al. 1991). Thirdly, institutional structures influence firms' R&D behavior by infusing the system with specific research paradigms and business models that move certain R&D activities and procedures to the forefront and others to the background (Dosi 1982; Samuels 1994).

²² Market failure is defined as a case where due to lack of information or the specific characteristics of the industry/activity, we should expect the private market to allocate a sub-optimal amount of resources.

There are two main strands of SI theories. The American strand of SI focuses more on the influences emanating from the different ways in which R&D is organized and financed (Nelson 1993). The European school, originated at Aalborg, has been more focused on explanations based on backward links between producers, and on the flows of information from users (or user sectors) to producers, and has a stronger emphasis on the role of the quality of demand on the development of capabilities (Lundvall 1992; Lundvall et al. 2002).²³

SI theories argue that three main variables explain the amount and sophistication level of industrial R&D of each system, all intimately connected to the fact that industrial R&D is a semi-public good. The first variable is the location of industrial R&D activities within the industrial system. The levels of industrial R&D sophistication and capabilities are different if most of the industrial R&D is conducted by the firms themselves, or by public and semi-public organizations like research institutions and universities. SI theories contend that there are major differences between systems depending on the location (public or private) and the identity of the agents that typically conduct most of the R&D. While most SI writers do not deal with these issues in detail, SI theories suggest that the more R&D is conducted by private firms, the more private industry develops sophisticated R&D capabilities.

The second variable is financing. Different financing modes affect not only the location of R&D activities, but also the focus (time horizons and product versus process innovation) and amount of industrial R&D. SI theories, again, do not fully elaborate their arguments on the subject but suggest that differences between public and private

²³ For an excellent example of a theoretical model for the importance of the creation of a users-innovators community to the successful implementation and continuous improvement of new technology, see Teubal et al. 1991.

financing, the financial gains that investors are looking for, and the origin of the financiers directly influence the R&D capabilities and business models employed in each industrial system. The more resources for innovative product R&D are available, the argument goes, the more R&D is conducted and the more sophisticated capabilities are developed. Similarly, the more there are sectoral limits on R&D activities, which inhibit the development of broader or multidisciplinary capabilities and knowledge, the more the scope of R&D capabilities will be limited. Finally, the more financing is linked with global capital and exchange markets, the more investors will seek financial exits that allow them to channel the profits back home. Accordingly, foreign, or foreign-financed VCs will push firms into business models that aim at either going public on the leading stock exchanges or being bought by an MNC. As these tend to utilize a business model emphasizing new product innovation, SI theories imply that the more the local industry is dependent on global VC financing, the more the industry will focus on product innovation and follow a business strategy aimed at foreign IPOs or merger and acquisition deals.²⁴

The third explanatory variable highlighted by SI theories is the industrial opportunity structure. By industrial opportunity structure I mean the composition of the local industry, including the links between producers, between producers and customers, and the links of the local industry with the global production networks, in particular with the MNCs that control them. Different opportunity structures affect the capabilities and business models employed by firms by giving different industrial systems access to

²⁴ SI theories usually do not pertain to the important national difference between the regulation of venture capital and stock exchanges. Thus, while they argue for a more general observation, claiming that VC financing leads to the rapid diffusion and use of American-like start-up businesses models, I prefer to refine their argument. Thus, I claim that only VC funds whose source of finance is the global capital markets and are linked to the leading global stock exchanges.

different information and skills, as well as by giving each local industry different sets of customer focus, business prospects, and market niche openings. A critical factor in this configuration is the local leading companies. In addition, as the main market for IT has always been the US, and as American MNCs (with some exceptions) also control the global markets, a key to understanding the different opportunity structure is to look at the different relationship that the local IT industry has with these MNCs, both inside and outside national borders. This has become especially true with the growing fragmentation of production.

MNCs (and leading local firms) are critical for the overall skills and capabilities composition of each national IT industry for a few reasons. First, MNCs and local leading companies are the main customers of new local IT companies. Secondly, MNCs are important for the local IT industry as key actors in the transfer and development of two critical spheres of skills and capabilities. First, the R&D labs of MNCs develop products and components on the technological cutting edge. Consequently, they are a major source of cutting edge technological information and knowledge, and, even more importantly, world-level R&D-conducting capabilities into the industrial system in which they operate. Second, MNCs are the best organizations in the world in designing and developing new products. Therefore, their R&D divisions diffuse into the industrial systems within which they are located the skills and capabilities needed to design new products as well as better knowledge of the customers in the final market.

For these reasons, major differences in industrial development patterns are to be found in IT industries that have different leading companies and different relationships and links with the leading MNCs. If the MNCs' subsidiaries and leading

companies within a specific country are conducting manufacturing activities and focus on process and manufacturing innovation, then their outputs into and inputs from the industrial systems are significantly different than if most of the MNCs' subsidiaries and leading local companies conduct critical R&D activities. Thus, the outputs MNCs and leading local companies seek from local firms, the inputs they put into the local industrial systems, as well as the ability of local firms to sell their own products and services to these MNCs globally, are different depending on the activities MNCs perform locally.

In the case of MNCs' manufacturing, subsidiaries, local firms might find it easier to sell manufacturing services or become components suppliers to MNCs, than to become suppliers of new technologies and innovations. In addition, the inputs of the leading domestic companies and MNCs into the local industrial system would be focused around manufacturing and process information and skills, including critical innovational capabilities around these activities. For the same reasons, local firms will find it harder to sell the same MNCs new technologies and the MNCs will diffuse less R&D and fewer product design skills and capabilities into the local industrial system.

In short, the global production network and the system of innovation theories give us a better understanding of the institutional underpinning of industrial development and innovation in a world of geographically fragmented industrial production. Using these insights, together with the lessons we have learned from late development and development-state theories, we can now develop a more comprehensive argument about the role of the state in the development of RIB industries in emerging economies.

Building the Theory

This dissertation develops an approach to understanding the role of the state in industrial development in a world of globalized fragmented production. It does so by presenting arguments about the roles and structure of the state in the development of high technology industries in emerging economies. Hence, we first need to explain how states can organize and interact with private industry to promote the growth of innovative high-technology industry, and to explain the political process of this interaction. Second, we need to explain how specific policies and state-business interactions produce different national industrial systems within the same industrial sector.

A New Model of RIB Industrialization Politics

Analyzing late development and developmental state theories, we noted that, in the development of high technology industries, the state should act as the flexible facilitating agent, and not as an overall commander. The state should no longer methodically plan the development of strategic industries by choosing specific products and product niches, forcing private companies to enter them and supplying some of the necessary finance and technologies. Instead, the state should concentrate on creating more broadly defined technological capabilities, and focus on motivating private agents to work in these areas and collaborate with each other and with the state. The state role is no longer seen as one where it makes the decisions and compels private companies to follow them, but rather motivates private companies to make long-term commitments to operate in RIB industries and activities. This argument is an opposite one to the strong developmental-state argument that gave the state the job of long-term planning and control over the industry. The neo-developmental statist argue that, in the case of RIB

industrialization, the state needs not only to spur the creation of the industry, but also to quickly grant the industry control if not full jurisdiction as it develops. At the same time, the state still needs to retain enough knowledge and skills to devise and implement policies that help the industry to grow and maintain its competitiveness in the world of constant technological change.

The state is pictured as the national management consultant and central arbitrator and promoter of the industry, with the distinction between public and private roles and power becoming more ambiguous. State-industry relations are described as a division of labor of the tasks each side takes to reach the same national goal of economic growth. In this way the state is seen as embedded, i.e., as an important agent, but not the overall leader, in a network of private and public agents that together makes the industrial system.

However, the neo-developmental arguments are still: i) structural in claiming that one specific structure of the state (differently named by different authors) has all the explanatory power; and, ii) aggregate in treating the whole state as either developmental or not. However, often success in one sector does not implies success in others, a point that the neo-developmental statisticians tend to neglect. Moreover, they still hold to the old timing logic of the Gerschenkronian argument – that the timing of the beginning of the rapid industrialization efforts inherently imposes only one successful model. For example, Alice Amsden argues for one specific mode in which “the rest” can industrialize, and Sean O’Riain sees Israel, India, Ireland, and Taiwan as representatives of the same model of a developmental state (Amsden 2001; O’Riain 2004).

In so doing the developmental statist marginalize politics in several ways. First, by maintaining that the explanation lies in a particular state structure, the neo-developmental statist repudiate the importance of specific policies, as it is no longer the policies that make the difference but the overall bureaucratic structure. At the same time, structural explanations also negate the importance of selecting between alternatives, as the only choice left is of either selecting the “correct” alternative or dooming oneself to economic backwardness.

Thirdly, the neo-developmental arguments disregard the importance of sectoral politics. By looking at the aggregate level and describing whole states as either successful or not, the neo-developmental state theorists cannot explain how embeddedness develops in the first place. Consequently, neo-developmental statist disregard the importance of politics in determining the success or failure of the sectoral state-industry co-evolutionary process. Moreover, looking at the aggregate level and advancing one form of state-structure, the neo-development statist evade confronting the realization that their own arguments suggest that there are multiple forms of embeddedness, each leading to a different industrial system. Accordingly, failing to notice that what determines both sectoral success and failure and the mode of success, are the politics of state-industry co-evolution that leads to each form of embeddedness. For example, there is nothing in the neo-developmental argument that would help explain why the Taiwanese hardware industry flourished while the software industry languished, although the two sectors had the exact same formal bureaucratic structures of state-industry embeddedness and rules of conduct.

Fourthly, the neo-developmental statisticians suggest that there are many differences between the developmental bureaucracies of different states, their policies, and the ways these policies are implemented. Nevertheless, they do not explain these different modes of state-industry embeddedness and bureaucratic structures and cultures bring about different trajectories of industrial development. *This dissertation aims to propose explanations of this phenomenon.*

Lastly, although these writers claim to explain growth in post-Fordist industries, the neo-developmental state argument proceeds without attention to the radical ways in which industrial production has changed since WWII. The neo-developmental statisticians cannot account for a particular set of institutions developing in a specific society or industry, nor for how certain institutions shape economic growth trajectories and behavior in global markets. *Our framework aims at rectifying this gap by utilizing insights from the systems of innovation and global production networks theories.*

Therefore, there is a need for a new model that delineates the role of the state in the politics of industrialization. This theoretical framework should build on the neo-developmental state arguments, taking into account the multiple ways in which successful development can simultaneously take place within the same industries; accordingly there are alternatives, with different consequences, to create and from which to choose.

The idea of network development can serve as our basis. My framework proposes that, in successful cases of RIB industrial development, state agencies will first aim at creating a set of firms and industrial actors, and then seek to develop a thoroughly multiplexed network among these actors, and between these actors and the international financial and production markets and networks (Ansell 2000; Locke 1995; O'Riain 2004;

Teubal et al. 1991). What I expect to find in successful cases of RIB industrial development are, *different political processes*, in which the state's first role is as a key actor in the creation of a network. First, a more hierarchical network, and then in the course of co-evolution, I expect to find the network becoming denser and more heterarchical/polcentric and international, with the state moving from a position of controlling the network to a position of centrality, i.e., an important node within a bigger and much more multiplexed, larger, and diffused network. Consequently, the state's main role becomes more that of a facilitator-organizer, rather than of an overall commander. Further, I predict that the different ways local and sectoral *politics* shape the development of these networks will vastly influence the industrial structure and capabilities.

In cases of RIB industrial development failure, I expect to identify two different kinds of failure. The first occurs because of the inability or unwillingness of the state to facilitate and participate in the growth of this industrial sector. An example of that kind of failure would be the state ignoring the industry, largely refusing to participate in its growth, or to channel the resources necessary to that effect.

A second kind of failure is anticipated when the state actively participates in the creation of the network, but then resists the relinquishing of its own power, trying instead to retain its position of control, aiming to maintain hierarchical relationships with private industry.

To successfully manage the dual staged process above, the state needs to acquire two assets: (1) sufficient technological and scientific skills, knowledge, and information to make informed decisions in the case of ever more complex industrial technologies development; (2) multiple relationships with the industry that enable the development

agencies to be constantly informed about the shape and needs of the industry, as well as to implement its decision without resorting to coercion. Moreover, the state needs to have and preserve its ability to make decisions independently. As I noted earlier, acquiring these two assets, managing these transitions, and developing the needed industry-state co-evolution processes suggest a model of the state that is incompatible with the Weberian ideal-type bureaucracy. In addition, as there are many ways to acquire the needed skills and create embeddedness within the industry, as well as many ways to manage the relationship with the industry, even within the same state, it follows that there are many different models of the new development state.

We can now propose a new model of successful state efforts for RIB industrialization. The new model suggests a bureaucracy that is less Weberian and isolated, but much more fragmented. However, it is also more technologically and scientifically knowledgeable and skillful, and closer to industry. The state's structure should allow the developmental agencies to react quickly to the needs of the industry, allowing the state to be the facilitator, but not overall commander, of industrial development. Thus, while the old model conceptualized the state as a unitary actor with personnel recruited, trained, and indoctrinated within the bureaucracy, the new views the state less as a monolith and shifts attention to its different agencies. It follows that differences in the ways the bureaucracy is constructed, the social origin and educational background of its personnel, and its ability to shape the decision making process must be analyzed.

There are many ways in which the developmental bureaucracy can acquire the needed skills and embeddedness within industry. One approach is for the state to be

involved as deeply as possible with the industrial R&D process, bringing the technology creating agents into its own structure. Of the three cases, Taiwan's strategy of utilizing two state-controlled public research institutions – the Industrial Technology Research Institution (ITRI), and the Institute for Information Industry (III) – as the main impetus for IT industrial growth, is an example of such a strategy. A second approach is to create a development bureaucracy with porous borders and employ a “revolving door” recruitment and training strategy, enabling scientists and industry leaders to move back and forth from state to private industry. Of our cases, the way in which Israel's main developmental agency – the Office of the Chief Scientist in the Ministry of Trade and Industry (OCS) – has been structured, is an example of such a strategy.²⁵ The third approach is a variant of the second, in which the state attempts to preserve the cohesiveness and Weberian principles guiding the developmental agency by creating specific subunits, usually with a more limited or advisory role, in which regular recruitment and training procedures do not apply and into which industry insiders are recruited on a temporary basis. Of our cases, Ireland's utilization of such subunits, of which the National Software Directorate has been the most influential, within larger development agencies that embodies Weberian ideals, such as the Industrial Development Agency (IDA) and Enterprise Ireland (EI), is an example for the use of that strategy.²⁶

The new framework differs from the old in the ways in which the developmental agencies create, conduct, and maintain their relationships with industry. In the old model, the development-state was portrayed as having strong relations with the leading big

²⁵ Since 2003, the Ministry is called the Ministry of Trade Industry and Employment.

²⁶ Since 2003, the National Software Directorate has been renamed the National Informatics Directorate.

firms. While dialogue was maintained, the state had the authority and responsibility of guiding and controlling the industry's development. In the new model, the state aim is to become embedded within the industry, industry-state dialogues are to be between equals, and the state's role is more of a facilitator than of a planner and overall leader. However, unlike the old theories, which described a fairly straightforward relationship and power structure, there are many ways in which the state can accomplish its roles and create the relationships that the new framework emphasizes. The shaping of these choices is done through a constant political process.

The choices available to the state can be conceptualized along two related continua. On one end of the first continuum, measuring control, are attempts by the state to get maximum control over development and direct industrial R&D efforts almost from basic research all the way to specific products. On the other end of this continuum we have a state formulating high technology industry-specific policies only after a few companies have already proved the growth potential of specific sub-sectors, with the state direct assistance limited to more mature firms. State decisions as to the degree of targeting sectors and technologies, can be conceptualized on a second continuum. On one end are states that formulate policies down to the level of defining specific generic products and technologies. On the other are states that see their role mainly as assisting in the realization of decisions made by private firms, employing horizontal technological policies that are neutral in regard to technologies and sectors (Teubal 1997). In between there are states that target specific sectors, for example software, but do not attempt to target specific technologies or define future products.

In our cases we have an example of the three main positions on these two continua, both extremes and the middle. On the one hand we have Taiwan, where the state has been targeting specific technologies and products, authorizing and financing its public research institutions to develop them to the stage of working product prototypes and then either deliver the result to the industry or spin off the research teams as companies to commercialize the results. On the other hand we have Israel, with a development agency that defined its role as fixing the market failures associated with industrial R&D and maximizing product R&D activities. The Israeli state followed almost ideal-type neutral horizontal technological policies (Teubal 1983). It implemented a policy of giving R&D grants for product ideas developed by private companies and entrepreneurs in every industrial branch, helping companies in all stages of development. In the middle is Ireland, which did not have a specific industrial policy for RIB industries until after the indigenous software industry achieved some success globally. Ireland then restructured its development agencies and policies to focus on specific industries and tailored its financial instruments to companies that, while still young, have already moved beyond the seed stage.²⁷

The last dimension along which the new model of the state is significantly different than the old model is in its role in relation to the global industry and financial markets. In the old model the state had three main roles. The first was to organize and facilitate technology transfer deals from the leading MNCs to local industry. The second was to use its control over foreign currency to shape industrial development, granting it

²⁷ That is not to say that the state was not important in the early development of the industry in Ireland. Indeed the then mainly FDI focused industrial agency – IDA – was critical in the industry’s development in the 1980s through its Enterprise Development Plan. However, as the name suggests, the aim of that policy initiative was to develop business in all sectors of the economy, without regard to R&D, and with its main goal still that of job creation.

to chosen firms that were successfully exporting, and denying it to others. The third role of the state was to prevent MNCs from gaining control of too large a percentage of the domestic market, crowding out local infant industries.

In our framework, the state's roles are much more complex. In a world of fragmented industrial production, vertical integration is no longer the sole option, and not necessarily the best one. Instead, there are many ways in which the local industry can become a part of the global production networks. In each of these, the local industry needs to develop specific relationships with the MNCs and with the global financial markets, and for each kind of relationship different technological and managerial skills are necessary. In addition, as the local industry is based more and more on indigenous R&D activities, the role of the state in strategically managing technology transfer, while it might still prove important in the early stages, is diminishing. These decisions relate to the heart of national politics: questions about national ownership, identity, foreign relations, as well as financial security and independence.

Again it is useful to think about state choices in enhancing the local industry's specific linkage with, and embeddedness within, the global industry and financial markets as two continua. The first continuum looks at the state's behavior toward foreign technology-based firms, in particular the MNCs that develop and control the global production networks. On one extreme, we have states that look at foreign firms as the main mode for industrial upgrading and focus on convincing foreign firms and MNCs to locate manufacturing facilities within their borders. The hope is that these firms' subsidiaries, once established, will become embedded within the domestic industry. On the other extreme we have states that focus most of their efforts on convincing MNCs to

locate their R&D labs within their borders, and pay close attention to the development of specific relationships of local companies with their foreign partners.

On the first extreme we have Ireland, which until the early 1990s focused its industrial policy almost solely on bringing MNCs to open manufacturing facilities in Ireland, without paying much attention to creating strong relationships between them and the local industry, either within or outside Ireland. On the other extreme lies Israel. By generating collaborative projects between Israeli IT firms and American companies, the Israeli state has established relationships in which Israeli firms focus on product R&D and their American partners focus on sales and marketing. Israel's developmental agencies have also been attempting to lure foreign firms to open R&D centers in Israel. Taiwan has chosen a middle course, first urging MNCs to open manufacturing facilities in Taiwan, but then goading them into buying a growing percent of their components from, and outsource their manufacturing activities to, Taiwanese companies.²⁸ At the same time, Taiwanese developmental agencies have tried to help local companies produce more components and improve their manufacturing and design services capabilities.

Relationships with global financial markets are better conceptualized along a second continuum. On one extreme we have states that try to link their local industry with global financial markets. They court foreign investors not only to back local firms but also be the financiers of the local VC industry, and encourage local companies to get

²⁸ In 2001, the Taiwanese Department of Industrial Technology (DOIT) embarked on an initiative to specifically lure MNCs to open R&D centers in Taiwan. This initiative has been quite successful with thirteen MNCs opening facilities in Taiwan within two years, and ten more MNCs on the waiting list. Indeed, if this new trend is sustained, and these MNCs consistently conduct high-level R&D activities in Taiwan, a very interesting future research project would be to gauge their influence on the Taiwanese IT industry after a decade or so of operations.

publicly listed on foreign stock exchanges. On the other extreme we have states that try to limit, as much as possible, the financing of their high technology industry to local investors, and try to limit, if not outright prevent, the public listing of local companies on foreign stock exchanges. In between, we have states that are either less active or aim to strike a balance between the two.

Of our three cases, Israel has done the most to lure foreign VC investors and urge public listing on foreign exchanges. State efforts have been a main cause behind the current situation: the vast majority of Israeli NTBFs' financing, either directly or through local VC funds, is foreign. In addition, Israeli companies all aim to be listed on foreign exchanges, making Israel, with only six million people, the state with the largest number of companies listed on NASDAQ other than the US and Canada. On the other extreme is Taiwan, focusing all its technology financing initiatives on the local investment community, and strongly advancing the Taiwanese Stock Exchange. Ireland has chosen the middle road: channeling EU money to the local VC industry, but creating the new funds mostly through local financial institutions.

Different Choices – the Varied Paths of Industrial Growth

Conceptualizing the new model of state-industry relationships helps us to analyze the different ways in which emerging states can structure themselves and their relationship with the local industry in order to nurture and support the growth of high technology industry. We can now consider how the different choices made by states influence their high technology industrial development path by utilizing our analysis of the systems of innovation and product fragmentation theories. We will then use these insights to explain how in the cases of Taiwan, Ireland, and Israel, specific state policies

and behavior has helped to spur the development of different IT industries, as well as the relative success and failure of each subsector within each of the three cases.

Our reading of production network theories highlighted the spatial clustering of similar production activities and the underlying linked dynamics of production stage specialization and production stage economies of scale and scope. These point us to several domains of interest. First, specific industrial R&D, dynamic economic capabilities, and business models are more suitable for certain stages of the production process. Second, the analysis of the dynamics of production stage specialization and economies of scale and scope indicates that industrial systems that specialize in specific stages of production tend if successful, with time and effort, to become ever more competitive and innovative in these specific stages. Consequently, if we want to understand the different evolutionary processes of high technology industrial growth we need to understand: (a) how industrial R&D and dynamic economic capabilities are created, improved, and maintained in each of our cases; (b) the growing utilization of certain business models in each of our cases; and (c) the development of specific relationships that the local industry has with the global industrial and financial markets.

In the words of SI theories we need to analyze the development of industrial R&D capabilities, capacities, and opportunity structures in each of our cases. In order to understand the growth of industrial R&D capabilities SI theories urge us to compare the different location of the R&D conducting agents, the R&D resources available and the way in which firms are financed, the scope and limits of R&D, and the industries' customers and relationships.

As to opportunity structures, with infrastructural variables being more or less equal, two main variables, the industry's customers and markets and the ways in which the industry is financed, strongly affect the business models and strategies firms and entrepreneurs employ. This leads industrial agents to focus on the building of specific innovative and manufacturing capabilities. In a world in which most of the trade in IT is done through global production networks, the relationships that local IT firms have with local leading firms and with foreign companies, especially leading MNCs, are one key factor in determining their opportunity structure. The second factor is the sources and forms of finance. For example, in a system in which the main source of financing available to technology entrepreneurs is product-development R&D grants, entrepreneurs and firms would devote much more attention to developing R&D capabilities, than in a system in which the main source of financing is not focused on the R&D stage. In addition, we argue that the more financing is linked with the global capital and exchange markets, the more investors will seek foreign financial exits. Consequently, foreign-financed VCs will push firms into business models that aim at either going public on the leading stock exchanges or being bought by an MNC.

We can now analyze how different behavior and structure of the state influences the development of the IT industry's R&D capabilities in each of our cases. First, decisions by the state on how to acquire the necessary R&D skills are influencing the identity of the agents conducting industrial R&D. The more the state bureaucracy encompasses the R&D conducting agents within its structure, the less industrial R&D activities private firms are encouraged to perform. Second, decisions by the state over the level it attempts to control the technological development path of the industry, including

decisions of how, and who, to finance bear on both the R&D resources available to the industry and the scope of R&D activities conducted. Thirdly, state efforts developing the first local leading companies have long-term consequences for the industry's opportunity structure. Similarly decisions that the state is making concerning the involvement of foreign firms and investors within its national borders, as well as decisions made whether to enhance specific relationships between local and foreign companies outside the state's national borders, affect the resources, the particular feedback and information the industry gets from its main customers, and the diffusion and development of specific innovative capabilities.

We expect that private firms in the high technology industry of emerging economies will have more limited R&D capabilities where the state has tried to control the industrial R&D development path, encompassed the R&D conducting agents within its structure, supplied only limited resources, refrained from urging foreign companies to conduct R&D activities within its borders, and limited the involvement of foreigners as financiers.

However, neither Taiwan, nor Ireland or Israel followed these idealized paths. In each case a particular mix of policies and initiatives across these different dimensions has been played out. Therefore, to have the full answer we will have to go into a more refined level of comparison, fully elaborated in Chapters Three to Five. Nonetheless, even a brief analysis along the lines described in our arguments can demonstrate our case.

Israel, Ireland, and Taiwan – the Argument in Brief

Taiwan is the case where the state attempted to firmly direct and control the technological development path of the IT industry. In Taiwan the bureaucracy recruitment is styled on the Japanese model where exams screen the candidates into different management and career patterns (Kim et al. 1995). However, unlike both Israel and Ireland, almost all of the top persons of the development agencies and ministries have PhDs in various engineering disciplines. In addition, all the Ministers responsible for industrial development, telecommunications, and Science and Technology policies, have had doctoral degrees in engineering, before and after democratization. The state, already relatively well equipped with scientific experts in its decision-making apparatus, opted to acquire the necessary skills and knowledge for IT industrial development by encompassing the industrial technology creating agents within its bureaucratic structure. It did so by establishing two public research institutes, ITRI and III. Nevertheless, Taiwan has also supplied funds for industrial R&D and the state encouraged R&D activities on a wide spectrum of technologies, even if they were conducted within its structure, and not by private companies. However, where throughout the development of the hardware industry ITRI saw as its ultimate goal the creation of a thriving private industry and has successfully managed its own diminishing role as the industry grew, the situation in software has been different. From its inception, III tried to maximize its control and financial resources, directly competing with private industry. In contrast to ITRI, III has been reluctant to see its power diminish and has continuously competed with the industry. In addition, III focused its strategies and policy initiatives around its own, and not around private industry's, growth. Thus, the case of the Taiwanese software industry is a case of stage II failure – inability of the state to relinquish its own power

over the sectoral industrial system and move from a hierarchical to a networked mode of governance.

On the local-global relationship front, Taiwan has aimed to help the local industry to excel in supplying components, and manufacturing and design services, to the IT industry's global production networks. Until recently Taiwan steered a middle course in regard to the activities it encouraged foreign companies to conduct in Taiwan. Unlike South Korea, Taiwan encouraged foreign companies to establish manufacturing facilities within its borders. But unlike Ireland, Taiwan then pushed these companies to acquire more and more components locally and to transfer the necessary skills and know-how to local suppliers. In addition, Taiwan has been encouraging local companies to be publicly listed on the Taiwan Stock Exchange and not on foreign stock exchanges. It has been targeting the local financial community as the main source for the IT industry's venture capital.

This partial analysis already helps us to understand why Taiwan's IT industry developed in the way it did. Taiwan has an enormously successful hardware industry in which the first leading firms have been focusing on supplying components and OEM manufacturing services to foreign companies. This gave rise to an industrial system, which focuses on 2nd generation, process, and manufacturing innovation, with a division of labor between the state and private firms. The state conducts most of the early technology screening and R&D, and the private companies focus more on final product development. It is an industrial system in which most of the firms are supplying components and design and manufacturing services to the IT industry's global production networks.

Israel has also been very active in the development of its local high technology industry, but with an almost opposite strategy. The state defined as its main goal the development of an industry with sophisticated, new product-oriented export-focused industrial R&D capabilities. The Israeli state devised and implemented its policies around this notion. The state supplied financial backing to R&D projects developed and executed by private firms and entrepreneurs across the industrial range, without any attempt to direct the industry's technological development path. Israel's bureaucracy never strictly followed the Weberian model. Throughout the years there have been attempts to both professionalize the bureaucracy and follow the American model of "government of strangers" allowing politicians to have more control over their Ministries by bringing with them many of their own people (Bowsher 1991; Deri 1993; Hecló 1977; Pfiffner 1992). The result has been a mixed structured civil service with relatively low status and workforce continuity. The OCS is also the best example, within the three national cases, of a development agency following the strategy of porous borders and revolving door structure to acquire skills and knowledge. Thus, the chief scientists (the heads of the OCS) have been traditionally recruited outside the agency, with a particularly large number of executives and employees either brought as consultants or recruited directly from other organizations outside the bureaucracy.

On the local-global front, the Israeli state pushed Israeli and foreign, especially American, companies to form partnerships in which the Israeli firms focused on R&D and the foreign firms on marketing and sales. Israel focused on trying to convince MNCs to open R&D centers within its borders, not manufacturing facilities, until recently a unique strategy among emerging economies. The state was also actively linking both its

companies and its VC industry to the foreign financial markets. We can now begin to understand why in Israel both the hardware industry and the software following its footsteps in a second stage of growth became equally successful with almost all firms following a similar strategy – industrial R&D leading to either the development of new technologies or new products based on cutting edge technology. Israeli companies position themselves as suppliers of new R&D inputs to the IT industry’s global production networks. Israel has become one of the prominent locations in which foreign companies and MNCs open large-scale R&D centers.

Ireland concentrated for many years on job creation. The state has also been following a much less active strategy in regards to the indigenous IT industry. While vastly improving the educational, physical, and communication infrastructures, Ireland’s industrial policy focused mainly on bringing foreign companies to open manufacturing facilities within its borders. Some thought was given to the ultimate goal of embedding these firms within the Irish industrial system, but there has not been, until very recently, coherent attempts to do so. As a result, many of these companies eventually left Ireland. For many years the Irish development agencies followed the ideal-type Weberian structure with internal recruiting, training, and career development procedures. However, they did so with an English flavor, including a strong distinction between the social-science-humanity-law “general-educated” employees who are being groomed to management, and the technical-engineering “expert-educated” personnel whose career does not lead them to high management positions (Rose 1981; Rose 1986). Since the 1960s there has been only one Secretary General of a Ministry who joined the civil

service technical personnel career track with an engineering background.²⁹ Accordingly, Ireland opted to follow the third strategy of acquiring technology and industry specific skills – creating domain specific subunits stuffed with industry insiders – when these skills were deemed necessary.

There were very limited resources devoted to R&D in Ireland. Even when the IDA established a program to promote local industry in the 1980s, its focus was on job creation and not R&D. This especially hurt the hardware sector, which needs more financing than software to successfully conduct R&D or commence operations. Local Irish hardware companies also had fewer opportunities to profitably employ service or consultancy business models. In addition, during the 1980s the hardware industry had to compete fiercely for the limited number of skilled engineers against MNCs who were recruiting for both their Irish and global facilities. With meager financial resources and unable to offer secure long-term employment the Irish hardware industry was at a severe disadvantage. This failure of the state to engage with the specific needs of the Irish hardware industry and to embed itself within it, even with the first successes of the indigenous industry – Mentec and Lake Electronic – both being hardware companies is a case of stage I failure. The Irish state, focused as much as it was on FDI strategy, was unable to allocate enough resources and attention to devise specific policy initiatives and embed itself within the industry to spur its growth. It was only a decade later, after a few software companies achieved some commercial success in foreign markets, with the software industry using all its political muscle, and with the IDA already changing its focus of attention, that Ireland developed a coherent IT industry focused industrial policy.

²⁹ Similarly to Taiwan, and unlike Israel, the top civil servants in each ministry (including the Secretary General, or the General-Manager) are chosen from within the ranks of the civil service.

Even then, the industrial policy was geared toward the indigenous software and not hardware sector. Moreover, the policy was focused mostly on companies that passed their early development phases, again putting at a disadvantage hardware firms that need larger amounts of pre-revenue R&D financing and find it more difficult to use consultancy or service business models.

Only in the late 1990s did Ireland start to pay close attention to the assistance its local companies might need abroad, and even then the state limited its role to that of a promoter of companies in various foreign markets and did not attempt to structure specific relationships between local and foreign firms. With regard to foreign financial markets, the state, while happy that some IT firms have publicly listed on foreign stock exchanges, has encouraged them to also list locally. In addition, while employing and channeling EU grants, the state has focused on local financial institutions as the main loci for its various initiatives to create a local venture capital industry.

Again we see that even a cursory analysis of Ireland along the dimensions suggested above helps us to understand why the Irish IT industry developed the way it did. Even with the IDA's long history of bringing foreign hardware firms to open large manufacturing facilities in Ireland, it is the indigenous software industry that has become the more successful sector, while the hardware sector has struggled. The Irish IT industry focuses on developing products of mid-level sophistication, most of which are innovative mainly in applying existing IT technologies to new domains. The more successful companies prefer to either double list on both a local (now also EU) stock exchange and a foreign one. The level of acquisition of Irish firms, while still higher than Taiwan's, is considerably lower than in Israel, both in total numbers and in the average size of the

financial transaction. The IT industry is still dominated by foreign firms concentrating on activities of relatively low sophistication, and the overall level of innovation in Ireland is the lowest of our three cases.

In sum, even with a brief analysis built on comparison of the behavior and structure of the state, in our three cases we can distinguish strong national patterns. These patterns greatly help us to understand the different development path of each industry, as well as the relative success of the software and hardware sector in each case. This empirical analysis lends strength to our theoretical arguments. The full analysis laid out in Chapter Three to Five looks at each of these cases in detail, giving us a much more refined understanding, and supplying us with lessons that can then be generalized

Plan of the Dissertation

This dissertation has three targets. The first is to expand our understanding of the roles and the limits of the state in the development of RIB industries in less developed economies. The second is to explain how the different approaches taken by Israel, Ireland, and Taiwan has shaped the IT industries, influenced the particular development path of, and capabilities developed by, each industry, and moved each industry into a different position in the IT industry's global production network. Lastly, by showing that emerging countries have real alternatives in regard to RIB industrial growth, the dissertation argues that politics and the political struggles of crafting and choosing between these alternatives, as well as the politics of state-industry co-evolution, are important not only to explain the difference between success and failure, but also to explain the reasons behind the specific choices made. Hence, by moving away our explanations from solely timing and structure reasoning, this dissertation aims to show

that both “state” and “politics” need to be explained if we want to understand both policy formulation and its outcomes.

The chapters are divided as follows. This chapter is followed by the empirical part of the dissertation – three chapters, each describing one national case. Each of these chapters presents the politics and evolution of the IT industry in Ireland, Israel, and Taiwan. All the chapters utilize our framework in the analysis of the history of state actions and interactions with the two subsectors of the IT industry, the national and subsectoral innovation systems, business models used, and the industry’s position in and interaction with the IT industry’s global production network. Chapter Six returns to the theoretical approach in a comparative way, reflecting on what can be generalized from this study to the more general question of RIB industrial growth in other emerging Economies.

Chapter Two – The Development of the IT Industry in Israel – Maximization of R&D as an Industrial Policy

*“Like old Soldiers, old R&D Projects never die.
There is always the sequel”*

Brigadier General (Ret.) Professor Itzhak Yaakov - Israel’s Chief Scientist 1974-78

Introduction

Israel’s IT industry is an impressive success story. In less than twenty years, the country has emerged as a key player in global IT technology, with Israeli companies pioneering many hardware and software market niches such as Voice over IP (VoIP), encrypting, Printed Circuit Board inspection, antiviral protection, digital printing, and firewalls. This small country of only six million has, after the US and Canada, the highest number of IT companies listed on NASDAQ. In 2000, Israeli IT industrial exports reached over \$13 billion and accounted for more than 71% of all industrial exports, and the IT industry alone accounted for 70% of GDP growth (CBS 2000b; CBS 2001; IAEI 2002).

Looking at Israel today, with its strong science and research infrastructure, one can easily claim that its success in the IT industry was predictable. However, nothing could be further from the truth. Israel’s industrial policy in its first two decades of existence resembled the model prescribed by the “old” developmental state theorists. The state employed long-term planning and directly intervened in the creation of specific sectors and industries, especially textiles and defense, without any thought given to the creation of high technology industries (Levi-Faur 1998; Levi-Faur 2001). In 1968, Israel’s science and technology (S&T) industrial policies were public research institution-based. R&D activities in the private civilian industries were almost unheard of. Standing at less than one percent in 1965, Israel’s total R&D expenditures as percentage of GDP

were lower than any of the OECD countries except Italy. The number of scientists and engineers – ten per 10,000 employees – was not low, but it was still less than half of the US, at twenty five, and Sweden, at twenty two (Katchalski 1968. Pp C/7.) The absolute number of R&D personnel in the industry was minuscule, and most R&D activities and personnel were concentrated in the defense and academic research sector.³⁰

What accounts for this enormous transformation and the success of Israel's IT industry? Throughout this chapter I make the following arguments: first, Israel's main competitive advantage has been its R&D capabilities – its competitive edge originated in an existing defense sector and academic research system. The state's almost exclusive focus on the enhancement of technological cutting-edge R&D capabilities has enabled firms to develop novel products based on the latest technologies, the new technologies themselves, or new applications of these technologies, and has led Israel's IT industry into its position as a supplier of new technologies to the global IT industry's production network. This development path brought the IT industry to success first in hardware and then in software; thus the software industry developed within an industrial system that was already centered around advanced product R&D activities.

I further argue this system was shaped by S&T industrial policies that from the beginning of the 1970s focused almost solely on developing capabilities to create new R&D-based products. In addition, the state's R&D policies viewed private firms as the main agents of R&D; the state saw its own role as the grantor of capital for R&D activities. It encouraged the development of R&D capabilities in the private market, diffused R&D know-how from the university and defense sectors to the civilian industrial

³⁰ The total number of workers with academic education involved in R&D activities in all branches of the civilian industry was 886; in addition there were 671 R&D workers with some technical education (Bar 1990. Pp. 41.)

sectors, and coordinated and provided public space in which private and public R&D agents could meet in order to enhance the flow of information and ideas (Breznitz 2004a; Breznitz 2005a). Thus, in Israel, the state's actions nurtured an institutional environment that stimulated private firms to develop advanced R&D capabilities, and gave them the resources to do so.

Thirdly, I argue that in Israel the state has forcefully advanced a specific division of labor between local firms and MNCs. The state advanced both a specific and prominent model of organizational development in the IT industry, and a specific model of embeddedness into the global IT Industry's production networks. This division of labor allowed Israeli firms to specialize in product R&D and to utilize American (and later European or Japanese) MNCs as marketing channels.

However, the state's almost exclusive focus on promoting R&D activities and business models that are based on new innovations is also the source of the industry's most severe weaknesses. With management and business development skills on the backburner many Israeli companies have difficulties in sustaining their initial success for the long-term. Many market niches that were pioneered and controlled by Israeli firms no longer have any Israeli firms operating in them. More worrisome is the fact that this is especially true in market niches that have grown in their importance and overall revenues. Indeed, for an industry with over thirty years of history of global success, it is extremely rare to see market niches in which the Israeli industry has had long-term leadership.³¹ Furthermore, the institutional setting of the industry, its strong imitation of the American start-up model and VC financing, and with it the need to focus on securing financial

³¹ It might be telling that there is no direct translation in Hebrew to the verb "sustain" or to the adjective "sustained."

exits, exacerbates this problem. It also becomes increasingly apparent that Israelis no longer control a growing percentage of the Israeli IT industry. Therefore, it is not at all clear whether it is Israel and its society that fully enjoys the fruits of the industry's success. In addition, the continuing decline of the rest of Israel's economy and its industrial productivity suggests that the IT/R&D sector is now disconnected from the rest of Israel's economy.³²

In this chapter, I present a full view of the co-evolution of Israel's S&T industrial policies, the particular growth pattern of the industry, and the state role in this growth. I first give an overview of Israel's early economic history as a background. It is important to show how the development of industry was profoundly influenced by the nature of the Israeli bureaucracy, national security concerns, and an ideology that privileged scientific research. The next section analyzes the decisions that led to the creation of the OCS and its early years. Following this account, I examine the growth of Israel's IT industry, first hardware and then software, by evaluating the intricate co-evolution process between state policies and industry's development, the changing roles of the OCS, as well as the particular division of labor that evolved between the local and the global industry, and between public research institutions and private firms. The last sections investigate the industry's development in the 1990s, the influence of a new set of OCS policies, the ways in which these policies, in turn, were influenced by the industry's evolution, and the industry's current strengths and weaknesses.

³² As the main positive effect attributed to IT is growing productivity, the fact that productivity in the business sector was decreasing in the 1996-2000 period, the same years that the IT industry achieved its greatest success, is especially worrisome (BOI 2004).

Historical Background and the Beginning of the IT Industry

In the first two decades of Israel's existence, industrial R&D in general and in private industry in particular, was almost unheard of. Nevertheless, 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 defense R&D sector, and a national ideology that gave very high status to science and technology (with scientists having easy access to political leaders). Furthermore, the flexible structure of the Israeli bureaucracy made it possible for leaders within the civil service, who came to see the development of IT industry as a national interest, to devise and implement policies with relative ease.

The transformation of Israel's industrial policies, especially the beginning and evolution of S&T industrial policies, had little to do with the ability of the bureaucracy to conduct long term planning and monitoring, or with its internal cohesiveness. It had more to do with the specific constellation of political leaders in positions of power in the development agencies and government, as well as their views on the proper goals for S&T industrial policy. The structure of Israel's civil service, with its porous borders and revolving doors between state, academia, and industry, eventually made Israel's IT industrial and financial elites not only look as one, but act as one.

This structure reflects a conscious political decision to give political leaders power in shaping and implementing policies—in effect, designing the Israeli bureaucracy more in the American view of civil service than in light of Weberian ideals (Deri 1993; Heclo 1977; Sharkansky 1989).³³

³³ This is not to say that this bureaucratic structure does not pose its own problems, such as governance and the low status of the civil service.

From independence to the 1967 crisis

From its 1948 independence to 1966, the Israeli state followed a protectionist economic policy coupled with an interventionist industrial policy. There were three goals: security and regional policy, industrial development, and the building of a private-ownership-based economy. While waves of immigrants from less developed countries lowered the average level of education, the institutional underpinning of Israel's education system and its research-oriented third level education system was already well established and enabled Israel to quickly upgrade its workforce. New immigrants were channeled to new cities, located according to a security-based logic, not on a purely economic basis. The state anchored these new cities around privately-owned, government-subsidized, large-scale plants. (Textiles was the one industry to be the focus of this state industrial planning, but parts of the defense industry complex and various other industries were enlisted in these aims.) The result was a quasi-private, large-scale, plant-based industrial sector, deeply dependent on, and actively lobbying for, government subsidies and aid.

During this period the growing friendship and alliance between two leaders of industrial and economic policy, Pinchas Sapir and Levi Eshkol, would have an important long-term influence on Israel's industrial and economic development and the setting of S&T industrial policy until the mid 1970s. Both served as ministers of the three main economic ministries: the Ministry of Development, the Ministry of Trade and Industry, and the Ministry of Finance. Eshkol was also the Prime Minister at a critical period of

Israel's development between 1963 until his death in 1969, with Sapir serving as his Minister of Finance.³⁵

This long-term alliance and friendship is critical for several reasons: first, the fact that these two strong political leaders remained in positions of influence for such a long period of time, gaining extensive and intimate knowledge of their domain, institutionalized specific patterns of state-industry relationship, and gave the two an unusually high level of influence over Israel's economic development, that was even higher than the relatively high level of power that Israel's bureaucratic structure grants political leaders. Second, this long-term stability and influence over the key industrial development ministries, especially the Ministry of Finance and the Ministry of Trade and Industry, enabled Sapir and Eshkol to follow a plan of making them more professional, populating them with handpicked personnel. Many of the graduates of the Hebrew University Department of Economics (at the time the only one in the country) were recruited straight to the bureaucracy, sometimes even before they finished their studies (Levi-Faur 1998). Third, Eshkol and Sapir nurtured long-term personal relationships with some of Israel's key scientists and early IT entrepreneurs. These relationships were crucial for the start of Israel's S&T industrial policies.³⁶

Ideology has also played a significant role in Israel's development, with social-democratic principles given cultural prominence, evident in the idealization of the Kibbutz (Tsuk 2004). Nevertheless, the state, led by the socialist party until 1977, had

³⁵ The Ministry of Trade and Industry changed its name a few times during this period, from Commerce and Industry, to Trade and Industry, and in 2003 to the Ministry of Trade, Industry, and Employment. The Ministry of Development was dismantled.

³⁶ According to the developmental state theories, stable long-term relationships between industry and state are key for the creation of specific patterns of development and the ability of the state to influence industrial development. For example, see Samuels 1988. P. 2.

also (surprisingly to some) used its considerable power to ensure that private ownership of the forces of production became the predominant form. The Labor Party's political leaders firmly believed that the future of the Israeli economy crucially depended on a strong capitalist industry led by private entrepreneurs. This tension came to a head in 1956 when the Federation-of-Labor-Unions' (Histadrut) industrial conglomerate – Solel Boneh – was deemed too powerful for private industry to compete against, and the labor party's national political leaders moved briskly to break it up and force the resignation of its manager, Dan Hillel. The labor-led government did so at a time when the party was controlling the Histadrut and with Hillel as a longtime party member. In a meeting of the labor party's MPs during the Solel Boneh crisis, Minister of Finance Pinchas Sapir's remark illuminates the economic belief behind these actions,

“When I spoke with Hillel Dan yesterday I realized that he has an interesting ideology. I think it is utterly destructive for the national economy, and I told him so. He says that there is no hope or future for private industry in Israel. Myself, I think that if there will be no private industry in Israel there will be no public industry in Israel... the conclusion of the things I just said is that Solel Boneh is impeding the growth of Israel. I am utterly sorry for it, but it does not prevent me from seeing the reality.” (Protocol of the parliamentary labor party meeting 12/11/1956 as it appears in Levi-Faur 2001, pp 179, my translation).

In 1965-7, Israel suffered its first recession, which ended with the 1967 war. The war became a critical point in the development of Israel's science and technology industrial policy thanks to the unexpected hero of the Israeli IT industry: French president Charles de Gaulle. Today, after three decades of close alliance with the US, few remember that in the first two decades of its independence, Israel's main ally was France. Israel bought almost all of its military equipment, including critical systems such as fighter jets and ships, from France, and Israeli engineers were working closely with French teams on the modification and specific systems R&D for various weapon

platforms.³⁷ In 1967, on the eve of the June war, with Israel under a severe security threat, de Gaulle declared an immediate military embargo on Israel, due to France's decision to ally itself with the Arab world. That decision resulted in Israel's inability to buy critical weapon systems off the shelf anywhere in the world.³⁸

The immediate reaction of the Israeli state was to put large amounts of resources and R&D power to ensure the rapid growth of Israel's high technology defense industry. A decision was reached that Israel should never again be completely dependent on a foreign power for military platforms. Starting in 1967, Israel's military R&D targets changed from developing niche weapon systems, the most sophisticated of which were radar-guided rockets, to developing its own weapon platforms such as tanks, fighter jets, and ships. At least as important as the skills and product R&D capabilities these projects helped to develop in Israel was the rising demand for scientists and engineers. As will be discussed later, this demand and the accompanying higher wages and status prospects for scientists and engineers in Israel created strong incentives in the Israeli labor and education markets to acquire these skills (Halperin and Berman 1990; Halperin and Tsiddon 1992).

The Seeds of the IT industry

While the official history of computing in Israel began in 1947 at the Weizmann Institute of Science (then known as the Sieff Research Institute), before the creation of

³⁷ Not only was France the main source of Israel's advanced weapon systems, but the two states also had many co-development research projects. France and Israel were also crucial for each others nuclear program, with France licensing the technology developed at the Weizmann Institute for the production of heavy water, helping Israel in return to build its nuclear reactors. Indeed one commentator from the defense sector portrayed that co-development defense industry relationship as being closer and more satisfactory than the one with the US (Amit 1988).

³⁸ The alliance with the US did not commence until after the 1973, war and even today the US does not allow Israel access to a number of crucial technologies (Vekstein 1999).

the state of Israel, the 1948 War of Independence and the continuing security threats propelled Israel's development of computing onto a different track. While academia, mainly the Weizmann Institute, continued to develop three generations of scientific computers called the "Golems," the defense apparatus and the state bureaucracy quickly became the torchbearers of computerization development in Israel.³⁹

Probably the first unit in the Israeli defense complex to develop and use computers was RAFAEL (the Hebrew acronym of: armament development authority).⁴⁰ RAFAEL, the first, and for many years almost the only, body in Israel to conduct high-tech R&D, had already started to use computers in the 1950s. In 1956 RAFAEL built an analog computer, one of the first analog computers ever made and designed in Israel. In 1959, RAFAEL created a more sophisticated analog computer, "Itzik," to enable larger-scale simulation. Later, RAFAEL developed a few early digital computers.⁴¹

The way RAFAEL was organized is an example of the high esteem that science had in Israel and the way it was used in building a national identity. RAFAEL was organized until the early 1990s more as an applied academic institution than as a company. Its researchers were considered academics and were granted all the educational benefits of full-time academic staff including a sabbatical every seven years, which most of them spent outside Israel at leading academic universities or IT companies. RAFAEL

³⁹ It should be noted, however, that the Golems were highly advanced worldwide. The building of the first electronic computer in the US was finished in 1952; the first Golem, which was built on a similar scale to the first US computer was finished in 1954, see also, Ariav, G. and Goodman S.E. (1994).

⁴⁰ Some might find it ironic that Raphael (spelled in Hebrew in the same way of Rafael) is the biblical angel responsible for healing (Rapha is the verb for heal, while AI stands for god).

⁴¹ The story behind the formation of RAFAEL is also of interest as it illuminates the significant influence and importance that prominent scientists had on public policy in the decades before and after Israel's independence. The initiative to create a special "science corps" was presented by two professors, Aharon Katchalski (the brother of Ephraim, head of the 1968 Katchalski committee) and Yuchanan Rutner to David Ben-Gurion, the leader of the biggest Zionist organization in pre-independence Israel and its first Prime-Minister, before the 1948 Independence War. In 1958, the science corps were separated from the Israeli Defense Forces and another prominent biochemist from the Weizmann institute, Aharon Bergman, stayed on as its first head (with Munya Mardor as its first MD).

sponsored graduate academic education for its employees both in Israel and abroad, amounting to more than a few thousand graduate degrees in Israel, and a few hundred in top US engineering schools such as MIT and Stanford, to which these graduates returned regularly as visiting scholars. Thus, from the point of view of a national contribution and international scientific connections, RAFAEL acted as a small-scaled elite engineering university.⁴²

RAFAEL played two other important roles, aside from being an important source of information diffusion in the areas of science and technology and R&D management, and generating spin-offs.⁴³ First, some of the scientists who founded RAFAEL, such as the Katchalski brothers Efraim and Aharon, formulated Israel's science-based industrial policy at the end of the 1960s. Second, RAFAEL was used by the state as an incubation center to "infect" other defense and civilian companies and organizations with IT R&D capabilities.⁴⁴ The most important of these were: i) the creation of the Israeli military computer unit (MAMRAM) in 1960 (Breznitz 2005a). ii) The first attempt in 1962 to upgrade the Israeli Aircraft Industries (then known as Aircraft Maintenance Corporation) into a high-technology company with the relocation from RAFAEL of the entire project team that developed the Gabriel, the first Israeli sea-to-sea radar guided rocket. iii) The creation in a joint venture with the Elron group, of a high-tech start-up called Elbit in

⁴² It is important to remember that the head of RAFAEL, even after it was separated from the IDF, was a member of the chief of staff forum ("Forum MATCAL"), the leading discussion and decision body in the Israeli security apparatus, a telling indication of the importance given to indigenous R&D throughout the history of the Israeli state.

⁴³ For example, RAFAEL pioneered the use of operations research and project management techniques such as P.E.R.T in Israel.

⁴⁴ Some of the data regarding these decisions is still classified; however, large parts of it have been published. For more details see the memoirs of Munya Mardor RAFAEL's first CEO, (Mardor 1981) and (Efrati 1999; Rehav 1998).

1966, the R&D basis for which was created by the relocation of the entire digital computer development team of RAFAEL to Elbit.⁴⁵

A second major computerization and software programming effort was conducted in the Ministry of Finance.⁴⁶ In 1960, the Deputy Income Tax Commissioner Emmanuel Sharon decided to computerize tax assessments. Due to the absence of software programmers in Israel, a special course was arranged, very similar in organization to the Military's MAMRAM's core programming course, on a onetime basis.⁴⁷ Graduates of these two centers later became the early leaders of the Israeli software industry.

While the state apparatus was generating future IT industry leaders, two interesting parallel developments in the private sector occurred. Their importance is not just in the fact that they culminated in the first globally successful Israeli IT companies, but also that they clearly show the differences between the co-evolution of state-industry relationships in Israel and that of Ireland's and Taiwan's. In Israel it were private entrepreneurs who gave the impetus to critical policy decisions, including the idea of financing industrial R&D ventures. This was possible because of the porous and flexible structure of the bureaucracy and its early embeddedness within the industry. These early

⁴⁵ Elbit's first product was a mini-computer that competed head to head with Digital's. Later Elbit moved toward more defense-oriented markets and is now Israel's largest defense high-technology company. In 1971, the American multinational CDC bought the Ministry of Defense's 50% share. In 1983 Elbit first listed on NASDAQ, and as of 2002, three of Elbit's companies -- Elbit Medical imaging, Elbit Ltd. and Elbit Vision System -- were listed.

⁴⁶ Interesting and, in retrospect, highly amusing were the conclusions of the 1960 Ministry of Finance committee for the assessment of computer uses in the Israeli national economy. Headed by Professor Dostrovsky from the Weizmann institute, the committee concluded that two Philco computers should be enough for the needs of the whole national economy in the years to come. These conclusions were sponsored by the Ministry of Defense with the hope that someone would buy a second Philco to be used as a backup to the one in MAMRAM. Fortunately enough, no one paid any attention to these conclusions, not the least the committee's own secretary Emmanuel Sharon, who at the same time was organizing the computerization of the Ministry of Finance.

⁴⁷ See, Sharon and Naamen October, 1961.

efforts of private industry were also critical for laying the foundation for the intimate relationship between the Israeli IT industry and the US, fashioning not only their basis but also the specific form that they would take in the future.

While most of the banks and investment companies in Israel, like their Irish and Taiwanese counterparts, found investing in the IT industry too risky, there was one critical exception: Discount Investment. At the time, the group was called the Israeli Company for Investment and Finance and was headed by Dr. Augusto Levi. Italian born and educated, Dr. Levi decided to follow the export-oriented industrial investment model of Italian banks. At the beginning of the 1960s, Dan Tolkowsky, who left the military after commanding the Israeli Air Force, joined Discount Investment. Tolkowsky became instrumental in moving the discount group into high-technology investment. In 1961, he first met Uzia Galil, the founder of the Elron group. Elron was the first, and for many years the main, hub of IT NTBFs in Israel. Throughout the 1960s and 1970s, the Elron group and Discount became the two main sources of NTBFs in Israel. Elron, Elbit, and Elscient, all of which later had IPOs on NASDAQ, were created by Galil with Tolkowsky, as the manager of Discount Investment, becoming their chairperson.⁴⁸

In 1965, without realizing it, Tolkowsky and Galil started the process that would culminate in Israel's first S&T industrial policy and development agency. Concluding that without state support there would be little hope for the industry's future, they came up with the idea of organizing a small industrial R&D grants program and presented it to the Ministry of Trade and Industry, arguing that the creation of "science-based" industry

⁴⁸ It is at this critical point – the birth of the Israeli high-technology industry – that we see again the importance of Israel's academic infrastructure, Galil started his forays into the private market from the Technion, and recruited Suhami, Elscient's (the combination of Elron and Science) co-founder, while Suhami was still a Ph.D. student. Indeed Elscient's first medical imaging products, on the basis of which Elscient became the first Israeli company on NASDAQ, were related to Suhami's work in the Technion.

was important for Israel's economic future. At the time Aharon Dovrat, then a protégé of Sapir, was the manager of the industry department in the Ministry.⁴⁹ In another example of the power Israel's bureaucratic structure confers on its politically backed mid-managers, Dovrat accepted the idea and was able to create a part-time position for a chief scientist to evaluate industry R&D-based new product proposals for support from a very small fund. Thus, it was the efforts of entrepreneurs that secured the creation of the forbearer of OCS.⁵⁰

Tolkowsky was also crucial at another decisive juncture for the Israeli IT industry, its relationship with the US industry, financial markets, and stock exchanges. In 1971, he flew to the US to interest the still young VC industry in investing in Israel. Knowing that on merit alone he would have limited chances, he approached Arthur Rock, who was not only one of Silicon Valley's most famous VCs (Rock was crucial in securing the financing for Fairchild Semiconductor and Intel, and later became involved in Apple), but, even more importantly for Tolkowsky, was Jewish. Rock turned him down, but introduced Tolkowsky to the other famous Jewish VC of the time, Fred Adler of New York (Adler was involved in Applied Materials and Data Systems at the time). Adler still remembers Rock's phone call:

“I got a phone call from Arthur about Dan Tolkowsky. He told me that Dan is seeking someone to invest in Israel. He then told me about Dan and his background: a fighter for the British RAF in WWII who became the

⁴⁹ Aharon Dovrat, Argentinean born, later left the civil service to become the CEO of Clal, an investment vehicle created by Sapir to channel and manage the investments to Israel of Jews from Latin America. Under his management Clal became one of Israel's prominent holding companies, and Dovrat, who left Clal in 1991, became one of Israel's prominent businessmen. In another example of Israel's porous borders between public and private Dovrat was also the chair of a committee (known as the Dovrat Committee) on the restructuring of Israel's K-12 education system, whose report has been accepted by the government as the basis for a radical and controversial reform, which the government hope to implement in the 2005/6 school year.

⁵⁰ To verify this account, interviews were conducted with Dan Tolkowsky 6/7/2000 and 8/10/2000, Uzia Galil 8/9/2000, and Fred Adler, 9/28/2000, see also Levav, Ibid, and Autler, Ibid.

commander of the Israeli Air Force. You must remember it was only three years after the 1967 war and I must admit that it got me so interested in the man himself that I wanted to meet him just because of that” (Interview with Fred Adler 9/28/2000).

Tolkowsky had better luck with Adler who later visited Israel and became involved with Elscient. Realizing that he could not raise VC for the company, Adler decided to bypass the VC stage altogether and raise money through an IPO in the US on NASDAQ. Adler assumed that after several IPOs had been successful, the Israeli industry would look more inviting to American investors. In the end this strategy would work, but it would take more than two decades and a critical state policy initiative.

Thus, by 1972 the Israeli IT industry already had its first global success and foreign listed IT company with American VCs on its board. Implementing its “self-reliance” ideology in the development of the high technology defense industry the state was gearing the accumulation of resources and skills toward a specific path of new product innovation. Furthermore, thanks to the high esteem science and scientists enjoyed in Israel and the efforts of private industry, the backbones for what would become Israel’s critical high technology development agency had been established.

Restructuring S&T Industrial Policy on the Side – The Creation and Early Activities of the OCS

In May 1966, in the midst of Israel’s first recession, Prime Minister Levi Eshkol convened a committee to look into the organization of government-backed research. The economic crisis convinced him that Israel’s industrial policy had to change and that one of the only sources of growth for a resource-poor country, was science. The second reason for convening the committee was that Eshkol faced a tough political challenge when the legendary leader of the labor party and Israel’s first Prime Minister, David Ben-

Gurion, decided to organize a new party and run against him, with the utilization of science in Israel at the top of his political agenda. Eshkol nominated his long time friend, Professor Ephraim Katchalski-Katzir then head scientist of the Ministry of Defense (as well as a university professor), as the head of the committee. Katchalski was a renowned scientist and involved in the early development of defense R&D in Israel.⁵¹

Contrary to the common myth that credit to the Katchalski committee for the creation of the OCS in its present form, the committee's original aim had very little to do with it. It is true that its recommendations started the process that led to the institutionalization of S&T industrial policies in Israel. However, the reconstruction of the OCS had to wait in what since has become a pattern until Israel's political leaders nominated a powerful outsider to head and reconstruct the OCS. The mission of the Katchalski committee was to review the fourteen civilian public research institutions and offer recommendations for their restructuring and management. The committee was also asked to review the working of the Israeli R&D authority (the Israeli equivalent to the NSF).⁵² The committee met thirty times over the course of eighteen months and conducted the most extensive research ever done in Israel on the role of science in the modern state's economic life, the role of the state in the advancement of science for the use of the economy, and the workings of the public research institutions in Israel.

In December 1968, the committee submitted its report and recommendations to Prime Minister Eshkol in a very different Israel from that of 1966. In the intervening period, the country had decisively won a war on three fronts, and, as a result, had much

⁵¹ Katchalski would later become the President of Israel, the symbolic head of state. At the time science and scholarly activities were so highly regarded in Israel that all the first four Presidents of Israel were renowned scientists or scholars.

⁵² See the letter of appointment to the committee Katchalski 1968. Pp. A/1-A/2.

more faith in its capabilities; it had also begun a massive industrial defense R&D effort, and had to deal with the Arab economic embargo.

Apart from its various recommendations for changes in the management of the public research institutes, the Katchalski committee report had a long-term influence in two areas. The first was its recommendation for the creation of an official position of a Chief Scientist in each of the main ministries. The role of the Chief Scientist was envisioned as the overall manager of the public research institutes and other R&D activities that related to the ministry's jurisdiction. The second role of the Chief Scientist was to be the personal advisor of the minister for science-related issues. This recommendation gave formal governmental legitimacy to the activities already conducted in the Ministry of Trade and Industry. The Chief Scientist positions were specifically designed as outside consultant positions. This allowed the ministries to hire people outside the civil service and offer them better wages.⁵³

The Katchalski committee also argued that the ability to convert basic science into practical technology was the key to national economic success, and then sharply lamented the fact that in Israel there was almost no civilian industrial research. The committee urged the Israeli state to take responsibility and spur civilian R&D activities. It contended that the Israeli state should act through the creation and restructuring of the industrial R&D infrastructure and through the work of the public research institutes. This turned out to be its more lasting influence.

Thus, the report not only led to the creation of offices of chief scientists in all of major ministries, but also, on the basis of a comparison of Israel to other countries,

⁵³ Positions of Chief Scientists exist today in all the major ministries and act more or less as envisioned by the Katchalski committee. The OCS has been the only one of these to grow into an industrial development agency.

crystallized a consensus that the economic future depended on the creation of science-based industries. These industries were portrayed in terms of R&D leading to new products and technologies. This conceptualization, together with the extensive and highly successful defense R&D efforts and a realization after the 1965-67 crisis of a need to change Israel's industrial policy, would eventually lead to the evolution of the OCS as an industry development agency.

From a Part-time Chief Scientist to the Rise of the OCS as Israel's Pilot S&T Industrial Agency

Between 1968 and 1974, the OCS continued to work in its earlier format, a part-time job of a university professor.⁵⁴ The OCS was inactive and most of its industrial R&D budget was still channeled to the public research institutions. Even when companies came with proposals, they faced a heavy bureaucracy, at times waiting for more than two years without getting a final answer to their proposals. However, during that time, the Ministry of Defense was busily developing the R&D capability of the defense sector. Most of the data about those activities is still restricted. But it is quite clear that the defense industry stimulated the changes of the Israeli labor force's skill structure between 1967 and 1980. In that period Israel had, at 260%, the highest growth rate of scientists and engineers employed in the industry in the world, twice the rate of Japan's economic miracle age (Halperin and Berman 1990). The implementation of the self-reliance in defense production doctrine was transformed in these years into major R&D efforts on almost all fronts and on almost all the platforms and equipment used by the military.⁵⁵

Most of the decision makers in these years thought that there was a perfect match between the goals of establishing a strong R&D-based defense industry and the economic goals of the Israel state, viewed as building a strong globally successful R&D-based high-

⁵⁴ Professor J. Gross was the first chief scientist, starting his tenure in 1965. He used to come to the office for one day per week (interview with OCS' chief economist 5/7/2002).

⁵⁵ This concentration on R&D was so high that in the first half of the 1980s the cumulative expenditure on defense R&D was higher than the cumulative expenditure of final systems procurement (Halperin 1987; Halperin and Berman 1990. Pp. 159.) Moreover, in 1984, one project alone, the Lavi (fighter jet), employed 10% of the overall supply of skilled R&D scientists and engineers in Israel. This demand, emanating mainly from the defense sector, led to the rapid expansion of the universities' educational capacity. If the *total number* of scientists and engineers in the industry (defense and civilian) in 1965 was 2427, by 1985/9 the *annual rate* of scientists and engineers finishing their studies (both graduate and undergraduate) in IT related disciplines was 4785 (CBS 2004).

technology industry. There is no doubt that the structural transformation of Israel would have never happened so quickly without the thrust given by the defense sector. This is especially true until the mid-1980s, when the negative effects such as the crowding-out of the private industry in the labor market started to overwhelm the positive effects of this strategy.

While these activities in the defense sector were on going and an internationally-renowned massively R&D-focused defense industry was created, very little happened in regard to civilian S&T industrial policy until the end of the 1973 war. By that time, two major transformations occurred that would convert the OCS to an active development agency: Elscient successfully went through an IPO in NASDAQ, supplying a “proof of concept” and a model for imitation. Secondly, with the 1973 war, the perception of the need to restructure the civilian industry became more urgent. In 1974, the Minister of Trade and Industry Haim Bar-Lev, a former Chief of Staff of the Israeli Military, recruited Itzhak Yaakov as the first full-time chief scientist.

From 1955 to 1973, Yaakov had served in commanding positions within the military’s R&D division. As head of the armament development department and as the overall head of R&D in the military, respectively, he was responsible for the management of the major transformation in defense R&D. Additionally, Yaakov’s educational background, as an engineer with an advanced degree in technology management from MIT, and his international connections, not the least with the World Bank, made him uniquely suited to this role.⁵⁶ Yaakov was promised a free hand and sufficient financial resources, as well as the political backing that allowed him to transfer his ideas to

⁵⁶ Yaakov was also a protégé of Katchalski, who was then serving as the President of Israel. After leaving the OCS Yaakov served as a special advisor of the World Bank to Taiwan and South Korea at the time they went through their rapid high technology industrialization period.

reality.⁵⁷ This was the first example of what has since become a pattern of S&T industrial policy development in Israel. Managers within the bureaucracy, many of them recruited from outside, are given a free hand to formulate and implement policies and build programs and agencies.

On taking the position, Yaakov moved on four fronts. First he formulated the goals and aims of the OCS. He prescribed an S&T industrial policy in which the state role was to fix the market failure in R&D by lowering, but not eliminating, the risk associated with R&D activities. The economic goal was the growth of industrial exports based on new science-based products. Private firms were seen as the optimal agents not only to conduct but also to decide what R&D projects to undertake and what technologies to develop. The logic behind this assumption was that private firms, deeply embedded within their markets, are far better equipped than the state or any other research institutions to formulate and devise successful product R&D projects.

Therefore, the state's role was limited to motivate private entrepreneurs to conduct more product R&D. The main way in which this was done was through the central R&D fund that granted 50% of R&D costs to project proposals submitted to and approved by the OCS in repayable loans (the loans were repayable as royalties only if the products were profitable). In addition, the bureaucratic processes were simplified, so, for example, a company could sign an agreement with the OCS within ten days of a proposal approval (OCS 1974; OCS 1975).

Seeing private companies as the optimal source of R&D ideas and performance agents, the OCS also sharply decreased the support it channeled to the public research

⁵⁷ While vastly larger than the funds given to the OCS before, the sufficient financial resources proved to be in the first year just above 15 million Israeli Liras (compared with the about 500 million Israeli Liras that were channeled into defense R&D annually at that time).

institutions, although it guaranteed that for joint ventures with private industry it would sponsor the institution's 50% of the project's cost (OCS 1974). This was a major break with the past, and since that day the importance of public research institutions to industrial development in Israel has been marginal.

Third, in 1974 Israel reached the upper limit of what the World Bank then defined as a "developing country." Yaakov, with the backing of Sapir and Bar-Lev, channeled the last World Bank loan to Israel into a program titled – "national R&D projects," which allowed the OCS to give 80% grants to up to eight projects. In addition, after President Nixon's visit to Israel, an agreement was signed to create a cooperative R&D fund for Israeli and American firms (OCS 1974). This fund, under the management of another outsider, Ed Mlavsky, would later play a vital role in the development of the IT industry as the BIRD foundation.

Yaakov also won approval for the OCS to grant the status of *approved factory* to science-based firms, giving them all the benefits provided under the *law for the encouragement of capital investment*, the same law used to grant aid to plants in the newly constructed peripheral cities.⁵⁸ That linkage became more important in later years when MNCs with R&D centers that registered as a company in Israel were de-facto operating under the same favorite tax regime they were granted in Ireland, and when Intel, National Semiconductors, and Tower applied for aid under its provisions when constructing silicon chip fabrication plants.⁵⁹

⁵⁸ Science-based firm was defined as: "a firm that its operation necessitate a high technological level and highly educational workforce, and that the firm conduct R&D activities that are high in relation to its overall activities and that a high percentage of its production and exports is based on these R&D activities" (OCS 1974). This definition gave the OCS the ability to define as science-based firms all the firms with approved project proposals.

⁵⁹ While probably critical in securing the construction of the fabs in Israel, the overall economic effects of the capital investment law were probably negative even in the 1990s, see Bregman et al. 1998.

Fourth, Yaakov transformed the OCS into an active industry-engaged agency.

Very shortly after his nomination he initiated company visits throughout Israel and urged the companies' managers to come up with ideas. These activities by the OCS quickly bore fruit; by 1974 the OCS approved 70 million Liras in proposals, three and a half times the amount approved in 1973. Yaakov recounted that some of his major problems were to change the mind set of the agency:

“Civil servants thought that industrial R&D was a waste of money, that the money could be better used to buy meat in Argentina, it was, don't forget, the Ministry of Commerce and Industry. There was also this belief that innovation came from public research institutes... I had cases where the office workers came to me and said: 'this project has no use and there is no need for it,' I'd usually send them back to the company that proposed the project to check it in person. More often than not they would return with their head between their hands because the company, operating in the market, knew better. I really wanted to get more industrial R&D activities in Israel off the ground, and I must admit I cut corners. For example, I went to the founder of Elscient, and told him, 'bring me one R&D project which you want to conduct and you cannot for lack of capital and I will declare it a national project and use the World Bank's finance to grant you 80% of cost.' He thought about it for a day and told me that he decided that CAT Scan is the future <this is indeed the technology on which Elscient flourished during the 1970s and early 1980s>. I said O.K. I will give you a letter granting you up to half a million liras and within a reasonable time send me a proposal and I will make sure it is approved. Now because it was a World Bank project I needed to assemble a prestigious research committee with a lot of academics. These professors wanted to show that they are smarter than the industry and argued that in Holland they already work on CAT Scan technologies. I had no choice, I fired the whole committee on the spot and filled it with people from my office that did not have a vested interest to show how smart they are.” (Interview with Itzhak Yaakov 9/28/2000).

The same picture of the OCS at the time was reflected in one of the OCS's first employees' recollection of that period:

“During the Yaakov period we tried to create a dynamic of R&D activities, we wanted the industry to routinely conduct R&D and to create a dynamic that will infuse these ideas that R&D is something that should be done throughout the industry. To create a sort of paradigmatic change in the way businesses thought about what they are doing. Nobody in the industry even thought about R&D at the time, it seemed to them as a horrible risk, so Yaakov just started going around the country trying to convince managers to conduct R&D. We

did not really care who, what, why, when, we just wanted to create an R&D dynamic” (interview with OCS employee 5/7/2002).

Needless to say, this mode of behavior is far removed from Weberian ideals.

In early 1978, Yaakov left the office to become a consultant of the World Bank in Taiwan and then in South Korea, before turning to private business and joining the American firm CDC. True to the revolving door between state and industry, he became instrumental again in the 1980s. Before he left, he submitted a series of policy papers formalizing the goals and aims of Israel’s S&T industrial policy, the role of the OCS in achieving these goals, and the procedures that the OCS should use in order to achieve them. These policy papers defined the role and scope of the OCS for years to come as a quasi-independent agency and became the basis for the OCS operation, with many of their provisions incorporated into the 1984 Law for the encouragement of R&D (OCS 1974; OCS 1975; OCS 1977; Yaakov 1974).

The most enduring legacy of these years has been, however, the ideological one. In a 2000 interview, Yaakov expressed his belief that industrial R&D remains Israel’s only economic future:

“From the national point of view, a failure in a research and development project is not a loss. This is especially true in the case of developing and resource starved countries such as Israel. *This was my sole guiding principle when I gave grants to companies. This is the philosophy that guided me all the time*, and I had many arguments about it with the civil servants at the Ministry of Commerce and Industry. If truth be told, if you took the long term, there was almost no approved project that failed to deliver some tangible results from the national point of view in the end. This is another thing typical to industrial development. Like old soldiers, R&D projects never die. There is always the sequel.” (Interview with Itzhak Yaakov 9/28/2000).

Over the years the OCS developed a core of professional long-serving high-level personnel with a special ethos and a strong identity. This is true even though a large percentage of its staff, including the chief scientists and many of its top advisors, has

been recruited for a limited period of service from the private market. Nevertheless, the early recruitment processes of the OCS clarify more than anything the differences in bureaucratic structures among Israel, Taiwan, and Ireland. People who were deemed worthy were recruited to jobs at all levels of the organization disregarding formal channels. For example, a top executive of the OCS recalled the ways in, and the reasons for which, she was recruited:

“Just before the enactment of the R&D law in 1984 the State-Comptroller came out with a report strongly lamenting the grant giving procedures of the OCS. This was the reason I was recruited. It was quite amazing when I arrived. There were neither coherent financial procedures nor procedures of how to manage the relationships with firms and how to recognize R&D costs. My first job was to create some semblance of order in this mess, the Chief Scientist at the time was very thankful. He was quite worried and no one here had a clue what to do” (interview with an OCS employee 5/7/2002).

Looking at our theoretical framework we can see that by formalizing the OCS’ role as fixing the general market failure associated with industrial R&D, Israel has become the first state in the world to employ as its main S&T industrial policy a set of policies that are both neutral and horizontal in regard to industrial sectors and technology (Justman and Teubal 1995; Teubal 1983; Teubal 1997). The aim of horizontal technological policies is to stimulate a certain set of activities and capabilities throughout industry, without targeting particular industries or technologies. However, with the success of companies in certain sectors, accordingly, the buildup of more focused capabilities, and the general trends of demand for certain technologies in the market, the system began over time to specialize in certain areas. The private market, not the state, determined the areas of technological specialization. In Israel, for example, we see a

build-up of capabilities in IT, particularly in telecommunication and medical equipment.⁶⁰

The Reaffirmation of the Local-International Division of Labor – BIRD Foundation

In 1976, two years after the initial agreement between the governments of US and Israel was signed, the Bi-national Industrial Research and Development Foundation (BIRD) started operation. In a similar way to the reconstruction of the OCS, only after a strong-willed outsider was put in charge did it become the critical and active developmental agency it is today. The idea behind the creation of BIRD was to encourage cooperation between firms from the US and Israel to jointly develop and sell new products. An endowment, later increased to \$110 million, was created as the financial basis of the foundation. BIRD was put under the jurisdiction of the OCS and under the auspices of the U.S.-Israel Advisory Council on Industrial R&D that consisted of senior scientists, officials, and businessmen from both the US and Israel.

At first, BIRD did not have any impact. Under its first director, Wade Blackman, an MIT graduate recruited in the US, BIRD did not manage to make even one investment. Ed Mlavsky, then an American member of the US-Israel Advisory Council on Industrial R&D and a cofounder and Executive Vice President of Tyco international described these times and the chain of events that led him to become BIRD's second director in 1978,

“I got a frantic phone called from Jack Goldman <then the VP for technology at Xerox>. “Ed,” he told me, ‘We must find a new director for BIRD. Not even one single project has been started, Wade is leaving, and the Israelis are impatient.’ The council convened a committee to select a suitable candidate. We met in New York. The committee was filled with very impressive people.

⁶⁰ In 1998, 78% of total R&D expenditures were spent in the optical and communication electronic sub-sector (Bentur 2002). See also graphs 1 and 4.

However, the candidates were not at all impressive. It was then that I made a fateful remark that just shows you that one has to take full and firm control of his mouth at all times. I said: "Gentlemen, this is horrible, even I can do a better job than any of them." Before I knew it all these notable people, including Jordan Baruch <then the Under Secretary of State under Carter> start to pressure me to go to Israel and check it out. I told them that they are insane, that there is no way I will do it. I even reminded them that I am married and my new family is not Jewish, that we have no emotional connection to Israel. In the end I agreed to come for two years. We put our US furniture in storage and I took a two years Sabbatical from Tyco" (interview with Ed Mlavsky 6/12/200).⁶¹

Mlavsky came to Israel in June 1979, originally for two years, and stayed as BIRD's director until January 1993 when he co-founded Gemini, one of the first Yozma initiative VC funds. Under his management BIRD became an active organization that, like the OCS, did not follow the Weberian ideas for bureaucratic management and development. Mlavsky described this process: "we just started to do things and crystallized a model after we had some cases to build on."

This model is still the cornerstone of BIRD to this day. BIRD funds up to 50% of a joint project in which two companies, one from Israel and one from the US, agree to develop and sell a joint product and to share the revenues. BIRD's aim has been for Israeli firms to concentrate on R&D and the American on product definition and marketing.⁶² BIRD coaches Israeli firms on how to approach, and cooperate with, American companies, a key skill that was not widely available to the Israeli IT industry until the end of the 1980s. BIRD also helps in the matching process and to that end maintains a database of American companies that might be interested in R&D, including

⁶¹ Dr. Ed Mlavsky was Executive Vice President of Mobil Tyco Solar Energy Corporation, a joint venture created by Mobil Corporation and Tyco Laboratories Inc. to develop and commercialize a novel photovoltaic technology initiated under Mlavsky's direction at Tyco, a company of which he was a co-founder in 1960. Until 1974, Mlavsky was a member of its Board of Directors and its Chief Technical Officer; in 1973, he became President and Chief Operating Officer.

⁶² As of 2003, with the growth of large Israeli companies, this division of labor was weakened to an assumption on BIRD's web site (BIRD 2004).

their product R&D areas of interest. This database is gathered by visiting hundreds of American firms.

Starting in the early 1980s, BIRD became prominent in luring MNCs to open R&D centers in Israel. BIRD helps, first, by exposing the American firms to Israel's R&D capabilities in a low-risk friendly environment. Second, BIRD actively convinces MNCs to open operations in Israel. BIRD employs two modes of operation, one assisting Israeli R&D executives who wish to come back to Israel, and the other approaching an MNC that participated in several successful BIRD projects and offering it to open an Israeli-registered R&D subsidiary. The financial benefit that BIRD offers is to recognize some of the R&D projects (starting with the first) of the Israeli-registered subsidiary as a BIRD project between the MNC's American headquarters and the Israeli subsidiary. Moreover, as the OCS also recognizes Israeli-registered MNCs' subsidiaries as Israeli firms for the purpose of R&D grants, they can enjoy both BIRD and OCS grants, enabling the MNC to start R&D operations in Israel at low cost. Both Dan Vilenski, who replaced Mlavsky as BIRD's director, and Dov Hershberg, the current director, emphasized the importance that BIRD gives to the luring of American MNCs to open R&D centers in Israel.

As with OCS, BIRD's financing is in conditional repayable grants, with the grants repaid as royalties of 5% of sales of the product to third parties, and for up to a maximum 150% of the original grant.⁶³ For many years BIRD has also been following the neutral horizontal policy logic and does not limit itself to targeting only specific sectors or technologies. BIRD became a spectacular success and a model for other bi-national R&D

⁶³ This gives firms the financial advantage that BIRD's grants and payments are treated as off balance financing with the royalties counted as pre-tax expenses but not as liabilities.

funds both in Israel and abroad.⁶⁴ It supports up to 35 full-scale projects (a support of \$500,000 to \$1 million over 2-3 years), and 20 mini projects (\$100,000 over a year) annually (BIRD 2000; BIRD 2004; BIRD Various Years). BIRD uses the royalty payments to increase the number of grants given. By the end of 2000, it had received a total of \$64 million in repayments, of which \$6 million accrued in 2000. The reuse of royalties by both BIRD and the OCS is another unique feature of the Israeli system.

Until the mid-1990s, when VC financing became available in Israel, BIRD and the OCS were the only two available sources of finance. Both of these institutions diffused a particular model of high-technology companies in Israel. This model views companies as R&D vehicles for the creation of new export-oriented products. The one and only high technology industry model it stimulated in Israel sees the industry as consisting of companies selling novel products based on intensive in-house R&D efforts. By financially supporting only firms that followed this view BIRD and the OCS were key factors in the creation of the particular model of the Israeli IT industry as a supplier of new technologies to the global IT industry production networks.

BIRD was also important in strengthening the R&D focus by enhancing a particular division of labor between Israeli companies and American MNCs. In this division the Israeli firms concentrate on R&D while their American partners participate in the product design stages and concentrate on marketing and sales. The relationship of Israel to the global IT industry's production network, in which Israel is a supplier of new

⁶⁴ BIRD's track record of success has made the foundation the subject of two Ph.D. dissertations in the US that tracked BIRD's project success factors, one at Wharton and one at Northwestern (Bizan 2001; Yahalomi 1991). By 1991, thirty-nine countries approached the US to establish similar programs, and BIRD itself became in 1988 a model of a Department of Commerce program, which was called the International Partnership for the Commercialization of Technology (IMPACT). In addition, many countries have signed similar agreements with Israel, and many more signed agreements between themselves and other countries built on the same model (Yahalomi 1991).

technologies, was further reinforced by BIRD's activities, with OCS' support, in luring MNCs to open R&D facilities in Israel.

Third, BIRD influenced the Israeli IT industry by enhancing its already existing propensity, after the success of Elscient, Elbit, and Scitex, to look on the US as the main market for both products and finance. In an environment where other financial resources were lacking, BIRD's encouragement of this American orientation throughout the Israeli IT industry cannot be underestimated. For example, in an internal evaluation of its activities, BIRD found that 75% of the Israeli companies listed on NASDAQ in 1992 enjoyed the support of BIRD, with a large percentage of these companies building their business around the basis of their BIRD project.⁶⁵ Last, but not least, apart from opening the doors of leading American companies to small Israeli businesses BIRD infused the Israeli system with two key skills: (a) knowledge of designing new products for the American market; (b) knowledge of conducting business based on new product R&D in the American market.

A remark by the founder and CEO of one company that received BIRD grants exemplifies these specific features of the foundation.

"For us BIRD was extremely important. We had a few BIRD projects. They enabled us, a company consisting of eight young people, who just finished their military service, to collaborate with big successful American software companies. BIRD not only put us through the door so we could actually talk to them and see what are the needs of the American market from the best sources possible, but also enabled us to offer them a risk free model. They did not need to put a dime on developing the product and if it was successful they distributed it using their channels. I see no other way in which an R&D team of

⁶⁵ During the interview with Ed Mlavsky, he insisted that this particular statistic is not of value because practically every Israeli company operating before the early 1990s used BIRD. Without getting into the debate of the exact influence of BIRD on NASDAQ IPO projects, the fact that BIRD assisted almost every Israeli company in this earlier formative period is another testament to BIRD's critical position in the Israeli IT innovation system during that period. In its first ten years of operation, 1979-1989, BIRD funded 156 full and mini-scale projects, of which 44% (69 projects) led to successful sales of new products (Yahalomi 1991. Pp. 124.)

eight Israelis could profitably sell so many copies in such a short time and also offer the needed customer support. Later when we decided to open facilities in the US our BIRD experiences proved invaluable. Our first two American employees knew us from earlier BIRD projects and they brought their friends. It would have been amazingly difficult for us, a god forsaken start-up from Israel, to recruit American employees of such quality otherwise” (interview with a software company cofounder and CEO 1/15/2002).

As the creation stories of the OCS and BIRD show, unlike the Irish and Taiwanese cases, in Israel the policy was not built as a part of an orderly overall strategic plan. Both the policies and the agencies were built in a process of trial and error, which was managed at the levels equivalent to a ministerial division head. In addition, proper bureaucratic procedures of orderly administration were not a defining attribute in the creation and development of the Israeli industrial development agencies.

Nevertheless, there are a few firm principles that have always been the backbone of Israel S&T policies. These can be defined as Israel’s particular variant of “Technonationalism” (Samuels 1994). First and foremost was the belief that new R&D on the technological edge with the aim to create novel products is the sole and proper basis for Israel’s high technology industry. The second principle is a clear definition of the role of the state, limiting it to a promoter and facilitator of R&D activities. The state goal is to maximize industrial R&D demand in private industry and to lower the risk associated with it. As a result, throughout the specific co-evolution of state-industry relationships that was built on the basis of these ideals, private firms were seen as the loci of both R&D-activities and ideas, a striking contrast to Taiwan.

With the formation of BIRD the Israeli state also started to advance a particular division of labor between the local and the global IT industries, where Israeli firms and MNCs who opened facilities in Israel were urged to focus on the R&D stages and specialize in the innovation of new products. This specialization in R&D was further

enhanced with the state's efforts to lure MNCs to open R&D subsidiaries in Israel, a very different policy than was followed by both Ireland and Taiwan in the same period.

The Rise of the New Industry – The Evolution of the IT Industry in the 1980s and Early 1990s

After the 1973 war, Israel suffered multiple economic crises that lasted for over a decade. Economic growth was almost halted, the balance of payments deficits rose in alarming proportion, and inflation rapidly rose to over 400% annually.⁶⁶ From 1977 to 1985, the first political transfer of power intensified the economic crisis. In 1985, a rainbow coalition government led a stringent stability plan. The plan succeeded in some areas; however, by the late 1980s, unemployment had become a problem, especially in the periphery.⁶⁷

In the same years that the IT industry grew, the traditional and mid-tech industries as well as agriculture continued to decline. Already by 1988, 59% of Israel's industrial exports were high-technology products, by 1998 over 71% of Israel's industrial exports were high-technology, and in 2000, the IT industry alone accounted for over 70% of GDP growth (CBS 2001). At the same time, in direct contrast to the developments in Ireland, Israel's corporatist wage agreement regime had been crumbling, with labor-union membership in rapid decline and the socialist ideology in rapid retreat.⁶⁸

By the end of the economic crisis in 1985, an IPO on NASDAQ was a legitimate and well-trodden path for the more successful Israeli high-technology companies.

However, the IT sector did not pass through the economic crisis unscathed, and with the

⁶⁶ Inflation in Israel was so high that by the end of the crisis Israel changed its currency twice. Between December 1978 and March 1986 prices rose by 109187%.

⁶⁷ For more about the causes of the crisis and the stabilization program, see an article written by the chairman of Israel's central bank at the time (Bruno 1989). Also, see Ben-Bassat 2002; Ben-Porath 1986.

⁶⁸ For more about the history of neo-corporatism in Israel, see Shalev 1992, and Grinberg 1991.

collapse of the banking system, both the Elron group and Scitex were faced with their biggest crises to date.

During the 1970s the growth of the IT industry was slow, the OCS found it difficult to allocate its maximum annual budget, and not many new NTBFs were formed. The main inhibiting factor, as in Taiwan and Ireland, was the unwillingness of private entrepreneurs to take risk. This entrepreneurship failing was identified as acute in the OCS' annual reports:

“It is evident that despite the opportunities described in this section on the one hand, and the massive government support on the other, too few new technology-intensive industries are being established... Clearly we have here *a problem of technological entrepreneurship*. Despite opportunities and massive government aid, there are not enough people willing to take the risk. To reach the ultimate goal of industrial R&D, i.e., new increased exports, *particular attention must be given to this phenomenon as well*” (OCS 1975. *Italics added.*)

After Yaakov's departure, the negative side of Israel's more flexible and highly embedded bureaucratic structure became evident. The OCS lost some of its standing. Not anchored in law, it was to fight chronic budgetary battles. The OCS' image was tarnished because of question marks over its capture by the industry appeared in the socio-political context of only a few relatively strong high technology industrial groups with political sway, and few new entrants (Stigler 1971). This was particularly true following political lobbying by Elscient that ended with a tax-sanction law, aptly nicknamed the Elscient law.

Until the mid-1980s when a decision was made to reduce defense R&D efforts and cancel the development of the biggest project, the development of a fighter-jet (“The Lavi”), the strategy of self-reliance in advanced weapon systems continued, and was implanted mainly in the R&D phase. In 1984, the year before the decision on the major

budgetary cuts was made, the annual defense R&D budget stood at \$750 million (in 1984 terms (Halperin 1987; Halperin and Berman 1990)). However, it is also important to remember that unlike the industrial defense sector the military did not cut down on its in-house R&D operations.⁶⁹

The intensification of the economic crisis gave another window of opportunity for the OCS to restructure itself and advance new programs, especially as it had the backing of two strong Ministers of Trade and Industry, Ariel Sharon from 1984 to 1990, and Moshe Nissim until 1992. The approval of the R&D law in 1984, the recognition of software as an industrial branch in 1985, and the cancellation of the Elscint law in the same year marked a change in S&T industrial policies and the move of the high technology industry to the forefront of Israel's industrial landscape. The period from 1984 until the beginning of the 1990s is the reconstruction period of the institutional basis of Israel's political economy.⁷⁰

However, under the new R&D law the OCS was quickly expanding its activities together with BIRD's. Sanctioned by the R&D law, which designated the OCS as Israel's official S&T industrial agency, the OCS regained its independence and public image as a professional agency. Critically, until the mid-1990s the R&D law authorized the OCS' main R&D fund to finance all of the projects that passed its due-diligence process. These

⁶⁹ The military enlists and trains a few thousands technologists annually. There are two paths in which the military itself employs and trains R&D personnel, first, through the "academic reserve," soldiers who are allowed to complete academic studies before starting active duty, serve as professionals, and in exchange sign for longer period of service. Many of them work in the military R&D units. The second path in which the military trains and employs R&D personnel, is the military's own training programs. These either operate in conjunction with the universities and aim to train an elite R&D personnel (the most prestigious program being "Talpiot"), or through in-house training, the most significant being software programming and computerization training, which is the sole technological area where the military has built its in-house technological school. For more about the military software school, see (Breznitz 2005a). The military has several units where IT R&D is being conducted.

⁷⁰ The transformation was not that apparent at the time and many commentators thought it had failed (Teubal 1993).

expanded financial resources significantly enhanced the ability of the OCS to create and sustain the industry's demand for R&D. Private IT entrepreneurship became more common, active, and successful.

The IT Industry in the 1980s and Early 1990s – The Growth of the Hardware Sector

Throughout the 1980s, with the available funds from OCS and BIRD reserved solely for R&D, two models of new company formation and growth emerged. Both of these models utilized the OCS and BIRD grants while answering two other financial needs: (1) the lack of working capital, especially for marketing and sales; and (2) the lack of expansion capital, especially acute during the first stages of international expansion.

Of the two broadly defined prominent organizational development models in this period the first was the creation of company groups. Successful entrepreneurs quickly found that they were being approached by other would-be-entrepreneurs looking for organizational and financial help.

Probably the one group that was critical to the industry's development is the Elron group, founded by Uzia Galil. It was Elron that pioneered the NASDAQ model, created the first connection with the American VC community, and was influential in the creation and early development of Israel's S&T industrial policy. Many of the group's companies, such as Elron, Elbit, and Elscient, but also less closely held ones such as Zoran, grew to become leading companies in the industry and listed on NASDAQ.⁷¹ Interestingly, the Elron group, unlike other groups, did not have a common technological sector, but

⁷¹ Zoran, Silicon in Hebrew, was established in 1983 by Levy Gerzberg to try out one of his ideas in the semiconductor industry. Today, after passing through a few transformations, Zoran is a fabless company applying DSP technology (digital signal processing – one of the Israeli IT industry's strengths and another indicator of its advanced R&D capabilities) to the image processing market, specifically DVD and digital cameras. In 2003, Zoran was one of only a few Israeli fabless companies in the world's top thirty largest fabless companies in terms of sales according to the 2004 McClean Report, with sales of over \$216 million a rise of almost 50% from 2002 (Insights 2004).

supported spin-offs and start-ups in areas that seemed to suggest an opportunity at the time to its management.⁷²

One of the companies growing out of this organization model, Orbotech, is also one of the only cases of Israeli companies managing not only to pioneer its market niche, automatic optical inspection (AOI) systems for Printed Circuit Board (PCB), but also to control it for a significant period. Orbotech's history also illuminates the wild competition and lack of planning in the Israeli IT industry in comparison to Taiwan and Ireland. Orbotech is the merger of Orbot and Optrotech, two Israeli companies that between them controlled the global market (85%) in their niche during the late 1980s, and merged in 1992. Dr. Shlomo Barak founded Optrotech in 1981 with the backing of the Elron group. Orbot was founded shortly after by a group of Israelis who first met in Boston where some of them were either professors or attended MIT. Ormat, another of the first globally successful Israeli high technology firms backed Orbot, which commenced operation in December 1982.

The second model of organizational growth was to build a company on the basis of OCS and BIRD foundation projects (as OCS grants are given per project, companies can enjoy several of these grants). Among the most successful were Gilat Satellite, Comverse, and Mercury, all of which became globally prominent companies in their market niches. In the second half of the 1980s, the move of defense-oriented companies

⁷² For more on the early electro-medical industry in Israel see: Teubal et al. 1976; Teubal and Spiller 1977. For a history of the semiconductors industry in Israel, see (Autler 2000). For a descriptive history of Israel high-technology industry see Levav 1998. For three accounts which briefly discuss the software industry and the causes of its success see, Ariav and Goodman 1994; Breznitz 2004b; de Fontenay and Carmel 2001.

into the civilian market accelerated. The most successful of these has been ECI Telecom that successfully moved, into the civilian market and listed on NASDAQ in 1982.⁷³

During the 1980s the flexibility and reach of the “porous borders” structure of the Israeli bureaucracy was crucial in securing another source of finance: “investor limited partnerships.” These partnerships were a classic example of state-business collaboration to achieve a common goal. The limited partnership model was organized after Yaakov, at the time working for CDC, discovered the existence of R&D tax incentives in the US. Yaakov (with others following him) collaborated with the OCS to create a specific set of legal entities to use the American tax shelter to channel finance into Israeli IT firms. Groups of US investors were assembled to form limited partnerships investing in the R&D efforts of a pre-selected set of companies. The OCS then assisted these limited partnerships with additional financing that was classified as loans for tax purposes, maximizing the tax returns for the American investors, and minimizing their risk exposure. The first limited partnership started to invest in 1980, and a few more followed, under the titles of Israeli R&D Associates (IRDA) or Israeli Technology Ventures (ITV). In 1985, the Reagan administration changed the tax regulations that were the basis of the limited partnerships. Activity continued in those that had already raised their funds until the late 1980s. All in all, the limited partnerships invested in 25 different newly created companies, the most successful of which were Technomatics, Comverse, Teledata, and Lannet. The main effect of these limited partnerships was to further strengthen both the

⁷³ ECI was established in 1961, and operated mainly as a defense contractor in the communication area. It went public on the NASDAQ in 1982 on the basis of its first internationally successful civilian product, which was an analog multiplexer; doubling the transmission capacity of telephone lines. After 1982, ECI quickly grew to become one of Israel’s most commercially successful companies until the end of the 1990s. At its commercial zenith, ECI had sales of over \$1 billion; today, the company is still in flux and its annual sales plummeted to \$421 million in 2003.

R&D focus within the Israeli IT industry and its connection to the American financial markets.

In the late 1980s, the growth of the telecommunication subsector of the Israeli IT industry helped another group of companies, RAD, to rise to prominence. The story of RAD is illustrative in several ways. Apart from the importance of the group itself, its growth marks a generational shift in the Israeli IT industry and with it the growing importance of graduates of the military R&D and intelligence units. Even more importantly, the growth and limits of the RAD group is one of the best examples of the strengths and the weaknesses of the Israeli model: creating the ability to secure a technological edge and to react quickly to changes, on the one side, and the relative lack of professional management, long term planning, and business development skills on the other side.

The Zisapel brothers, Zohar and Yehuda, formally established the RAD group (or the RAD-Bynet group as it is known in Israel) in 1981.⁷⁴ The Zisapels are both engineers and Zohar was a commander in one of the Israeli military's most respected electronic R&D units before he joined his brother in the civilian market. In 1985, the brothers decided to use their two companies as an incubator for R&D-based companies. Not having any specific plan or product in mind, they recruited Benjamin Hanigal, a young engineer who had just left the Lavi project and together the three started to search for ideas.⁷⁵ In 1986, Lannet was established and raised its first financing from the OCS and a

⁷⁴ Bynet commenced operations as early as 1973. RAD, the manufacturing, R&D, and internationally-oriented part of the group was established in 1981.

⁷⁵ Hanigal later became a VC, first with Star Seed, and currently is one of the three Israeli partners of Sequoia Capital, a prominent Silicon Valley VC firm with a dedicated branch in Israel.

limited partnership.⁷⁶ Just as Lannet was raising its limited partnership finance the American tax regulations were changed and Lannet managed to get only a third of the original sum. As a result, the company quickly changed course, starting operations with a different and smaller project. During its first year of operation Lannet started a second line of products using the technology on which it would grow, Ethernet. A former Lannet senior manager argued that the reason that Lannet could develop a product that sold successfully worldwide was the existence of a large pool of engineers within the group who were users of Local Access Networks (LAN) and could be asked to play the customers, helping in building the product specification.

As Lannet had no other sources of capital, it needed to rapidly increase its revenues and became profitable at a very early stage of operations. In 1991, Lannet had its first public offering in NASDAQ, having already an annual revenue stream of a few million dollars.⁷⁷ However, very quickly, the LAN market matured and started to consolidate. Lannet decided that it could not compete with the better-organized and more financially capable American firms. It merged with Madge, de-merged, and was finally bought by Lucent. In the end Lannet's Israeli R&D operations became Lucent's R&D center in Israel.

Motivated by the success of Lannet, the Zisapel brothers expanded the RAD group and opened about thirty companies following more or less the same strategy, recruiting or backing engineer-founders with ideas for a new product within the

⁷⁶ In an interview, one of the Lannet executives remarked that without the OCS' assistance, Lannet would have never been established.

⁷⁷ Unlike past public offering of Israeli firms, Lannet's IPO valuation of \$190 million was considered high even for NASDAQ in that period. Thus, Lannet's IPO, together with the IPOs in 1992, of the 4th (new) dimension, Teledata, Comverse, Lanoptics, and Sapiens, all of which with valuations of over \$100 million, was critical in changing the perception of American investors toward Israeli companies, to one which saw Israeli companies as being able to supply a profitable exit even for American VCs.

telecommunication market broadly defined. From one point of view, RAD is an immense success story, with the group backing the largest number of companies listed on NASDAQ apart from Elron. Another view sees it as a perfect example of the limits of the Israeli IT industry, if only for the reason that none of the RAD companies managed to grow even to the size of the still-privately-held anchor company, RAD Data communications.⁷⁸

The story of Lannet and its end as Lucent's Israeli R&D center also symbolizes another trend that grew in importance in the 1980s, the R&D activities of hardware MNCs in Israel. The rise in the scope of MNCs' activities was so rapid that it caused a concern in Israel that the IT industry had become no more than a node in the MNCs' global activities, with most of the innovation and spillovers going overseas and with only few local spillovers (Felsenstein 1997). In the 1980s the MNCs that had major R&D operations in Israel were almost solely American semiconductor MNCs. The most important of these MNCs in the 1980s, apart from Intel and IBM (which opened its first IBM research facility outside the US in Israel), were Digital, Motorola, and National Semiconductors.⁷⁹ All of these companies, apart from IBM, had VLSI chip design centers

⁷⁸ As of 2004 the RAD group companies that are listed in NASDAQ as independent companies are: Radware, established in 1997 by Yehuda's son Roy; Silicom, established in 1987; Radvision, established in 1993; RiT Technologies, established in 1989; Radcom, established in 1991; and Ceragon Networks, established in 1996 as Giganet.

⁷⁹ National Semiconductor activities were also important, as it was the second MNC to open fabrication facilities in Israel. The fab was opened in 1986, was spun off as Tower Semiconductors, Israel's first pureplay foundry, and listed on NASDAQ in 1994. Hence, Israel had one of the first pureplay foundries in the world after Taiwan. The existence of Tower's and Intel's fabs helped Israeli firms to access and try new semiconductor technologies, for example Saifun, in which Tower is an investor, develops some of the most advanced technologies to maximize the performance of FLASH memory chips. However, Tower never grew to become a globally leading pureplay foundry and many Israeli fabless firms prefer to subcontract their chip fabrication to TSMC and UMC.

in Israel, with all except Digital also having manufacturing facilities in Israel in the 1980s.⁸⁰

The relative importance of Israel as a supplier of new technologies is evident when we take into account that with one exception these Israeli R&D centers were the first that the MNCs had opened outside the US. The exception was Motorola but even Motorola's Israeli R&D VLSI center was the largest and most autonomous outside the US, and in 1964, when Motorola Israel was established, it was Motorola's first fully owned daughter company outside North America (R&D operations started in 1972, the VLSI design center in 1982). These centers became crucial as one of the main training grounds for the technological capabilities that enabled the Israeli IC Design industry to grow to become the fourth largest in the world, and the most innovative after the US-Canada, in the 1990s.

Thus, unlike Taiwan and Ireland, already in the 1980s MNCs viewed Israel as a preferred location for R&D and the development of new products and technologies. These R&D efforts were in some of the most advanced areas of research in the world at the time, such as microprocessors and applications of DSP technology. By the beginning of the 1990s, after the success of Israeli-based R&D operations of a growing number of MNCs, many more American MNCs started to look seriously at Israel and to acquire Israeli firms for their technologies. The fact that by that time both BIRD and the OCS were actively offering MNCs R&D-activities-related benefits served as a catalyst.

⁸⁰ VLSI stands for very large scale integration. To put the Israeli VLSI skills in context: TSMC's spin-off in 1987 was the successful conclusion of ITRI's VLSI project in Taiwan. Ten years earlier, Israeli engineers, in Israel, were already working on cutting-edge innovative design. The skills of the Israeli industry were well enough known that when National Semiconductors decided to start CPU design and manufacturing operations it chose to open an Israeli subsidiary to manage this new business venture.

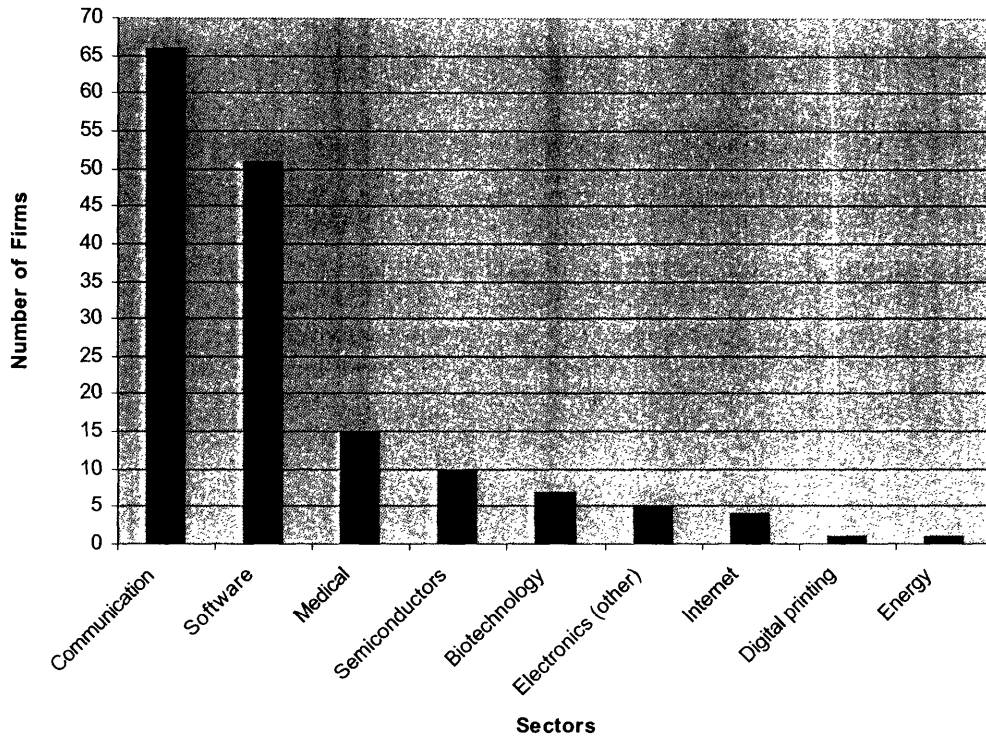
The importance of the OCS in that period, both in increasing the formation rate of new IT firms and in focusing their operations on new product R&D cannot be underestimated. Two prominent examples, out of a few hundred, are Comverse and Mercury Interactive, respectively the second and third largest software companies in Israel. The entrepreneurs behind both companies came back to Israel in order to utilize the OCS' help.⁸¹

As is evident from the stories of ECI, RAD, and Comverse this period also saw the early raise of the telecommunication sector to prominence within the Israeli industry, a position it still holds, as can be seen in Graph 1 below.

⁸¹ Comverse's beginning was in 1982. Kobi Alexander, an Israeli, was working as an investment banker for Shearson Loeb Rhodes (now Salomon Smith Barney) in New York, when he met an Israeli engineer, Boaz Misholi. Misholi had an idea for a business venture developing centralized voice and fax messaging hardware systems to enable big organizations and telecommunication service providers to offer voice and fax mail to their customers. Within a week, the two returned to Israel and established Efrat Future Technology with the aim of applying for OCS grants to finance their R&D. In 1984 the founders came back to New York and established Comverse, which became the parent company of the Israeli Efrat. Similarly to many Israeli companies in that period, Comverse went public on NASDAQ in 1986 and used its IPO as a final VC round. During the 1990s Comverse moved to rely more on software than on hardware products and started to grow also by acquiring other companies in Israel and the US. In 2000, Comverse's revenues were \$1.2 billion; in 2002, after spinning off two publicly traded software companies, Verinet and Ulticom, Comverse's revenues were \$735 million. While the full details of all the support Comverse has been granted through the various OCS and BIRD programs are not public, Comverse companies were awarded at least sixty-nine R&D grants for different projects through the main OCS program between 1990 and 2000. Mercury Interactive became Israel's third largest software company in terms of sales in 2003. It was founded by Aryeh Finegold, an Israeli who was the founder and manager in the 1980s of a once high-flying Silicon Valley firm, Daisy, and a group of former Daisy executives led by Amnon Landan the current CEO. The group decided that although they were very well connected in Silicon Valley they would establish Mercury with the help of OCS grants in Israel. At first Mercury following the well-trodden path for Israeli companies to focus on products assisting in R&D and software development developed a software-debugging tool. The company listed on NASDAQ in 1993, started to acquire other companies in 1995, and, with the growth in the importance of the Internet, changed its focus from software debugging to testing and analyzing the performance of enterprise and web-based applications.

Graph 1

Israel Internationally Publicly Traded Technology Firms - Cumulative Number by Main Market (1972-2001)



Source: Author's calculations.

Changes in both the domestic and international market in the telecommunication industry completely transformed this industry and made it the fastest growing IT industry worldwide in the late 1980s and all through the 1990s. These changes created a profitable market for niche companies with new technology, a category of firms which the Israeli IT industry, with its strong focus on R&D and new products, excels in.⁸² The first change was the transformation in the regulation of the telecommunication industry and the worldwide move from a regulatory regime that viewed the industry as a "natural"

⁸² It was also fortunate for the Israeli IT industry that the same technologies (telecommunication, DSP, and command and control) have also been some of the core technologies developed as part of the defense R&D efforts.

monopoly to one that specifically aimed to spur competition, opening a market for small R&D-based companies to sell into. The second was advances in telecommunication technologies, specifically in wireless and data communication, both of which opened up new, rapidly expanding markets with big firms looking for new services to offer and new ways to manage their old businesses.

Israeli firms quickly excelled as suppliers of new technologies in all niches of the telecommunication subsector pioneering for example Voice over Internet Protocol (VoIP) technologies, LAN systems and chips, DSP chips, urban networks, switches, routers, software, mobile phone technology, and internet wireless and “last-mile-solutions,” among others.

However, even in this sector success and sustained growth necessitate not only technological edge, but also some access to management, and business skills, as well as logistics and distribution resources. Acquiring these was not systematic and had more to do with good fortune and random effect. The story of Amdocs, the only Israeli software company to date to become one of the top 30 software companies in the world, and its critical relationship with SBC, is such an example. By 1984, Amdocs, then called Aurek, became a leader in selling automated telephone directory systems (Yellow Pages) in Europe. This proved to be of immense strategic importance when on the first of April 1984, AT&T was divided into seven regional telephone companies that were desperate to buy reliable software systems from companies other than AT&T. Very quickly Southwestern Bell (now SBC) and Aurek started a joint venture to develop and sell automated directory systems. With SBC backing and with a few software systems all aimed at this market niche, Aurek soon became the global leader in this small niche.

However, Aurek's transformation from a leading player in a marginal market niche to one of the world's top 30 software companies came in the early 1990s and was prompted not by Aurek but by SBC. SBC asked for, and assisted Aurek in developing, a telecommunication billing system. In 1995, the new package, called Ensemble, was ready for the market. The former partners in Aurek, together with SBC and a few other investors, established a Channel Island company called Amdocs, a new holding company for all of the Aurek group companies. Very quickly Amdocs, with the clout of SBC behind it, became the leading provider of billing systems for telephone companies in the US and later worldwide. In 1998 it went public on NASDAQ. Amdocs then showed remarkable strategic planning skills for an Israeli company and employed a strategy of mergers and acquisitions to become the leading supplier in another related niche – CRM systems to the telecommunication industry. In 2002, Amdocs concluded its second strategic transformation by becoming a full service provider to the telecommunication industry, offering integrated systems of billing, CRM, and order management systems. At the same time Amdocs started to offer outsourced services and a few companies, such as Nextel, turned over all their billing functions to Amdocs. While Israeli managers and engineers have been controlling and navigating this growth, without SBC's early guidance and constant support Amdocs would not have been able to grow in the way it did, and probably could not even recognize and realize the market opportunity in billing systems.

Thus, the success achieved by many Israeli IT companies in these years should not make us disregard the weaknesses of the Israeli R&D-focused model of development. The particular limitations of this model are apparent on both the micro company level,

and the macro level of the industry as a whole, and are caused by over-emphasis on R&D and technological-engineering capabilities. This focus creates an Achilles' heel in other areas of management, from marketing and market research to planning and business development. The lack of these capabilities, in particular of managing sustainable long-term expansion and defending market niches against new entrants, leave most Israeli IT firms vulnerable to competition from better organized and managed foreign firms.

The Beginning of the Software Industry – the 1980s and Early 1990s

In the late 1960s and early 1970s, while the seeds of the Israeli IT industry were planted and a few hardware companies achieved worldwide success, the software industry was practically non-existent. The industry consisted of a few service-oriented data processing centers and the IT units of government offices including the defense apparatus and a few big organizations. However, the rapid expansion of defense R&D and the fast accumulation of IT skills by both university graduates and graduates of the military technological units created local demand for IT usage, the knowledge base to supply it, and a positive attitude toward this nascent industry.⁸³

The first product-oriented software companies appeared only at the end of the 1970s and the beginning of the 1980s.⁸⁴ Unlike the first software companies in Taiwan and Ireland, they appeared within an industrial system that already had a few highly successful IT hardware firms that were publicly listed on NASDAQ, as well as an already well-developed local market that had many sophisticated users, most of whom were

⁸³ For more on the role of the military in the development of the software industry, see Breznitz 2005a.

⁸⁴ One company, Comet, that offered information management systems on IBM platform, was established in 1969 and had an IPO in 1994, but very quickly thereafter declared bankruptcy.

sponsored directly or indirectly by the state's defense R&D efforts.⁸⁵ Even more importantly, these software companies appeared in an industrial system where many R&D activities, both civilian and defense oriented, were taking place. Hence, a critical mass of knowledge on the problems associated with IT usage, the IT R&D process itself, and software development was amassed in Israel, and a large market existed for software products that solved them. As problems in R&D and software development are very similar worldwide, an Israeli software company that developed solutions for these had products that answered global needs. Moreover, the customers for these products, being engineers and programmers, are more sophisticated than the average consumer. Hence, software products that were too complex and crude in their user interface to be sold to the consumer market could still be sold to these highly skilled customers.

It is not surprising, therefore, that the common thread of most of the successful companies established in these years is that their products offered solutions helping with IT development. As we usually categorize companies by industrial subsectors, and not by their cognitive focus across sectors, some examples of the more successful companies are in order: OptiSystems Solutions, established in 1982, focused on optimization of computer systems; Magic, established in 1983, developed a Rapid Application Development (RAD) tool for relational database applications; Cimatron, established in 1982, has been offering CAD/COM software for the tool industry; Nikov Haifa, now known as Attunity, established in 1988, moved away from its origins in ERP consultancy and started to develop RAD tools for reports programming, a product line which brought it to NASDAQ in 1997 and has since been abandoned; and Sapiens, established in 1982,

⁸⁵ By 1984 the local sales of the Israeli software industry were \$365 million (1984 terms) higher than the total sales of the Irish-owned software industry in 1994 (1994 terms); therefore, the local market could support the growth of more than a few software companies.

has been focused on rule-based systems for RAD.⁸⁶ All of these companies were assisted, after 1985, by OCS R&D grants that enabled them to conduct large-scale R&D efforts, and all of these companies had an IPO on NASDAQ in the 1990s.

As venture capital to the industry was not available, the business model of many of these companies was either to create a joint venture with a more established company that acted as either the financial backer and/or the main customer, or to find their first customer before they started their development phase. A few also developed from an IT consultancy business, but not many of these managed to transform to a product-based business model successfully. In addition, as most of these companies could not secure enough capital to open an American branch, their first export market tended to be the European market.

Another common thread in this period is the importance of the state apparatus in being either the origin of the entrepreneurs, the companies' first and main customer, or the source of the technology itself. Thus, Amdocs had its origin in a team that worked for the Israeli Postal and Telecommunication Ministry and in a system developed as a joint-venture with the company that had the license to organize and sell the telephone directory of Israel. A team of former officers of the military's central computer unit (MAMRAM) established Magic Software Enterprises, and its first breakthrough sale was to the Israeli military. In addition, the state was sometimes the source of the software product itself; for example the Fourth Dimension (later known as the New Dimension) acquired from the

⁸⁶ For papers focusing on the evolution of the Israeli software industry and the histories of its various firms, see Breznitz 2004b; Breznitz 2005d.

Ministry of Defense a product for operations automation developed internally for the Air Force, in exchange for a promise to update and maintain it.⁸⁷

In the late 1980s both domestic factors, described in the earlier section, and external/international factors influenced the growth of the Israeli software industry. The external factors in these years that completely changed the software industry were the rapid diffusion of PCs, not only to the consumer and home market but also in the corporate market, and the growth of Microsoft's OS and programming platforms (first DOS and then Windows) as the dominant platforms and the de facto standards of the industry. The two most important effects of these technological changes on the Israeli software industry were: (a) the opening of new markets to the industry, while at the same time lowering the cost of development; and (b) the manifold enlargement of the global need for platform crossover and conversion technologies. This was a demand that the Israeli software industry, already experienced in developing solutions for problems that directly relate to IT development, was well positioned to supply.

Thus, during the second half of the 1980s and the beginning of the 1990s many software companies managed to enlarge their activities and penetrate foreign markets. Two examples of veteran software companies that took advantage of the growth of the global market and the new technologies are those of Magic and the New Dimension. During the second half of the 1980s, the two companies managed to first secure critical sales in Israel and abroad before moving into the American market. Both went public on NASDAQ in 1991 and 1992. Another development in the second half of the 1980s and the beginning of the 1990s was a new cohort of internationally successful companies. The

⁸⁷ Yossi Holnder, the technological founder of the Fourth Dimension, served as a software technologist in one of the military intelligence units, and had looked into the idea of acquiring the rights to several programs developed inside the military before settling on that specific one.

common ground of all the Israeli software companies established in this period, differentiating the industry from that of Ireland and Taiwan, is that all these companies were developed by software programmers who were actively looking for product ideas that offered solutions needed in their own industry – software programming.

Another common theme of these companies was the relative lack of business, management, and financial skills of their founders. This led many of them in the era before the advent of the Israeli VC industry to either join forces with other companies or to rely on luck and intuition, in their early product development and expansion to foreign markets phases. Precise is such an example. Established in 1990, Precise specialized in software systems optimization, and almost went bankrupt before it recruited Shimon Alon, a former manager of Scitex. Under his management the company stabilized, listed on NASDAQ, and was sold to the American software MNC Veritas in 2003.

The 1980s also saw the beginning of the subsector in which the Israeli software industry truly achieved global fame – data security. In addition, more than a few Israeli software companies have focused on the creation of new software technologies or new applications of software technologies. The most prominent sub-sector in which these companies operate has been the telecommunication market, which is also the sub-sector of strength of the Israeli hardware IT industry. A well-known example of that period is Vocaltec. Established in 1989 to develop speech recognition technologies, Vocaltec was the first company to sell VoIP telephony products for the PC. Vocaltec went public in 1996, and was soon followed by a wave of Israeli companies in the same market niche, such as Mind CTI that develops VoIP billing solutions, and Arel Communication that develops video conferencing over IP.

These trends continue today. Looking at Table I below we can see that of the top 20 software companies by term of sales in the 2001-2003 period the products of nine are addressed to IT R&D and development, and six more are providing products for the telecommunication industry.

Table I – Israel’s Top Software Companies by Sales 2002-2001 (USD millions)

Name	Primary subsector	Total Sales 2003	Total sales 2002	Total sales 2001
Amdocs	Telecommunication billing, CRM, and automated directories	1483.3	1613.60	1533.90
Comverse*	Voice mail (Telecommunication)	735.9	1270.20	1225.10
Mercury Interactive	Software Systems Optimization	506.5	400.10	361.00
Checkpoint	Date Security	432.6	427.00	527.60
NDS	Data Security	392.7	368.70	304.80
Formula Systems	HC and software house	366.8	283.30	376.90
Nice Systems	Monitoring	224.3	162.50	127.10
Verinet	Telecommunication	157.8	120.60	141.70
Precise Software	Optimization	Bought by Veritas	76.00	55.60
Magic	RAD	63.4	60.00	76.60
Aladdin	Data Security	59.7	49.50	46.60
Sapiens	Data Conversion	52.3	64.80	63.40
Crystal System Solutions**	Data Conversion	54.3	36.60	38.40
Radvision	Telecommunication	51.3	49.10	46.20
Fundtech	Financial	47.6	39.80	44.20
TTI	Telecommunication	45.9	58.30	60.80
DSSI	Software House	35	55.90	45.90
Ulticom	Telecommunication	29.2	58.20	47.40
Cimatron	CAD/CAM Design	21.6	21.68	22.95
Total			5215.88	5146.15

Source: Hoover’s financial, companies’ SEC filings.

* After spin-off of Verinet and Ulticom.

** After merger with Liraz systems now operating as BluePhoenix

Industry-State Co-Evolution – The Restructuring of S&T Industrial Policy

From the second half of the 1980s until the early 1990s the IT industry was rapidly expanding and Israeli companies, both hardware and software, achieved growing

international success. However, industry growth was limited by some severe weaknesses. Two in particular were venture financing – especially at the pre-seed, seed, and the early sales and distribution stages – and business management skills and capabilities. While the knowledge of how to do business, and especially how to interact with the American financial markets, already existed within the Israeli industry, it was limited to the few firms that had been successful and there was no systematic sharing and dissemination of that knowledge.⁸⁸

Hence, by the beginning of the 1990s it became clear that the two bottlenecks of the Israeli IT industry were, first, the lack of venture funds to enable both deeper and more consistent R&D activities, especially in projects that related to the technological edge and, accordingly, necessitated longer R&D efforts without any revenues. The second bottleneck was the lack of management skills and knowledge, especially in regard to planning, marketing, and finance.

In 1989, the latest period in the development of the IT industry began. The USSR started its democratization and break-up process, and Jews, who had been unable to emigrate until that time, started the last large immigration wave into Israel. This wave was seen as bringing with it the best and the brightest technologically educated workforce from the USSR, and together with the thousands of engineers who had been made redundant by the defense industry, the question of tapping this body of knowledge sprang

⁸⁸ One example was the 1987 crisis of the New Dimension, one of Israel's premier software companies to be. The company found itself in acute financial difficulties. It had a couple of million of dollars in future orders but not enough working capital. At that time, the founders, all technologists without any business education, started to look around frantically for what venture capital was available. Fortunately, the wife of one of them worked for Comverse, and Kobi Alexander, Comverse's financial entrepreneur, agreed to meet with them. He was somewhat surprised to learn that they sought investment instead of using the simple financial tool of bridge loans.

to the top of the political agenda.⁸⁹ In addition, the Israeli government secured the United States' help in raising \$10 billion in bonds to finance the settlement of so many immigrants (20% of the total population in less than one decade), giving it some financial resources.

Thus, the political and bureaucratic apparatus of the Israeli state, knowing it had to act and having sufficient finances, was very open to new initiatives led by the OCS.⁹⁰

Starting in 1991, the OCS, led by Yigal Erlich, with the strong political backing of the then Minister of Trade and Industry Moshe Nissim, initiated and implemented three new programs. The Ministry of Finance initiated another failed program aimed at the VC industry. These programs were devised through a process of analyzing the strengths and the weaknesses of the industry both internally by the OCS and in conjunction with academics.⁹¹ The aim of these new policies was the enhancement of the formation, survival and success rates, and R&D capabilities of firms. All of the programs have been following the logic of neutral horizontal policies. While the OCS' three programs, the Technological Incubators, Yozma, and Magnet, started operation between 1992 and 1995, they were all planned and approved in 1991, the year that can be seen as the high point of the latest political window of opportunity.⁹² In 1991, two new programs started operations, each aimed at remedying a perceived market failure at a different development-stage of NTBFs. From the macro level the main effects of these new programs have been twofold: increasing the R&D focus and usage of business models

⁸⁹ During the early 1990s more than 20,000 employees, both skilled and unskilled, of the defense industries were fired (Rehav 1998).

⁹⁰ For more about the present R&D policy and schemes, see Trajtenberg 2000.

⁹¹ For four works that influenced the construction of these programs, see Brodet et al. 1990; JIM 1987; Justman et al. 1993; Teubal et al. 1996.

⁹² Interview with Yigal Erlich 8/21/2000.

based around novel products on one side, and increasing the embeddedness and dependence of the Israeli industry with the US and its financial markets on the other.

The end of the 1990s marks another transformation. With growing public and political interest in the IT industry and the OCS, its institutionalization and public supervision on it increased. The manifestations of this are many, from the establishment of a public committee process to recommend nominees for the position of a Chief Scientist to the growing supervision of the OCS by the Parliamentary Committee for Science and Technology. Indeed, of all developmental agencies in Ireland, Israel, and Taiwan, currently it is the OCS that supplies the most comprehensive and transparent information about its current and past activities.

The New Programs of the Early 1990s

The Inbal program, proposed and implanted by the Ministry of Finance, was the first serious government attempt to induce the creation of a private VC industry in Israel. At that time only two VC institutions were present in Israel: Tolkowsky and Adler's Atena VC fund, a limited partnership fund established in 1985 based on the American model, and Star, a private equity fund established in 1989 that became a Yozma fund after 1993. The Inbal program was an attempt to foster publicly traded VC companies by creating a government insurance company ("Inbal") that guaranteed a minimum value, calculated as 70% of the value of their initial public offering, to new VC funds traded on the Tel Aviv Stock Exchange. As such, the program was similar to Taiwan's initiative, structuring the VCs as companies, and viewed the VC not as an industry but as a pool of capital, with no attempt to foster learning, or to import and transfer professional VC skills

and capabilities.⁹³ Four funds were initially established, but initiated no follow-up activity and the funds' valuation on the stock exchange tended to be low. The four Inbal funds also faced what they perceived as excessive bureaucracy and in the end left the program. Today all the funds are under the management of one holding company – Green Technology Holding (Avnimelech and Teubal 2004).

When the OCS initiated the Technological Incubators Program, in 1991, the program was presented as a solution to two problems. First, there was the inexperience and inability of many technically-oriented or scientific entrepreneurs to become successful commercial entrepreneurs and find very early stage financing for their ideas. Second, there was the difficulty of many of the technologically skilled new immigrants from the former USSR to find jobs and successfully integrate in a capitalist market. The idea was to open a network of technological incubators that would help entrepreneurs in their very early stages by giving them most of the financing and a large amount of professional business and management help.

The incubator program is also the latest example of the pattern evident in the restructuring of the OCS and BIRD – an outsider coming in as a manager and making the program a reality. However, this time the early crisis period was prevented. Yigal Erlich the Chief Scientist at the time, realized the need and re-recruited Rina Pridor, Yaakov's right hand for many years, both in the OCS and afterwards in CDC and the limited partnership period. Her return is yet another example of the OCS' porous borders and networked structure. Under Pridor the program quickly commenced activities and grew in importance.

⁹³ On the importance of discerning between policies that treat VC as a “pool of capital,” and these that treat it as an industry, see Avnimelech and Teubal 2003a.

The goal of the program has been that after two years, when they graduate from the program, companies will be mature enough to secure private VC financing. In a similar fashion to the other OCS programs, incubation proposals had to come from the market.⁹⁴ Until 2001 (when specialized incubators approved, even if none had yet started operation), the incubators operated on the principle of neutral horizontal policy. While some of the incubators became more specialized over time, overall the technological incubators network did not pick any sectors, and R&D projects from all branches of the industry were admitted. As a result, the distribution of projects by industry through 2000 was as follows: electronics and communication 11%, software 11%, medical 18%, chemistry and materials 20%, biotechnology 20%, and others 23%.⁹⁵

Two of what may be the most important impacts of the program have yet to be considered and tested properly.⁹⁶ First is the major impact that the program has had on changing the preferences of technologically and scientifically educated personnel to become entrepreneurs. Second, as the technology industry crisis between 2000 and 2003 showed, the program is important in ensuring a minimum NTBF formation rate, which is

⁹⁴ By the end of 2000, 24 incubators were in operation and 883 companies had been part of the program. Of these, 240 were still in the incubation centers and 643 had graduated. Of those that graduated, 53% have continued operations and 47% have been closed down. The total private VC financing that the graduating companies managed to secure was in excess of \$525 million. In addition, one company, Compugen, is already publicly listed on NASDAQ, and a few more were acquired by American MNCs, with the biggest sale being that of X-Technologies (a medical equipment company) to Guidant in 2003. Compugen is also interesting as it is exemplary in showing how deep and multidisciplinary R&D skills are available in Israel to even tiny new companies. Compugen's first product has been a dedicated computing hardware for biological/molecular calculation (gene research) that the company started to sell in 1994. The second line of products is software based: algorithms that help in the discovery of new genes, which Compugen both sells and also uses in-house to find and patent genes. Following that line of business Compugen decided, in 1998, that in order to be taken seriously in the gene discovery business it needed to develop strong "wet" biology skills and opened a full scale lab and a third line of business. All of these extremely advanced and multidisciplinary R&D activities were conducted before its IPO on NASDAQ in August 2000. After the IPO Compugen also spun off a subsidiary, Evogene, for plant and agriculture biotechnology.

⁹⁵ Interview with Rina Pridor (2/8/2000), Trajtenberg, *Ibid*, and the incubation program web site <http://www.incubators.org.il>.

⁹⁶ There are two recent reports on the incubation program. One was conducted independently (Shefer and Frenkel 2002) and the other done under the auspices of the OCS (Economics 2001).

independent of the volatile behavior of the VC industry in regard to the amount of investment, and the herd mentality and fashion-like behavior of VCs in their sectoral investment criteria. A comparison with Ireland is striking. In Israel, to a great degree thanks to the OCS' programs, the annual formation rate of new companies remained above a hundred even after 2000. In Ireland, with the Irish VC industry managing record high levels of capital, in the whole of 2001 there were a total of three seed investments, which together equaled \$750,000, a sum which is slightly less than the support granted to two incubator companies. For a state like Israel that is economically dependent on the high-technology sector, securing this baseline is of critical priority.

In the same years that the OCS was busily developing and implementing new programs, new developments in the private sector were changing the IT industrial landscape in Israel. Before 1990 there had been a total of ten IPOs of Israeli firms on NASDAQ. In 1991 alone, three companies went through IPOs, and in 1992 there were another nine. Moreover, unlike the low valuation IPOs of the past, some of these IPOs resulted in a large enough market capitalization to allow a respectable exit for an American VC at the time. In addition, 1991 was also the year in which the first pure software companies went public on NASDAQ.

In 1992, learning from the failure of Inbal, the OCS initiated another program aimed at inducing the creation of a vibrant VC industry in Israel – Yozma. The aims of this initiative were fourfold: increasing the amount of venture capital available to Israeli firms, especially in their expansion phases; creating a professional VC industry that would possess the business skills that the IT industry was lacking at the time; injecting the Israeli high-technology industry with systematic knowledge of the American markets,

both product and finance; and expanding what the OCS perceived as a too-tight group of financiers.⁹⁷

This time, and in almost complete opposition to its behavior in the past, the OCS, again led by Yigal Erlich as Chief Scientist, decided that the necessary skills and knowledge did not exist in Israel, and that in order to succeed an Israeli VC industry would need strong networks with foreign financial markets, and not with the Tel Aviv Stock Exchange. Yozma was created as a government VC fund of \$100 million that had two functions. The first was to invest \$8 million in a series of ten private limited partnership venture funds, which would be 40% or less of the total capital – the rest to be provided by the other private limited partners. Second, a separate fund of \$20 million started operation at the same time. In order to get this financing, the funds' managers had to secure investment and partnership from at least one established foreign financial institution and from at least one local one. Moreover, the OCS made a deliberate decision to pick one organizational model for the future Israeli VC industry, the American style limited partnership fund, and focused on early-stage financing VC.⁹⁸

Unlike Inbal, Yozma became highly successful and was a model for VC-aimed policy worldwide. The precise construction of the program, in particular the fact that it treated the VC as an industry with specific skills to be acquired and capabilities to be nurtured, unlike similar initiatives in Ireland and Taiwan, had a few positive impacts. The first effect was the professionalism and education of the venture capitalists themselves. In Israel, with its already long history of the R&D-based IT industry, there was already a growing pool of experienced technological entrepreneurs who successfully managed their

⁹⁷ Interestingly the need for government action to expand a “too tight group of financiers” was also strongly emphasized in Ireland, see Chapter Four.

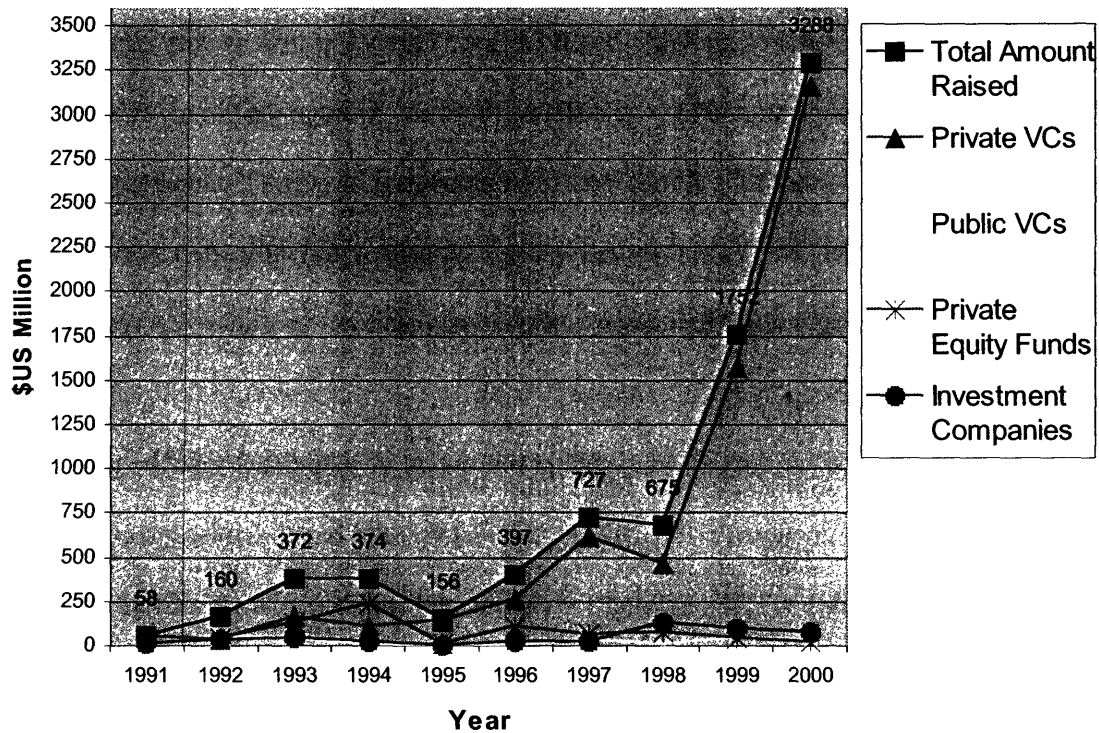
⁹⁸ Interview with Yigal Erlich 8/21/2000.

companies, and this, together with the demand of Yozma to bring in a professional foreign partner, created a VC industry where the average background of the VC is as an entrepreneur or manager of an R&D-based IT firm. This VC profile is very similar to the ideal American background, and very different from the average profile of VCs in Ireland and Taiwan, where most VCs do not have entrepreneurial or even IT management backgrounds. Second, the Yozma initiative itself sponsored and cultivated many venues of collective learning within the industry, which enhanced its capabilities (Avnimelech and Teubal 2003a).

The first Yozma funds had excellent returns on investment thanks the growing success of Israeli companies on NASDAQ, the fact that the Israeli landscape at the time had many high quality NTBFs looking for capital, and the coincidence with the start of a period of rapid growth in demand for IT and the related financial boom. This success resulted in rapid investment of capital into the Israeli VC industry. Most of which opted to use the limited partnership organizational model, as can be seen in graph 2. In turn the existence and growth of the VC industry, both accelerated the rate of new company formation and, even more importantly, finalized the transformation of the Israeli IT industry turning it into the mirror image of the American one. Today the Israeli IT industry has the same focus on the American financial and product markets and the same milestones, namely either an IPO on NASDAQ or an M&A, as in the American IT industry.⁹⁹

⁹⁹ A three years study of the Israeli VC industry was recently concluded. For some of the results, see Avnimelech and Teubal 2003a; Avnimelech and Teubal 2003b; Avnimelech and Teubal 2004.

Graph 2 - Venture Capital Raised in Israel 1991 - 2000



Source: (Avnimelech and Teubal 2002; IVA 1997-2003).

As of 2004, the Israeli VC industry consisted of over 70 local funds, with many of the top US and global VC funds having local operations in Israel and with total capital under management of approximately \$5 billion. The virtuous dynamic of both a growing and successful IT industry and VC industry brought another facet of professionalism into the Israeli VC industry – a career pattern where successful entrepreneurs who managed to sell or publicly list one or more company would later opt to become VCs.¹⁰⁰

¹⁰⁰ Some examples are: Benjamin Hanigal of Lannet is now a partner of Sequoia Capital in Israel; Moty Ben-Arie, cofounder and manager of Radcom, is now a partner of Walden Israel; Orna Berry, cofounder and manager of Ornet before becoming the Chief Scientist joined Gemini in 2000; and Arad Naveh, cofounder and manager of Class Data, an Israeli software company acquired by Cisco, is now a partner at Benchmark Israel.

In addition, the success of Israeli companies in the US in the 1990s transformed the IT industry's own networks. Lately many Israeli IT companies have raised capital directly from established foreign VCs and financial institutions in all stages of the companies' development. This is highly important for the Israeli IT industry that to a large degree imitates the American mode of start-up growth, based on an expensive R&D phase, followed by an even more expensive build-up of marketing and distribution channels, during which the firm is hardly able to secure revenues from sales. Hence, the creation of the Israeli technological VC industry, and the ability of the Israeli IT new product R&D-based firms to secure venture capital abroad make the Israeli IT industry different from Ireland and Taiwan in being able to compete successfully with the amounts of capital that American IT start-ups manage to secure.

The last initiative designed by the OCS in 1991, MAGNET, also started operations in 1992. Unlike the other OCS programs, MAGNET, the Hebrew acronym of Generic Non-Competitive R&D, aims to solve two problems relating to the later stages of development and maintenance of the long-term R&D-based competitive advantage of Israeli NTBFs. The first problem is the fact that in Israel a large number of companies work in the same technological space, all of them too small to be able to compete on the basis of cutting edge *infra-structural* research activities that are crucial for their ability to sustain the competitive advantage against the bigger MNCs. The second perceived, if more debatable, problem was the underutilization of academic research done in Israel.

Similar to other OCS programs, MAGNET grants aid to programs initiated by private industry, and operates on the principles of a neutral horizontal policy. However, as MAGNET aims to create a consortium to develop generic technologies, a consortium

is created for a period of up to three years, and all IP outputs are shared among the consortium members, who also agree to license this IP to local companies at a cost that does not reflect monopoly status. A consortium, consisting of at least a few companies and one research/academic institution, applies in a competitive fashion to MAGNET, and if approved, is granted financing to the level of 66% of cost. MAGNET financial aid is given as grants with no need to repay. A parallel process exists for users' consortia, with the aim of distribution and implementation of generic technology.

Again a comparison with Taiwan is illuminating. In Taiwan, research consortia were created by the government as an instrument to assist technological learning, upgrading, and catch-up as part of attempts at industry creation. In Israel, the aim of the state in establishing research consortia was to help pre-competitive advanced R&D. Thus, the national goals behind the usage of a structurally similar policy vehicle are as different as can be, and symbolize the very different policy and development path of the IT industry in the two countries.¹⁰¹

In addition to the new initiatives, OCS's budgetary growth during the 1990s was quickly transformed into extensive investment in the industry. As can be seen in Table II the success of projects financed by the OCS in turn increased the amounts the OCS was able to channel to industry, even without an increase in the budget allocated to it by the government, creating a virtuous co-evolution cycle throughout the 1990s. It remains to be seen, however, whether the budgetary cuts imposed on the OCS in the last two years will limit its ability to continue this level of support or to open new programs in the future.

¹⁰¹ In Ireland there has been no attempt by the Irish state to establish any program of research consortia, see Chapter Four.

Table II - the OCS's Budget 1988-1999 (in 2000 \$USD million)

Year	R&D Grants	Paybacks	Magnet	Incubators	Paybacks as % of investment	Number of approved grants to IT firms
1988	120	8	-	-	6.7	
1989	125	10	-	-	8.0	
1990	136	14	-	-	10.3	380
1991	179	20	0.3	3.6	11.2	460
1992	199	25	4.7	16	12.6	458
1993	231	33	4.6	23	14.3	481
1994	316	42	10	28	13.3	605
1995	346	56	15	31	16.2	559
1996	348	79	36	30	22.7	556
1997	397	102	53	30	25.7	517
1998	400	117	61	30	29.3	505
1999	428	139	60	30	32.5	506

Source:(OCS 2000).

Note: Paybacks from each successful project are paid to the OCS throughout a several years period.

While the wave of immigration from the former USSR undoubtedly created the pretext with which the OCS was able to secure finance and political agreement to start these four programs, the Russian immigrants themselves have not, thus far, become successful technological entrepreneurs. They seem to play the important but more minor role of providing highly-skilled labor. A preliminary analysis of an original dataset that I collected on the career paths of founders of Israeli IT NTBFs that went public on foreign exchanges did not find one new immigrant from the former USSR among the 151 founders on which comprehensive data was acquired.¹⁰² This finding is reinforced by an

¹⁰² The founder of one medical equipment company, Medinol, on which comprehensive data on the founders has not yet been added, is a new immigrant. However, the story of how Medinol was founded by Kobbi Richter, a very successful and experienced Israeli-born entrepreneur, who befriended Medinol's new-immigrant technological founder on the beach, points to the exceptional circumstances of its founding and to the difficulties that immigrants from the former USSR have had in establishing successful NTBFs in a capitalist economy.

analysis done by the Central Bureau of Statistics on the distribution of new immigrants in the IT labor market (Abouganem and Feldman 2002. Pp. 27-28).¹⁰³

In short, the industrial development agencies of the Israeli state proved quite able and flexible in advancing the overarching goals of creating science-based industry in Israel and advancing NTBFs as the cornerstone of this industry. The focus on R&D activities as the source of the competitive edge of the industry has been reinstated and even refined with two programs, MAGNET and the Incubators program. These programs specifically aim to nurture R&D activities in early and advanced stages of companies' lives this goal was also been strengthened with an another policy initiative, Yozma, that treated VC as an industry with specific skills and a center anchored in the US. The view of private companies as the source of R&D activity ideas was maintained, as were the dual principles of horizontalism and neutrality with regard to sectors and technologies. The division of labor between the local industry and MNCs that sees the role of Israel as an R&D location was even sharpened by the Yozma initiative. The new programs, together with the continuation of the older programs such as BIRD and the OCS' main R&D fund, fortified and supported the organizational focus of the Israeli IT industry on product R&D.¹⁰⁴ In addition, all these new programs were again initiated and implemented by the OCS with the agreement of the Ministry of Finance as 'secretary general instructions,' not anchored in law or in governmental decision. Only on the 7th of

¹⁰³ Looking at three sub-categories of the high-tech labor-markets from 1995 to 1999, the findings are that the total number of new immigrant workers in *industry* (i.e., more routine and maintenance jobs) rose at a higher rate than that of Israelis. In *telecommunication* there was a slight increase in the number of new immigrants, but the number of Israelis grew faster 95% of the workers were Israelis. However, in the most high-skilled labor market category, *computerization and R&D* (i.e., high level R&D and programming jobs), the total number of new immigrants decreased while the total number of Israelis increased sharply (over 25% growth).

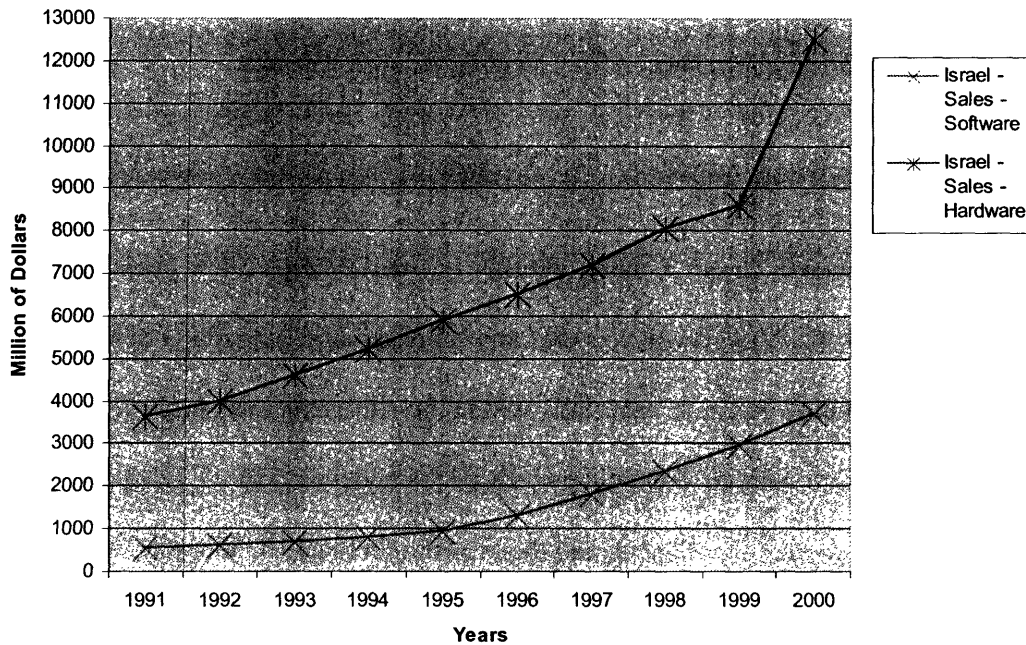
¹⁰⁴ By the end of the 2002 financial year, the OCS supported more than 4500 companies since 1968 (OCS 2002; OCS 2003).

April 2005, did the Israeli parliament enacted of a new Industrial R&D law. This is a repeat of the pattern of the first (1984) Industrial R&D law: anchoring in law activities that the OCS has already been successfully running for over a decade.

Success, Growth, and its Limitations – The Advantages and Disadvantages of the Israeli Model

As can be seen in Graph 3, the IT industry in Israel through a few years of unprecedented growth. This growth was the result of changes in perception of the Israeli industry in the global IT markets, especially within the American industrial and financial communities, coupled with the dramatic growth in global demand for IT products and services, a related boom in NASDAQ, and the growth of a local VC industry. However, while this section briefly describes the development of the Israeli IT industry, its main aim is to illuminate the current strengths and weaknesses of the Israeli IT industry development model.

Graph 3 - Total Sales Israel



Source: (IAEI 2002; IASH 2002). Note: Israel's software sales data is underestimated.

The second half of the 1990s saw significant growth of old Israeli hardware companies that managed to transform themselves and achieve prominence in their chosen market niches. Israeli companies continued to operate in every subfield of the industry, from memory, in particular flash memory, where Israeli companies pioneered key technologies, to telecommunication, which continued to be the main area of operations of the global IT industry and even more so in Israel.¹⁰⁵

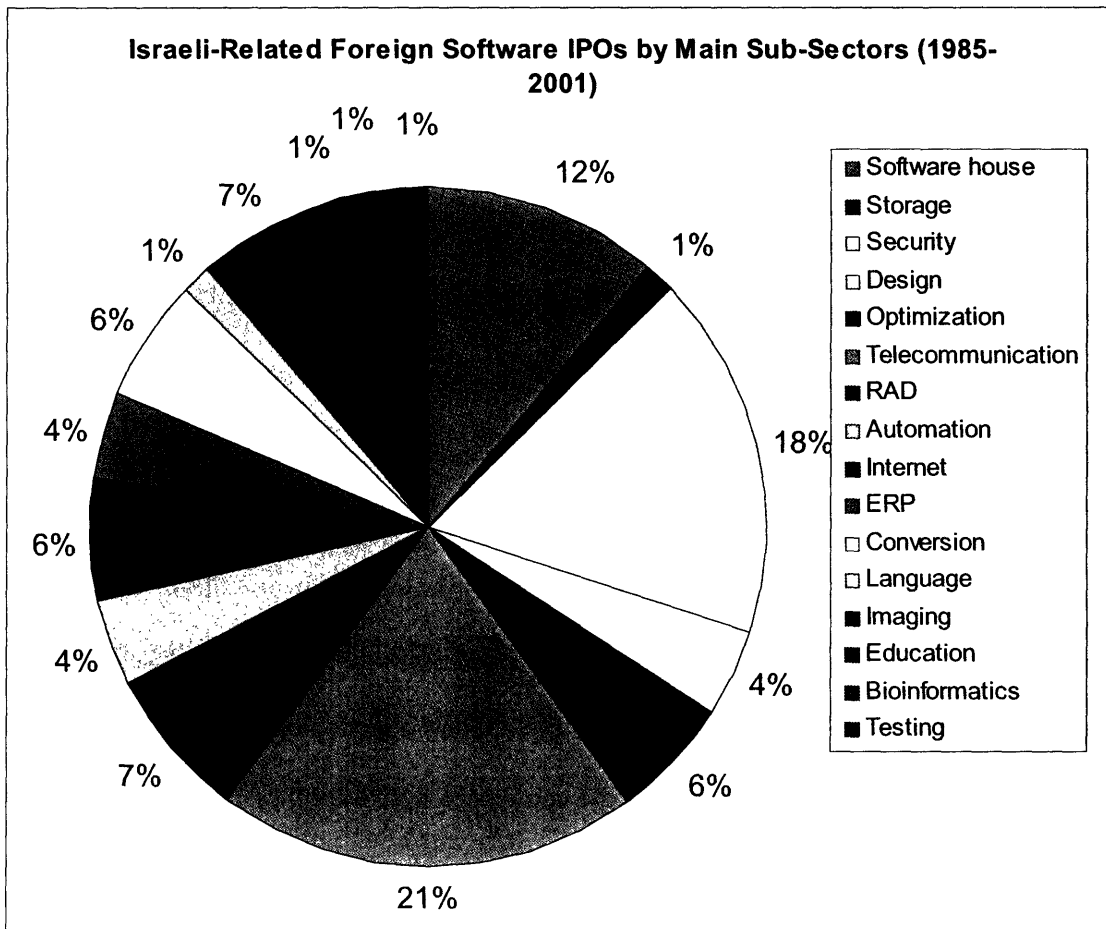
While the defense state-owned companies continue to be in state of flux, many of the sector's graduates, from both military and industry, left to establish their own

¹⁰⁵ By 1998, 78% of R&D expenditure in Israel went to telecommunication. This is probably an over concentration of investment from the national point of view, since it is 20% more than the equivalent figures for Finland, which include the activities of Nokia, and 60% more than the OECD average (Bentur 2002).

companies. RAFAEL, again, proved to be innovative in dealing with this trend, establishing the RAFAEL Development Corporation (RDC) as an incubation company with investment funds from Elron and Discount to commercialize ideas emanating within it. The lengthening history of industrial success also created another advantage for the Israeli IT industry: cohorts of young and middle-aged experienced managers and entrepreneurs who had passed through at least one cycle of company creation and growth. It is increasingly common in Israel to see serial entrepreneurs – entrepreneurs who specialize in the creation of new companies.

The software sector has seen the most spectacular wave of successes in the late 1990s. While the average age and education level of the entrepreneurs stayed more or less constant in the hardware sector, both the age and educational composition declined sharply in the software sector. Graduates of the military's technological and intelligence units founded growing number of software companies right after they finished their period of service. The number of foreign IPOs increased and Israeli companies appeared in almost all of the industry's market niches, as can be seen in Graph 4 below.

Graph 4



Source: SEC filings, companies' website and press releases. Note: for companies that are no longer traded the main business line at time of IPO was recorded as main sub-sector.

Toward the end of the 1990s, the growth profile of new IT Israeli companies became increasingly similar to that of technology-based new American IT companies, with IPOs and/or M&As by foreign MNCs becoming common. American semiconductor MNCs are still the most active in Israel, and in the last five years Intel, Motorola, and IBM, together with the Israeli universities, are the biggest Israeli international patent issuers (TAF 2002). However, starting in 1995 with Siemens' decision to acquire Ornet, MNCs from other parts of the world and other sectors of the IT industry have also been

conducting more R&D activities in Israel and acquiring Israeli companies for their technologies.¹⁰⁶

With the VC industry rapidly growing, the industry of creating, developing, and selling companies became almost as important as the sales revenues of the Israeli IT industry. The growing amount of VC finance, which necessitates 'exits' in order to make a profit, enlarged both the rate of company formation and the trends toward the sale and public listing of companies. Even with the known uncertainty of such statistics, it is significant that the official annual rate of new NTBFs in Israel grew steadily between 1990 and 1995 from less than a hundred to a hundred, and then with the rapid increase in VC financing between 1995 and 1999, the annual rate swiftly rose from 100 to 800 (Avnimelech and Teubal 2003a).

Nevertheless, a structural weakness limiting the ability of Israeli firms to achieve sustained growth, which is a direct result of the Israeli industry basing all its advantage on advanced R&D, also became more acute. By employing business models that rely solely on either being the pioneers or technological leaders in a market niche, Israeli firms have a window of opportunity lasting between two to four years in which to secure their market position before facing intense competition from above and below. If successful, Israeli firms quickly face competition from above when better organized and more financially secure MNCs and American start-ups enter their market niche.

Additionally, as the technologies on which their products are based become commoditized and cheaper, Israeli companies face competition from less technologically advanced but cheaper competitors, many of them Taiwanese. Israeli companies imitating

¹⁰⁶ Cisco is one MNC that is rapidly expanding its activities in Israel to rival Intel, IBM, and Motorola for the top position as the MNC with the most R&D activities in Israel. Cisco bought six companies since 1999 and recently finished the development of the world's fastest router in its Israeli R&D center.

the American model, without the American infrastructure and MNCs, the long experience and skills necessary to grow and maintain leadership under these conditions, without a local IT manufacturing industry with which to collaborate, and with the added disadvantage of being far away from both their markets and their subcontractors – rarely manage to sustain growth while staying in their original market niche.

The institutional weakness of the Israeli IT industry leads many companies that do not believe they have the necessary skills to survive competition to choose one of two strategies. The first strategy is to quickly change niches and products with the first hint of intensified competition. If successful, this strategy allows Israeli companies to completely reinvent themselves, moving from one technology trend to another; however, it also severely limits the ability of these firms to secure significant and sustained sales or to become the market leader. A perfect example is Attunity, which not only changed markets and products three times but also its name. The second strategy is to agree to be acquired either by a leading MNC or by another start-up deemed to possess better management skills. A chief example here was Galileo Technology, a NASDAQ-listed Israeli fabless communication company that continuously grew its annual sales by ~50% since it was listed in 1993 and was seen as one of the most promising Israeli firms. In 2001, Galileo suddenly agreed to be acquired by Marvell technologies, an American start-up with a shorter history and smaller sales.

This structural weakness of the industry is glaringly apparent when we compare the Israeli IT hardware industry to the Taiwanese, and nowhere more so than in the IC design subsector. If the weakness of Taiwan's IC design industry is the lack of advanced R&D skills, its advantage is that it developed as a part of a virtuous co-evolution within a

system consisting of both the world's leading pureplay foundries and OEM/ODM companies. This enabled the Taiwanese IC design companies to utilize a model of competition from below, entering various market niches pioneered by Israeli or US firms, gaining a controlling market share, and establishing long-term sustained growth (Breznitz 2005b; Breznitz 2005c; Breznitz 2005d). Israeli IC design firms are usually the pioneers in their market niches. Nevertheless only two Israeli companies are now in the world's top 30 fabless companies by sales, and both are in the lower third of that list. Thus, while Israel's IC design industry is the fourth most successful in the world, its long-term prosperity, sustainability, and even the ability of its firms to imitate the success of the Taiwanese and become one of the world's ten largest companies in term of sales, is questionable.

The growth of the American-style VC industry and the growing reliance on it as the main source of finance might aggravate this institutional weakness. The positive effects of the VC industry have already been discussed. In addition, its contribution to the professionalism of the Israeli IT industry in the earlier stages of company life, and in acquiring more business and financial management skills, has been invaluable. However, the VC industry makes money through financial exits. Hence, its main aim is to maximize the market capitalization value of firms in the shortest amount of time with the minimum of effort, and then help to execute the financial transition in which the VC earn their profits. For VCs, careful building of sustained long-term businesses is a goal only as long as it increases the market value of the company. Accordingly, as long as it does not significantly lower the firm's value, VCs have an inherent incentive to ensure that their companies either conduct an IPO, or agree to an M&A, as early as possible. This is

especially true for first-time VC funds that need to establish a track record in order to secure investments for their next fund. The Israeli VCs of the early 1990s consisted almost exclusively of first time funds. Furthermore, if from the national point of view Israel might prefer that more of its companies stay independent, for VCs an M&A is usually preferable to an IPO. The comment of one Israeli VC is common,

“To be honest, I would prefer to have only M&As, especially cash M&As. I get my money quickly and have no further commitment to the company. I can then focus my attention on new deals. Do you know how much pain it is to go through an IPO process on NASDAQ? And why? As a VC it does not help me at all. The only reason I might go for an IPO is that many excellent entrepreneurs will avoid VCs that never back an IPO.” (Interview with an Israeli VC 8/20/2000.)

It is regarding this key issue of the proper role of VCs in the IT industry’s future development that the over-embeddedness of the OCS in the industry is a source of some concern. Yigal Erlich, who stepped down in 1993 as Chief Scientist to manage the Yozma VC fund, also immediately became the chairperson of the Israeli Venture Association (IVA) and stayed in this position until 2002. Under his management the IVA became Israel’s best-organized high technology industry association and an effective lobbying group. In addition, of the five former and present Chief Scientists that are still active, three (including Erlich) are VCs, and the last private industry position of the current Chief Scientist was that of a VC.

Additionally the high involvement of MNCs in the Israeli IT industry has become even more pronounced. By now it is noticeable that MNCs control most of the productive parts of the Israeli industry, a large and growing share of the IPR created in Israel, and an ever-increasing share of the industry’s revenues and profits. While this might actually improve the long term sustainability of the Israeli industry, from the national point of view the growing loss of control, the fact that Israelis working for most of these MNCs

will not acquire business development and management skills, and the fact that a large percentage of the fruits of the industry success are not redistributed in Israel, might be a concern.

The way in which most MNCs enter Israel has also changed and most now opt for utilizing acquisitions. The list of MNCs opting to buy an Israeli firm and convert it into their local R&D center includes all the major players, both software and hardware. Israel has truly become a key location for new product R&D for these MNCs. For example a former VP for business development in a leading US MNC remarked in an interview,

“Our first acquisition of a company outside North America was of an Israeli company in 1999. In 2001, when I became VP of business development for the rest of the world, the company was very attracted to Israeli technology. We discovered that in every technology that we are interested in, there is an Israeli company developing something. When I became VP it was obvious that for the organization, Israel is the capital of the ‘rest of the world’” (5/9/2002.)

If there is one subsector of the Israeli industry that from a national industrial development point of view exemplifies the best and the worst of the development of the industry and the Israeli model since the mid-1980s, it is the software data security subsector. Throughout the 1990s the data security subsector has been the most successful subsector of the industry (Teubal et al. 2002). In addition, it is the only sector of the software industry in which all three countries, Israel, Ireland, and Taiwan, have companies that are globally successful and listed on NASDAQ.

Of the three industries, the Israeli industry had the best starting point. It had strengths in all the necessary technological areas for data security. The source of these strengths was both in the defense sector and within its universities, in particular, Professor Adi Shamir, whose research was central to the development of the public key

infrastructure technology that became the global standard.¹⁰⁷ Israeli companies pioneered many key market niches such as encrypting, authentication, IPR protection, antiviral protection, and firewalls. On one hand, the industry has been a tremendous success, with five IPOs on NASDAQ and two of the biggest five Israeli software companies, NDS and Checkpoint, being data security companies. Israel has also become a key location for the development of data security technologies for leading MNCs. For example, CA acquired three Israeli companies to establish its data security worldwide R&D center in Israel, and many other MNCs conduct their data security R&D in Israel, not the least Microsoft's efforts in firewall technologies.

On the other hand, there are no longer any independent Israeli antivirus companies, while Taiwan's Trend Micro, starting in a far worse market position, managed not only to stay independent but also, with \$449.4 million in revenues in 2004, became larger than all Israeli data security companies. In addition, in the authentication and PKI fields, the Irish industry, with the success and subsequent failure of Baltimore and the continuous success of Trintech, demonstrates that better business and market analysis skills may be more important than a technological edge. From over twenty Israeli companies that existed long enough to secure significant investment and some sales, only three managed to remain independent and significant players in their own niche. Of these one, NDS, managed to accomplish its sustained growth only after being acquired by News Corporation and with the help of its superb financial, market penetration, and management capabilities.

¹⁰⁷ Professor Adi Shamir of the Weizmann Institute of Science is 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.

A closer analysis of the growth of a few of the more prominent companies clearly shows all the strengths and weaknesses of Israeli IT industry discussed in this chapter. The industry's strengths have always been superior technology and pioneering R&D, its weaknesses the lack of market knowledge and, frequently, management skills, as well as the difficulties that even its leading companies have of growing into a true leader of the field. For example the beginning of the data security sector has more been due to a random event and good technology than to superior management and planning skills. Aladdin, the first globally successful data security company, and one of the only three that are now both publicly listed and independent, was established in 1985 in order to build an expert system for graphology.¹⁰⁸ The technological founder, Yanki Margalit, a young self-taught software programmer, was very aware of the software piracy problem in Israel, and developed an anti-piracy software plug before commencing sales. By the end of the first year of sales, only two expert systems were sold; however, so were more than 2000 copies of the anti-piracy plugs. Good fortune continued to be the company's trademark even after the other three partners but Margalit left the company and Margalit's brother, Danny, joined the business, focused now on IPR protection. Completely innocent of any knowledge of how to start exporting, the Margalit brothers decided to buy a small ad space in Byte, the leading industry newspaper of the time, without even knowing the tax procedures for export sales. European customers responded in earnest, and in less than four months after that first ad, Aladdin had distributors all over Europe.¹⁰⁹

¹⁰⁸ Graphology is analysis of handwriting for personality testing procedures.

¹⁰⁹ During 1991-93, the Margalit brothers found out that while this strategy works very well in Europe, they did not manage to sell in the US. After the establishment of a US subsidiary, Aladdin Inc, in 1991, Aladdin went public on NASDAQ in 1993. Aladdin continued to grow through 1991-1996 through revenues and

Almost the same technological virtues, utter lack of professional management and financial capabilities, and pure good fortune are evident in the story of Israel's first antivirus software company, now turned technology investment house, BRM. The two original founders of the company, Omry Man and Yuval Rakavy, at the time computer science students at the Hebrew University, developed what was probably Israel's first antiviral software during one night of work trying to fix Omry's PC. They then distributed it for free on the Hebrew University campus. Only a couple of months later the two came up with the idea of developing a generic antivirus program, and the two joined forces with the Barkat brothers, Eli and Nir, to establish BRM.

For about a year the company survived without any substantial growth as the part-time hobby of the four partners, each of whom had either another company or a full time job.¹¹⁰ BRM's major turning point came when the founders met Hanina Brandes, one of Israel's leading lawyers at the time, who agreed to represent and coach them, and to delay his payment until BRM made enough money to pay for his services.¹¹¹

acquisitions of Israeli and foreign companies. However, since 1998, Aladdin, with its base in software IPR protection, has faced difficulties in adapting itself and its products to the new era of the Internet, as well as in its moves to new areas such as defense against malicious code. Nonetheless, in 2003 Aladdin sales were \$54.7 million, just over 17% growth from 2001.

¹¹⁰ At the time a few more antivirus companies were established in Israel such as Iris, Carmel, and Eliashim that was later bought by Aladdin.

¹¹¹ Following this turn of events, BRM quickly signed an OEM agreement with a leading American software company at the time – Fifth Generation – that renamed their product and sold it worldwide. In addition, as Fifth Generation R&D capabilities were weak, BRM started to do more and more R&D projects for its American partner. As a result, it started to diversify and tried, not very successfully, to imitate the business model it had with its antivirus program with other technologies. In 1993, partly for the reason that before the advent of the VC industry no bank in Israel was willing to secure a working capital loan for what was deemed to be a small company with no tangible assets, BRM sold its antivirus technology to Fifth Generation (which was later bought by Norton) for what was then considered in Israel to be a significant amount of capital. While still in a flux after the sale and without any clear business strategy BRM stumbled on what turned out to be Israel's most successful data security company, Checkpoint. Following Checkpoint's success BRM transformed itself into a technological investment house.

The story of Checkpoint, Israel's premier data security company, also shows some of the same weaknesses as well as of some learning in the management and market analysis realms. Checkpoint has been the inventor as well as the market creator and leader of firewalls, now a basic security feature. Three friends, all graduates of the military's technology and intelligence units, founded the company. Unlike the stories of Aladdin and BRM, Checkpoint founders had a very clear idea of what the firewall technology should be, gained from their service in the military. Moreover, realizing that the civilian market was not mature enough, they waited a few years before commencing operations. The company was established in 1993 as NSK, and if only to show the relative lack of financial experience in the Israeli IT industry as a whole, got its first seed finance (and some R&D help) from BRM in the way of selling 50% of its shares for a \$300,000 loan.¹¹² Checkpoint secured a strategic OEM agreement with Sun Microsystems that counted for most of its early sales, and secured an important VC investment with a leading American fund, Bloomberg. In addition, showing the growing management savvy of the Israeli industry, Checkpoint established and led several industry forums that helped it in securing its technologies as the industry's standard. In 1996, Checkpoint went public on NASDAQ, and has since aggressively been diversifying its products through both in-house development and acquisitions. However, with the growing success of firewall technology Checkpoint is facing increased competition, not the least from Cisco, Juniper, and Microsoft's forthcoming Longhorn Operating System. Hence, its continuous growth and even independence are not assured.

¹¹² This proved to be a boon for BRM that not only profited from the high share price of Checkpoint when it went public but also got its \$300,000 loan back.

Conclusion

This chapter analyzed the development of the IT industry and the co-evolution of state-industry relations in Israel. In particular, it inquired into the different ways that the state acquired its technological and scientific skills and capabilities as well as the industry's evolution. It evaluated policy vehicles and the amount of control the state attempted to have on the IT industry's technological development path. In addition, the chapter examined the role of the state in shaping the local industry's relations with the global markets.

Since the 1970s, the Israeli state has promoted a particular model of IT industrial development. This model has seen R&D activities leading to new product innovation as the sole basis for Israeli industrial growth. The particular interpretation given to this concept perceived private firms as the agents for both ideas and their execution, and the state role as stimulating these agents in order to maximize R&D activities throughout the industry, in all sectors and technologies.

This conceptualization also led the Israeli state, with its particular model of civil service, which is not fully consistent with Weberian ideals, to disinvest itself from most of its R&D conducting agents and any attempts to control or guide the industry's technological path. Hence, in contrast to Taiwan, and in more or less the same period, Israel decreased both the size and the support it gave to its then-extensive network of public research institutions and concentrated on acquiring and maintaining a more limited set of skills. These skills were acquired through the development of agencies that had porous borders with, and embeddedness within, private industry. A pattern emerged in which strong-willed outsiders were given political backing to construct these agencies and implement their own interpretation of S&T policy ideas.

The ideal of building up Israel as a location for cutting-edge R&D activities is also prominent in state actions aimed at establishing specific relationships between the local industry and the global IT production networks, both with regard to activities of MNCs inside Israel, and with regard to the relationships of Israeli firms with foreign products and financial markets. This has been apparent throughout the activities of the OCS and BIRD, from the early programs sponsoring a particular mode of cooperation between Israeli and American firms, in which the Israeli companies focus on the R&D stages, to OCS and BIRD actions in luring MNCs to open R&D centers in Israel, to the Yozma program that deeply embedded the newly created Israeli VC industry in the American one. Furthermore, the OCS always followed the dual principles of neutral horizontal policies, never targeting specific sectors, products, or technologies. This has been true both for its broader programs such as BIRD and the general R&D fund, and for its latest more stage-focused programs, such as the incubation program or MAGNET.

Since capital for any high technology industrial development in Israel was chronically lacking for many years, particularly for the IT industry, one cannot underestimate the influence of the various OCS programs, the main source of capital, on the specific organizational modes and business strategies chosen by Israeli IT companies. The OCS promoted a specific model of organizational development and business models focusing around the innovation of new technologies and products. These policies have assisted the Israeli IT industry to evolve in two phases, which more or less correlate to the technological and market evolution of the global IT industry, first developing the hardware sector, and only then developing the software sector.

Throughout this industrial development process the OCS, while crucial, was not the sole source of policy ideas. The network structure of the OCS and the overall construction of the Israeli civil service, which aims to give political leaders significant control, supported the transfer of many policy ideas that originated in the private industry. For example, the original idea for the OCS creation was formulated in the private market; the NASDAQ-orientation model, while later significantly and deliberately encouraged by state actions, was developed in the private market; and even the first attempts to create a VC industry and the legalization of the limited partnership fund model were first tried out by private entrepreneurs. Nevertheless, this embeddedness and networked structure of the OCS, together with the relaxed attitude toward orderly bureaucratic procedures, has not been without problems, as seen in the cases of the Elscient law and the amount of political power the VC industry has recently accumulated.

In short, the growth story of the Israeli IT industry and the particular mode of its development as a supplier of new technologies to the global production networks show the utility of our theoretical framework. Helping us to analyze the development of rapid-innovation-based industry in Israel, it pointed us to key areas of inquiry, and assisted us in understanding them. However, our framework also illuminates for us the fact that our ability to generalize lessons from the Israeli case might be limited.

Since many commentators have looked to the Israeli case as a case of success to be emulated, it is important to note that Israel's S&T industrial policies were all built around the notion of diffusion of already domestically existing top notch R&D and technological capabilities. Therefore, it might be that the lessons other countries can learn from Israel are limited, and helpful only in certain stages. Israel is a particularly useful

case from which to learn when there is a need to diffuse already developed R&D capabilities throughout the innovation system. However, states that do not already possess R&D capabilities should look to other countries as their model.

The Israeli IT industry, while being one of the world's most successful in the 1990s, is not without some serious weaknesses. These weaknesses are a direct result of Israeli industrial development path with its sole focus on product R&D and its intimate connection with the US. Undoubtedly these two are also the main causes of its tremendous growth. The first weakness of the Israeli IT industry is that the pull of the American market on Israeli NTBFs is becoming ever more pronounced. With not only their customers, but also a growing share of their investors and shareholders being American, and with the Israeli market becoming less important, more and more Israeli companies feel the need to become as American as they can.

This development is emphasized by the growing importance of American MNCs in Israel and their ability to capture a large percentage of its innovative capacity. If we return to our patent data it comes as no surprise that American MNCs are, apart from the universities, the leading patent issuers in Israel. The acquisitions of Israeli firms by MNCs looking to establish R&D centers in Israel continued in the last four years even under more averse market conditions. This fact makes the question of the ownership of the IT industry, and more importantly of who enjoys most of the fruits of its growth, even more keenly felt.

These trends have been intensified in correlation with the growing importance of the VC industry in Israel, and the fact that Israel's VC industry, unlike the Taiwanese or Irish, relies almost exclusively on financial exits in foreign markets. Since VCs make

their money only via financial exits, the growth of the VC industry correlates with a growth in the number of Israeli firms going through foreign IPOs or M&As.

The last widely felt weakness of the Israeli IT industry is the still limited ability of Israeli firms to achieve sustained growth. This weakness is a direct result of the Israeli industry and state focusing all their energies on securing advantages that are based solely on advanced R&D. Israeli companies are in fact imitating the American model, but without having the American infrastructure and MNCs, and the long experience and skills necessary to grow and maintain leading rapid-innovation-based companies under intensified global competition. In addition, the Israeli IT industry does so without the Taiwanese advantage of a local IT manufacturing industry with which to collaborate, and with the added disadvantage of Israeli firms being far away from their markets and their subcontractors.

The combination of all these trends put the ownership and control of Israelis over the Israeli IT industry in question. Furthermore, it raises significant issues in regard to the distribution of the fruits of its success and the connection it has with the rest of the Israeli economy. However, they do not put the continuous existence of Israel's IT industry in serious question. As long as the Israeli IT industry, MNC-controlled or not, can continue to come up with breakthrough innovations its continuation is assured. A much more serious question mark will hang over the future of the Israeli IT industry if Israel's education system deteriorates and its ability to produce highly qualified R&D personnel diminishes. It is therefore worrying that Israel's education system from K-12 to the

higher education institutions is indeed in crisis with declining quality and standards in the teaching of math and science.¹¹³

It seems as if the future of Israel's IT industry is in danger due to a double jeopardy caused by its own success. The growing success of the IT sector not only turned public attention away from the growing problems of Israel's education system, it also aggravated them by tempting many good researchers to leave the academy. All of these developments have been happening in a time of flux in the Israeli higher education system with the establishment of regional colleges in the 1990s and the growing question marks over the long-term commitment of the Israeli government to building the academic R&D infrastructure and sponsoring university level research.¹¹⁴

Hence, while Israel's model of development with its R&D focus and particular division of labor between industry and state, as well as between local and global companies and markets, brought its IT industry to unprecedented success, it also makes the Israeli IT industry more vulnerable than the industries of Ireland and Taiwan.

¹¹³ Reliable longitudinal international comparative studies of elementary and secondary student achievements are notoriously rare. However, the TIMSS study of 1995 and the Repeat-TIMSS of 1999, the biggest international studies conducted to date, might give us a glimpse. In both, the Israeli students scored lower than average in math and science and their scoring had one of the sharpest decreases= from 1995 to 1998 (Beaton et al. 1996; Martin et al. 2000; Mullis et al. 1997; Mullis et al. 2000).

¹¹⁴ According to Israel's Central Bureau of Statistics the level of state support for universities in the 1990s was about 51% to 57%, the OECD average for 1997 was 82%, a gap of more than 20%. In addition, while the OECD average of the state expenditure on third level education out of total expenditures was 2.7%, in Israel the average stood at 2.2% (Bentur 2002; CBS 1999a; CBS 1999b; CBS 2000a; CBS 2000b).

Chapter Three – The Development of the IT industry in Taiwan – Public Research Institutions as Growth Impetus?

“If you want to build something new where nothing was before, go to the US. If you want to build something that would last for 20 years, go to Japan. If you want to work successfully under always changing conditions and changing regulatory systems, go to Taiwan.”

A founder and manager of one of Taiwan’s first IT companies

Introduction

Even within the world’s most distinguished group of successful emerging economies, the East Asian Newly Industrialized Countries (NICs), Taiwan has one of the most inspiring stories. Taiwan is the only society in the region that has closed, in many critical aspects, the gap in innovational activities with the leading western industrial nations and Japan.¹¹⁵ Taiwan has also developed a vibrant industrial system of indigenous new small and medium size enterprises, a system that is not dominated by a few huge conglomerates or subsidiaries of foreign MNCs (Wu 2001).

Taiwanese companies have become a prominent force in the IT industry’s global production network. During the 1990s Taiwanese companies pioneered the model of the pure integrated circuit (IC) silicon chips fabrication foundries (hereafter: pureplay foundries) in semiconductor, and more than half of the world’s silicon chips are now being fabricated in Taiwan. Designing and manufacturing products for the world leading MNCs, Taiwanese IT companies manufactured, in 2001, 70% of global production of motherboards, 55% of laptops, 56% of LCD monitors, 51% of color-display-tube monitors and 36% of digital still cameras.¹¹⁶ In addition, with 225 companies and \$147.8NT billion in sales the Taiwan’s IC design sub-sector is the second largest in the

¹¹⁵ In international patent issuing, one of our most reliable proxies for industrial innovation, Taiwan moved from issuing one patent in 1973 to issuing 3693 in 1999, reaching as early as 1997 a ratio of international patents per capita, which is higher than any of the G7 countries except Japan and the US (Hall et al. 2001; Trajtenberg 2001).

¹¹⁶ In addition, Taiwanese companies operating in the mainland manufacture a large percentage of the same products that are made in China.

world after the US. The total sales of the Taiwanese electrical and electronics industry in 2002 reached almost \$88USD billion and on top of that the semiconductor industry added another \$21.4USD billion.¹¹⁷

How did this transformation happen? In Taiwan the state itself, acting as the technology-creating agent, has spurred the growth of the IT sector, the Taiwanese state acquired the necessary technological information and skills for high-technology industrial development policy by embedding the technology creating agents within its structure. The main policy vehicle behind this achievement was the establishment of two public research institutions responsible not only for making the decisions on what R&D to conduct, but also implementing and executing them.

Nonetheless, the Taiwanese approach to S&T industrial policy was not without its limitations, mainly the stagnation of the software sector and the limited new product innovation capabilities developed by the private industry. In addition, under the KMT, the state purposely built a financial system with a severe scarcity of patient capital, in stark contrast to both Gerschenkron and the developmental state models following it (Amsden 1989; Amsden 2001; Gerschenkron 1962; Johnson 1995; Woo-Cumings 1999). Taiwanese companies' average equity/debt ratio has been as low as in the US and, at times, even lower (Cheng 1990; Cheng 1993; Fields 1997; Gold 1986). This helped the Taiwanese economy to remain relatively unscathed from the East Asian financial crisis (Park 2000). However, it limits the ability of Taiwanese companies to compete in many IT manufacturing sectors (Fuller et al. 2003). Even in comparison to Israel and Ireland the state has taken limited financial commitments (Cheng 1990; Cheng 1993; Pack 1993; Park 2000).

¹¹⁷ Sources: III various years; ITRI various years; MoEA various years.

Taiwan has also followed a distinct policy in regard to MNCs and the shaping of the relationships between its local IT industry and global markets. Early in its industrial efforts, its policy goal was to make Taiwan into a supplier of components, systems, and design and manufacturing services to the global IT production network. Thus, the story of the spectacular and unique growth trajectory of the Taiwanese IT hardware industry, and the less than spectacular growth of the software industry, do not stem from massive investment of patient capital, but from a distinctive institutional system of industrial innovation. A system built around public research institutions-led R&D S&T industrial policy, and a policy goal of attaining a defined position within the IT industry's global production network.

This chapter analyzes the general growth of the Taiwanese IT industry and the Taiwanese Science and Technology (S&T) Industrial policies. It pays special attention to the successful political processes of co-evolution between the Industrial Technology Research Institution (ITRI) and the private hardware industry, and the unsuccessful process of co-evolution managed by Institute for Information Industry (III) and the software industry. The chapter also analyzes the state's strategy in acquiring the necessary technological skills and information and its affects, and the state's attempts to control and plan the technological development path of the IT industry. Lastly, the chapter inquires into the changing roles of the state in the construction of MNC's activities in, and relationships with Taiwanese companies, within and outside Taiwan.

My conclusions are, first, that the success of the hardware sector and the relative failure of the software sector stems from the different politics of state/industry co-evolution in the two sectors. In hardware, ITRI evolved from being the initiator and

leader of the industry to a position of a supporting actor; in the process this instigated the move of the Taiwanese industry to leadership positions in semiconductor manufacturing and design as well as desktop, laptop, and other electronic systems, and components' design and manufacturing. In software, from the beginning, III evolved to a position of a competitor to the private industry doing as much to compete with it as it did to support it. III never managed to take a contributing leadership position in any software technology development project in the same way that ITRI did in hardware. Thus, the Taiwanese software industry that developed, did so in spite of III, not because of it. These differences originate, I argue, from the different positioning of the two institutions by the Taiwanese state, as well as from some inherent differences in the industrial sectors for whose development they were nominally responsible.

My second conclusion is that the institutional system of Taiwan, a system with strong division of labor between industry and public research institutions, limits the R&D capabilities of private firms by motivating these firms to concentrate more on the development part of the R&D. This system was developed by the particular decisions of the state on how to acquire its own technological skills and knowledge. In this system, it is the public research institutions that decide which R&D projects should be pursued, conduct the lion-share of R&D, and only then diffuse the results to the private industry; accordingly, core R&D capabilities' development is concentrated almost solely within the public sector. Thus, in Taiwan, specifically because of this institutional system, the industry focused and successfully developed world-leading capabilities in second-generation, process, and manufacturing innovation, but not in new product development.

My third conclusion is that the decision of the state to focus its attention on building a local supplier network for MNCs, coupled with the way it constructed its capital markets, paved a development path for an IT industry that concentrates on several complementary activities of the global IT industry's network: components development and design, coupled with manufacturing and OEM/ODM services. This development path correlates very well with the IT innovation system, which has been developed around the private-public division of labor, with its strength in second-generation innovation and integrated design capabilities. However, it remains to be seen if Taiwan can, or should, move to original new product R&D activities in the future, the main declared goal of government policy are the last decade.

Historical Background

Looking at the successful Taiwanese IT industry in the beginning of the third millennium, one easily forgets that in the 1950s Taiwan was a poor agriculture-based island with almost no industrial and technological infrastructure, ruled by what was for eighty five percent of its population a foreign force, the defeated mainland China KMT. Taiwan's emergence as a democratic society has been equally remarkable since its politics started from foreign domination and the KMT's organized killing of many of Taiwan's native intellectual elite (Gold 1986).

Much of the literature that attempts to explain Taiwanese economic growth depicts Taiwan as a "poster-child" neo-development state. In almost all accounts, Taiwan is described as a society in which the state takes the lead in new economic activities, always, however, with the aim of spurring private entrepreneurs and always through interactions with private industry (Amsden 2001; Amsden and Chu 2003; Evans 1995;

Fields 1997; Fuller 2002; Hong 1997; Hung 2000; Mathews and Cho 2000; Wade 1990; Wang 1995; WB 1993). In most accounts, Taiwan's industrial and innovation systems come through as a humming machine of industrial development, with a smooth and well-functioning division of labor between government and industry. It is this division of labor that is considered responsible for Taiwan's leading role in the global Information Technology industry. Indeed, from the point of view of the development of the IT hardware industry, Taiwan does seem to be an exemplary case of a state managing to handle the complex, changing, and sometimes contradictory roles our theoretical approach argues, that a state needs to handle to spur the growth of innovation-based industry.

Three recent accounts of Taiwan's high-technology industrialization exemplify this point by reaching an almost complete agreement on the ways in which the state and industry in Taiwan have co-evolved in developing the IT hardware industry since the early 1970s (Amsden and Chu 2003; Hong 1997; Mathews and Cho 2000). While each author has a different vocabulary, each describes a similar two-phased process. First, the state's research agencies acquire a technology from abroad, absorb it and improve it, and then spin-off private companies to spur the industry. Second, after the private industry has emerged, the industry and state settle on a new division of labor in which the state's role is to locate, absorb, and infuse the industrial system with new technologies, and to assist private firms with their own advanced R&D projects. However, the actual socio-political-economic history of these developments was far from smooth.

The 1960s – the world’s semiconductor industry going global

The beginning of Taiwan’s modern IT industry dates to the 1960s.¹¹⁸ At that time, the semiconductor industry – a new industry – had evolved in the US to become the first to have truly globally fragmented production. During the 1960s, new developments made it feasible to geographically disconnect the heavily low-skilled-labor-intensive final assembly stages from the rest of the production processes. At the time Taiwan opted to follow an MNCs-FDI industrial policy very similar to Ireland’s, and the state marketed Taiwan as a business friendly place with an unlimited supply of stable, reliable, hard-working labor, and a growing market (Klintworth 1995). In these years, Taiwan had many of the same attractions to western companies that Mainland China now seems to possess.

With the help of USAID, the Taiwanese state was actively targeting foreign MNCs, following the same tactics that will become the hallmark of the Irish IDA in later years. Extensive background work on individual executives was performed to create a feeling of personal connection. Executives of US firms coming to Taiwan were treated like honored guests; they were ushered to personal meetings with Ministers who were thoroughly briefed on their personal background and sometimes even managed to put symbolic pictures, emphasizing a common past, between them and their visitors in their office (Wade 1990).

As part of those early efforts at FDI attraction, Taiwan also established export-processing zone (duty-free manufacturing area), again a striking similarity to Ireland’s first attempt at FDI attraction around the duty-free industrial region around Shannon

¹¹⁸ Local assembly of radios started in the 1940s; however, only in the 1960s did the MNCs start to reorganize their global IT production networks and embed Taiwan within it (Wade 1990).

(Hwang 1991). The year 1961 marks the beginning of the transformation of the global IT industry into an industry ruled by global fragmented production networks. In that year, Fairchild of the US and Phillips of Holland established their first semiconductor final assembly factories in Asia, Fairchild in Hong Kong and Phillips in Taiwan.

In 1964, after aggressive overtures by the Taiwanese government, General Instrument opened its first facility in Taiwan. In 1965, what the Taiwanese claim to be the world's first export-processing duty-free zone was opened near Kaohsiung and between 1964 and 1966, twenty-four US firms joined Philips and GI in opening manufacturing facilities in Taiwan.¹¹⁹ These efforts also mark the beginning of the rise to prominence of Taiwan's two most influential S&T industrial policy leaders, the technologists-politicians Dr. Y.S. Sun and Dr. K.T. Li (Cheng 1990; Hong 1997; Mathews and Cho 2000; Wade 1990). In 1965, by creating Taiwan's first data processing and software company – the China Data Processing Center – the state also pioneered what would later become a pillar of its IT industrial policy, the establishment and subsequent privatization of public firms in new technological areas.

The FDI-based IT industrial policy proved, at first, to be very successful. Exports of electronics boomed at 58% annual growth rates between 1966 and 1971. However, relatively quickly it became apparent that the US semiconductor companies have no intention of locating any higher-skilled operations in Taiwan. Therefore, the sustainability of this first success in semiconductor and advance electronics relied on relative low wages (Amsden and Chu 2003; Wade 1990). With wages rapidly rising as a result of the early economic success, it became apparent that unless something was done, this success in semiconductor would only be temporary.

¹¹⁹ The world's first export-processing duty-free zone was opened in Ireland around Shanon in 1958.

In the same period, and even earlier, the electronics manufacturing industry in Taiwan was already rapidly growing. Here, the Taiwanese government policy sharply diverged from that of Ireland. The Taiwanese state started to demand that a large and growing percentage of the components used for final assembly in Taiwan by MNC subsidiaries and joint ventures would be locally manufactured.¹²⁰ The policy proved to be very successful in breaking the enclave positions of MNCs. This was especially true in the case of the Japanese MNCs, which aimed to sell to the local market and hence were more susceptible to the new local components requirements. By 1971, 37% of all components used by the electronics industry in Taiwan were manufactured locally. Moreover, the first Original Equipment Manufacturing (OEM) relationships between Taiwanese companies and foreign MNCs started in these sectors, becoming prominent first in the manufacturing of color TVs (Amsden and Chu 2003).¹²¹

This policy had far-reaching impacts on the future of the Taiwanese IT industry and S&T industrial policy. From its early beginning, the political situation of Taiwan, which led to the creation of a financial system that specifically limited the use of large investment of long-term capital and the accumulation of debt led to a particular vision of the future of the Taiwanese IT industry. Accordingly, the goal of the Taiwanese S&T industrial policy was to spur the growth of a local IT industry that supplies, first, many of the necessary components, especially the higher-value ones, to the global IT production

¹²⁰ The Taiwanese government also urged MNCs to establish joint ventures with local manufactures in which the MNC transferred some of its manufacturing technology to the local suppliers instead of establishing a fully-owned subsidiary. In electronics and electrical consumer goods, unlike semiconductor, the Japanese have always been a more important source of FDI and technology to Taiwan than the US.

¹²¹ OEM is a sub-contracting manufacturing relationship in which one side manufactures equipment for the other side to be sold under the second sides brand name and in accordance with the second sides detailed specifications. ODM – Original Design Manufacturing – is a subcontracting relationship in which the manufacturing side is also giving detailed and integrated design services to the brand name company, which supplies it with only high level design specifications. OBM – Own Brand Manufacturing – happens when the manufacturer is manufacturing products to be sold under its own brand.

network. Second, the goal was to develop a local IT industry that provides manufacturing (and later design) services of increasing sophistication to the world's leading MNCs. It has never been the goal of the Taiwanese state to create big vertically integrated national champions in the same way as other Asian NICs, such as S. Korea, did. Nor, was it ever the goal to create cutting-edge innovation-based firms similarly to Israel or the US. Of our three cases, Taiwan was much more persistent in its efforts to convince MNC manufacturing subsidiaries to embed themselves more deeply within the Taiwanese industry, and in urging them to transfer more and more responsibilities over growing span of activities to local suppliers.

For these reasons, by the time the economic and political crises of the 1970s hit Taiwan, its electronic industry was already geared toward a specific relationship with, and embeddedness within, the global IT industry production network. Moreover, the Taiwanese innovation system and industrial policy were already centered around components manufacturing, thus, on manufacturing and process innovation, not on the generation of R&D-based new products.

The Crisis of the 1970s and the Crystallization of the Public Research Institutions-Based Industrial Policy – The Creation of the Semiconductor Industry

In the early 1970s, the global economy in general and Taiwan's economy in particular went through several waves of severe economic and political crises. In 1971 the Bretton Woods system was dismantled; in 1973, the first oil shock resulted in a steep rise in the price of oil, and many of the advanced industrial economies started to suffer from stagflation. Taiwan's exports, then mainly textile and footwear and low-level electronics, started to face competition from less developed countries and protectionists' measures in their target markets. In addition, with the reemergence of China on the global political

scene and the de-recognition of Taiwan in the United Nations in 1971, Taiwan has started a long period of formal political isolation. It was under those conditions that Taiwan reformulated its S&T industrial policy. Nonetheless, for many years many politicians and bureaucrats did not view the IT industry as a primary source of growth. As will be discussed in details below, the overall budget of ITRI's semiconductor technology development efforts have been minuscule in comparison to the amounts dedicated to other industries by the Taiwanese state and in comparison to the investment of other states in their semiconductor industries.

By 1973, some Taiwanese-owned subcontracting firms for assembly and packaging of semiconductor appeared; however, there were still no direct forward or backward linkages and the semiconductor industry was still an MNC enclave utilizing relative low labor costs and focusing on low-skilled final assembly stages. In January 1973, Dr. Yun-Hsuan Sun, then the Minister for Economic Affairs (MoEA) and later the Premier, oversaw the establishment of ITRI near Hsinchu, a strategic location close to Taiwan's two leading engineering universities, National Chiao Tung University and National Chinghua University. ITRI was created through the merger of three existing governmental labs. Using his considerable political power, Dr. Sun managed to transfer the responsibility for electronics R&D from the Ministry of Telecommunication laboratory to the newly formed ITRI. However, very similarly to the beginning of Israel's OCS, ITRI was not at the time considered to be a major policy initiative, and its overall

financing was negligible from the point of view of the state's overall industrial policies.¹²²

The idea behind ITRI's creation was to form one main national lab, which would be responsible for the upgrading of Taiwan's industrial technology through technology transfer, development, and diffusion. The objective was that the government would take it upon itself to solve the risky and more challenging part of the R&D process and would then diffuse the results to the industry, which would concentrate on final development and manufacturing. Thus, the state has opted to bring the R&D-creating agents within its own structure, developing a particular division of labor between the industry and the state. This division of labor, which after a few successes became prominent in the innovation system of Taiwan's semiconductor and electronics industry, has had significant influence on the kind of capabilities private firms developed, and on the kind of business models and business strategies that gained paradigmatic hold in Taiwan.

In August 1974, Dr. Sun met his friend Dr. Wen-Yuan Pan, a Chinese-American engineer working at RCA's David Sarnoff laboratories, in Princeton, New Jersey. The two agreed on a plan to formulate an S&T industrial policy geared toward the creation of a semiconductor industry in Taiwan. Dr. Pan, subsequently, established a group of mostly Chinese-American engineers working for leading American semiconductor companies in the US. The group regularly conveyed at Princeton as the Technical Advisory Committee. The committee submitted specific recommendations for the establishment of a specialist lab in ITRI that would act as the focal launching point for the industry. In September 1974, the Electronic Research Service Organization (ERSO) was established

¹²² The total amount of resources dedicated to the first ERSO project which culminated in the creation of UMC was less than \$15USD million given over five years between 1974 to 1979 as part of the first stage of the Electronic Industry Development Program (EDIP) (Fuller et al. 2003; Hong 1997; Meany 1994).

in ITRI with its main first goal being the development of technological capabilities to spur the growth of a semiconductor industry.

ERSO started to look for sources of IC fabrication technologies. However, it did not manage to find any suitable partners until, through Dr. Pan's influence, in 1976 RCA agreed to transfer its already obsolete technology to ITRI. At that time RCA decided to get out of semiconductor and saw this as an opportunity to earn royalties from its old and soon to be unused 7-micron CMOS fabrication technology. This was a technology that was already far behind the world limit of 2-micron. A group of 40 engineers, many of whom later became the leaders of the semiconductor industry in Taiwan, spent almost a year in RCA's facilities in the US, and ERSO built its first IC fabrication plant with RCA's guidance. In 1977-78 the first trial wafers were produced and the Taiwanese team started to test its own experimental designs. In 1979, the ERSO team advanced to such a degree that it had better yields than RCA's and started to sell small amounts of chips to supplement its financial resources.

At the same time, the Taiwanese state was establishing the physical and business infrastructure needed for the semiconductor industry. It is here that Dr. Kuo-Ting Li leadership over Taiwanese S&T industrial policy became crucial. Dr. Li served as Minister of Finance after serving as the Minister for Economic Affairs. In 1978, Li conveyed a special conference on Taiwan's economic and scientific future. The result of this well-attended event was "The Science and Technology Development Program" which was adapted by the Cabinet and called for: (a) the creation of a special permanent advisory body for science and technology: the Science and Technology Advisory Group

(STAG), to be chaired by Li, that would report directly to Premier Sun; and, (b) the creation of an infrastructure focused on the needs of science-based advanced industries.

The latter project was championed by the president of National Chinghua University, S.S. Hsu, who urged for the creation of a science-based industrial park next to Taiwan's three prominent engineering institutions in Hsinchu to imitate what he perceived to have happened around Stanford University in California (Hong 1997).¹²³ The park, named Hsinchu Science-Based Industrial Park (hereafter: Hsinchu Park), was put under the jurisdiction of the National Science Council (NSC) and launched in 1980.¹²⁴ Hsinchu Park became an extremely important factor in Taiwan's subsequent success in the semiconductor industry. Hsinchu Park has been accepting only firms with significant R&D operations, for which, apart from providing specialized infrastructure, it has been granting these special subsidiaries, such as tax holidays, duty exemption on equipment importation and commodity exports, low-interest-rate loans, and matching R&D funds.

However, it was not private industry that established the first, and many of the subsequent, leading firms of the Taiwanese semiconductor industry. In the late 1970s, facing what seems to them to be large initial investment with high uncertainty, no private entrepreneur, industrial group, or investor was willing to invest capital in commercializing the technologies developed in ERSO. Under these conditions both Dr. Sun and Dr. Li decided against the establishment of a fully state-owned company and

¹²³ At the time, advancement to the higher administrative positions in Taiwanese universities was political; hence, S.S. Hsu, the president of Taiwan's leading technical university, wielded considerable political power within the KMT.

¹²⁴ Some authors argue that in building the Hsinchu Park the Taiwanese state was utilizing the same model of the export-processing zones geared, this time, toward the development of a local industrial sector (Hwang 1991).

chose to create a joint private-state venture. In 1978, the head of ERSO, together with one of the 40 engineers who went to RCA, proposed a plan for the establishment of a private-state company. MoEA accepted their proposal and invited some of Taiwan's biggest companies as investors.¹²⁵ At first, none of the companies invited agreed to join. MoEA then used its direct influence and organized a coalition of local companies who finally agreed to invest in the project, and between them, 51% of the shares of the new entity, United Microelectronics Corporation (UMC), were distributed. The total sum invested stood between \$14USD to \$20USD million.¹²⁶

Apart from receiving all of its technical staff and technology from ERSO, UMC was also granted technical assistance from, and the use of, ERSO's fabrication plant, a source for many subsequent conflicts of interest. UMC quickly engaged in another series of fund-raising and built its own first fully-owned fabrication plant in the newly established Hsinchu Park in 1982.

Diversifying and Deepening the Technological Base of the Semiconductor Industry – ERSO Strategy of Parallel Capabilities Development

ERSO's prominence over the development trajectory of the Taiwanese semiconductor industry did not end with the spin-off of UMC. On the contrary, the successful launch of UMC encouraged subsequent formal and less formal spin-offs, i.e., teams of engineers leaving to establish their own companies. Following the establishment of UMC, ERSO itself slightly changed its focus. At the urging of its American advisors, ITRI/ERSO made a few important decisions, the first was to stay clear from what would

¹²⁵ In order for the company to have the legal status of private company the government could not to own more than 49% of the shares.

¹²⁶ As with many other records and statistical data regarding the IT industry in Taiwan, there seem to be a slight disagreement between different researchers and official statements. For two different cost statements, see Hong 1997; Mathews and Cho 2000.

become an extremely capital-intensive market niche, memory chips, specifically DRAM.¹²⁷ The second decision was to base the Taiwanese semiconductor industry around capabilities that would allow it to competitively and quickly design and manufacture custom-tailor chips (also known as Application Specific Integrated Circuit – ASIC), and not just around specific products. ERSO argued that by developing this technological capability Taiwan would, first, strategically differentiate itself from Korea and Japan, who had embarked on a strategy of high-volume rapid-generational-upgrading chips such as memory chips, which necessitate extremely deep-pocketed companies of the kind Taiwan did not possess. ERSO further argued that this strategy would enable Taiwan to focus on the consumer industry, where Taiwanese electronic manufacturing companies were already globally successful and reached substantial revenues using relatively simple technology. ERSO rightly contended that by developing these capabilities, Taiwan's semiconductor industry could innovate across the whole spectrum of the IT industry (Wade 1990).

The Taiwanese semiconductor industry developed capabilities that: i) both strengthened the Taiwanese IT hardware OEM and ODM industry; and, ii) allowed it to excel in the market niches open to it by the existence of the Taiwanese OEM and ODM firms. In other words, the decision by ERSO to prompt the development of strong ASIC capabilities in the semiconductor industry positioned the industry perfectly to take the advantage of the opportunity structure offered by the successful IT design and manufacturing subcontractors industry, and strengthened the competitiveness of that industry in turn. As the next part of the chapter shows, this, in turn, has reinforced

¹²⁷ DRAM (Dynamic Random Access Memory) chips quickly became the focal point of, first, Japanese-American, and then Korean-Japanese, investment and price wars.

Taiwan's embeddedness in the global IT production network as a supplier and innovator of components and design and manufacturing services and processes.

As part of its strategic decision to focus on ASIC technologies and capabilities, after UMC's spin-off ITRI/ERSO pursued a dual capabilities development strategy. The strategy focused on developing both ASIC capabilities and the fabrication technologies needed to manufacture them. ERSO managed to move its own fabrication capabilities to 4.5 micron in 1981 (still far behind the world's technological edge at the time at 2-Micron), and to acquire and develop complementary technologies that would enable Taiwan to excel in ASICs. In the early 1980s, ERSO expanded its capabilities in design, testing, and several other stages of IC production, including masking. It was in this early stage that many teams of ERSO employees started to leave ITRI to open IC design houses that utilized ERSO's and UMC's fabrication facilities, one of the first being Syntek in 1982 (Chang and Tsai 2002). Hence, even before the establishment of the pureplay foundry model by another ERSO spin-off – Taiwan Semiconductor Manufacturing Corporation (TSMC) – more than a few design houses were operating in Hsinchu Park and within a year after the establishment of TSMC their number was estimated at forty.

Transforming the Global Semiconductor Industry – Establishing the Pureplay Foundry Model in Taiwan

The pureplay foundry business model, pioneered by ITRI/ERSO and spun-off as TSMC in 1986, developed as part of ERSO's efforts to infuse the Taiwanese industry with Very Large Scale Integration (VLSI) capabilities. ERSO's foreign advisors, who did not view the progress to 4.5-micron technology as fast enough to close the gap with the world's technological leaders, urged these efforts on. In 1981, STAG, chaired by Li,

argued that Taiwan should achieve VLSI capability of 1-Micron or better, the technological frontier at the time.

A political battle immediately ensued, as this view was attacked from almost all quarters in Taiwan's economic development bureaucracy, including the Ministry of Finance, the Council for Economic Planning and Development, and a large percentage of ERSO's personnel. However, with the backing of by-then Premier Sun and Dr. Li a decision was made to go forward with a VLSI 1-micron technology development project, simultaneously with ERSO's other activities. In 1983, \$72.5USD million were allocated to a five year program on various semiconductor projects, a larger amount by far than those given before, but still insignificant in both international terms and in comparison to other Taiwanese industrial policies. The goal was to reach 1-micron capabilities by 1988. Once again, ITRI was leading the private market.

The decision on the implementation of the VLSI research project was a continuation of the earlier strategy of a division of labor in R&D between public institutions and private companies, with the public institutions commencing most of the research and the results diffused to private companies that focused mostly on development and design. After a battle with UMC, which argued that it should be responsible for the development of the VLSI technology, ITRI/ERSO was again the chosen agency, in part to prevent an over-concentration of power and capabilities in one private company (Fuller et al. 2003; Hong 1997; Mathews and Cho 2000; Meany 1994). This time ERSO decided to follow a joint-venture technology development strategy and did not go for technology transfer contracts. The chosen party was Vitelic, a small Silicon Valley firm founded by Chinese-American engineers in 1983. The R&D phase was

successful with a DRAM chip developed by June 1986. However, at the time, neither the government nor the private sector in Taiwan was willing to supply the necessary manufacturing facility, and as a result Vitelic sold its technologies to various Korean and Japanese companies (Meany 1994).

This awkward situation strengthened politically those who argued for more direct state intervention in the building of VLSI fabrication facilities in Taiwan (Hong 1997). In addition, by the end of 1986 it became obvious that there is a wider demand for VLSI fabrication facilities as many of the new design houses in Hsinchu Park opted to follow Vitelic and sold their technologies to Korean and Japanese firms.

In the same time that ERSO developed VLSI technologies, UMC also developed its own similar technology, utilizing both in-house development and joint-venture agreements. This technological competition was straining even more the conflict of interest between ERSO and UMC, especially as at the time Morris Chang, the head of ITRI, was also serving as the Chairman of UMC. Morris Chang also epitomizes another important trend in Taiwan's rise to prominence in the semiconductor industry, the returning immigration wave of graduate level-trained engineers from the US.¹²⁸

Taiwan has one of the highest numbers of engineering and science students who immigrated to the US to get advance engineering and science degrees. For most of the period until the early 1980s, these Taiwanese ex-patriates did not see any opportunity to employ their skills profitably in Taiwan and most of them stayed on in the US. However, with the creation of ITRI and even more so with the growing success of the semiconductor industry, a large percentage came back or established cross-country

¹²⁸ Before his return to Taiwan to head ITRI, Morris Chang had been the highest level Taiwanese executive of an American semiconductor MNC, Texas Instruments. He was persuaded to come back to Taiwan to head ITRI by Dr. Li and Bob Evans, one of STAG's most influential American members.

businesses. This so-called reverse brain drain has been one of the most important factors in the rapid growth of the semiconductor industry (Saxenian and Hsu 2001).

However, while the influence of the returnees has been important, we should remember that this pullback started and strengthened only after many of them saw an economic opportunity in Taiwan, not vice-versa. Moreover, while returnees established many companies, locals founded most of the key companies.¹²⁹ In addition, while the fact that many of them came back from Silicon Valley is celebrated, the influence of returning immigrants from other parts of the US, notably the large contingent coming back after long stints in Bell Labs and IBM, has been at least as important, a fact that was repeatedly referred to by our interviewees during our research trips to Taiwan (Amsden and Chu 2003; Saxenian and Hsu 2001).

In 1986, after some internal debate, a decision was made to move forward with the privatization of ERSO's VLSI efforts and the construction of a VLSI fabrication facility employing an innovative business model – the pureplay foundry. This decision marks a turning point, not only for the Taiwanese semiconductor industry but also for the global semiconductor industry. Similarly to UMC, the decision was to commercialize and privatize the VLSI project by creating a joint public-private company, TSMC. Again, the Taiwanese state faced a similar investment landscape to the one it faced with UMC. Although by now the success of UMC and the growth of the industry was proof that the semiconductor industry in Taiwan can be profitable, the private market was still unwilling to commit to a leading investment. This ironically proved to be a boon for

¹²⁹ It is rare to find a returning immigrant in the founding teams of any of the key companies, apart from Morris Chang, who returned not to establish a company but to head ITRI from which he moved to head TSMC. This should not surprise us since the returning immigrants usually lack strong local knowledge and social networks, which were necessary in the early phases of the industry to secure finance, customers, and high-quality workforce for newly established companies.

TSMC as Phillips, the Dutch MNC, agreed to invest 27.5% of TSMC's initial investment and became its leading private shareholder, with another 48.3% of the investment coming from the China Development Corporation, an investment arm of the ruling KMT party (Fuller 2002; Fuller et al. 2003). Apart from securing some business from Phillips, having Phillips as its main shareholder gave the new venture legitimacy, and even more importantly a full patent swap agreement that was critical in the beginning in protecting TSMC from offensive legal actions.¹³⁰

The pureplay model had major revolutionary influence on the global IT production network, on Taiwan's embeddedness within it, and on the reshaping of Taiwan's semiconductor industry. The pureplay foundry model is one of the best examples of an organizational innovation that enabled new levels of fragmentation of the semiconductor industry's production network. An innovation spurring a rapid process of advances in product stage specialization and product stage economies of scope and scale, consequently in stage specific innovation. Before the establishment of TSMC and the pureplay foundry, the semiconductor industry consisted mainly of companies that utilized the business model of integrated device manufacturers (IDM). The IDM model calls for the creation of large vertically-integrated firms that perform both design and fabrication in-house. The leading semiconductor firms were all IDMs that built their own dedicated fabrication plants. The industry also consisted of design houses that were smaller and marginal and that needed to secure their fabrication capacity from IDMs with no standards for information transfer, and with the added risk of sharing their IP with potential competitors. Moreover, the process was lengthy and cumbersome, putting the design houses in distinct disadvantage.

¹³⁰ Interviews with TSMC's president and senior VP for corporate development 5/31/2001.

The pureplay foundry model calls for the creation of companies whose sole business is fabrication. Pureplay foundries receive codified designs from the design houses and fabricate their chips for them. Thus, they enable stage specialization in both design and fabrication. In 1986, the viability of the pureplay foundry was still unclear, as the technology for full codification of the designs was not yet developed. However, in the particular case of Taiwan: the industry's growth limited by the political choice of a financial system that limited the use of long-term financing and debt; the already growing number of design houses in Hsinchu Park; the political pressure arising from the lack of VLSI fabrication capability that brought many of these design houses to outright sell the IP to foreign firms; and the political constraints that the existence and lobbying of UMC put on ITRI/ERSO, the pureplay foundry model seems to be worth these uncertainties. The additional advantage of the model was that a pureplay foundry could also learn from its customers. Many of TSMC's early customers passed on their technologies to TSMC so it could fabricate their chips. They were willing to do so only because TSMC's pureplay foundry model allayed their fears of it becoming their competitor. Consequently, TSMC has been using customers' feedback to refine and expand its fabrication method (Fuller et al. 2003).

For a few years, TSMC's growth was slow. Nevertheless, even then its effect on the Taiwanese semiconductor industry was immense. Its services enabled a growing number of fabless companies to profitably commence operations. This unleashed the commercial potential of the Taiwanese industry's ASIC specialization and skills. By 1994, there were already sixty-five design houses in Taiwan (ITRI 2003; ITRI various years). In this year the design codifying and transfer technology was fully developed, and

from 1997 the pureplay foundries have been fabricating the lion-share of chips in Taiwan with many of the IDMs, including UMC, converting to the foundry model or being bought by pureplay foundries in need of more fabrication facilities.

The pureplay became the prominent production model in the global semiconductor industry, completely transforming it in several ways. First, the pureplay model enables groups of engineers to quickly bring innovative designs to market with only limited financial resources, fostering even more rapid innovation cycles in the semiconductor industry. Secondly, the lower cost also enables group of engineers to profitably utilize the business strategy of offering cheaper chips in already developed niche markets using second-generation technologies. Third, the pureplay model transformed the industry by creating virtuous cycles of internal innovation and growing efficiency that make it even more profitable, vis-à-vis the IDM model. Today, thanks to their head start, the Taiwanese pureplay foundries, TSMC and UMC, are the global market leaders, with sales in 2002 of just below \$5USD billion, and just above \$2USD billion, respectively. TSMC and UMC and are the main reason behind the growth of the Taiwanese semiconductor industry to its current status as the world's fourth largest IC producer.

Apart from UMC and TSMC, ITRI/ERSO was also responsible for a few more of the leading Taiwanese semiconductor firms before ERSO was closed and the computer and communication lab (CCL) remained ITRI's sole semiconductor technology division. The Taiwan Mask Corporation (TMC) was spun off ITRI in 1989, ending the successful development of the masking technologies project at ERSO, began with technology

transfer from the US in 1977. TMC successfully grew in the years since, and in 2000 it bought Innova, Taiwan's second masking company.¹³¹

The two other important quasi-official spin-offs from ERSO were Vanguard and Winbond. Vanguard was the official spin-off of ERSO's submicron project that culminated in an industrial-size fabrication plant in Hsinchu Park. It was auctioned in 1995, with TSMC becoming its main shareholder. While not an official ERSO spin-off, Winbond should still be looked upon as quasi-official due to its particular history. In 1987, after the launch of TSMC, ITRI/ERSO was still in possession of its first pilot fabrication plant and its personnel. The plant manager, Dr. Yang, engineered an MBO, secured with financing from the Walsin Lihwa Corporation, launching it as Winbond., Unlike other Taiwanese companies, Winbond has been following the OBM model and has stayed as an IDM company, moving into both memory and logic. In 2002, Winbond's sales were slightly less than \$1USD billion.

From OEM to ODM: The Technological Upgrading of the Electronics Suppliers – ITRI's Role as a Supporting Actor

Taiwan's ODM/OEM firms are as important, if not more so, to Taiwan's success in the IT industry as are its semiconductor firms. Taiwan's OEM/ODM firms are successful in all sectors of the IT industry, employing many different business models. The range of strategies moves from more focused OEM/ODM companies, such as Quanta or Inventec that design and manufacture most of the world's laptops, and Asustek that does the same in motherboards, to more flexible OEM/ODM firms such as Sampo,

¹³¹ Masking is a discrete stage in the production of IC chips. It is estimated that because Taiwanese companies have local masking services available, about twenty days in the IC production cycle are saved (Amsden and Chu 2003. Pp. 108; Lin 1987). Hence, the perfection of the masking technology was an important part in ERSO's strategy of building a semiconductor industry whose competitive capabilities are related to its ASIC technologies.

BenQ (formerly part of the Acer group), Tatung, and Mitac that operate across a wider array of products.

The existence in Taiwan of local world leading OEM/ODM companies also propelled the growth of the semiconductor industry in a particular trajectory. The existence ODMs have given the Taiwanese IC design industry a competitive advantage and a unique opportunity structure focusing on second-generation innovation. These opportunity structures are not available to Israeli, Irish, and American IC design companies. The OEM/ODMs, in turn, have been strengthened by the success of the local IC design industry, which caters specifically to their needs and help them to improve their quality while lowering their costs.

ITRI and the Taiwanese state have been as important to the success of this sector as they were to the semiconductor industry. However, if in the semiconductor industry ITRI was the first and, for a long time, the only actor in the field, in the case of the OEM/ODM electronics, ITRI's main goal has been to technologically upgrade existing firms, some of which, like Tatung, have been around since 1918. Therefore, this sector give us an excellent example of how the Taiwanese state has pursued the same goal – developing a local IT industry that supplies many of the necessary components and manufacturing services to the global IT production network – applying the same division of labor in R&D, while using a different mechanism – the state-led research consortia. In addition, the case of OEM/ODM enables us to follow another angle of the co-evolution of industry-state relationships.

As has been vividly argued by John Mathews, the main goal of the Taiwanese R&D consortia has been technological learning, upgrading, and catch-up as part of

attempts at industry creation (Mathews 2002). This is a very different objective from Israel's goal where, as described in Chapter Two, the state constructed a special program to sponsor collaborative R&D efforts in an attempt to enable smaller Israeli firms to successfully compete with MNC on the basis of their own developed cutting-edge technologies.¹³² Like the Israeli state, the Taiwanese state also realized that the smaller size of its manufacturing-oriented companies, with their lack of sophisticated in-house R&D capabilities, hinders the ability of the Taiwanese IT industry to upgrade and compete in global markets. The solution was to assemble a series of ITRI-led research consortia. From the start of this process, the same division of labor in R&D that had been used in the case of semiconductor was applied, with ITRI conducting the R&D and the private companies concentrating in manufacturing and final product development. Even in the later research consortia, in which private companies assume leadership roles, this division of labor has been maintained.

The first few, and some of the most significant consortia, were developed as part of ITRI's multi-client projects in the early 1980s. These projects assisted in the creation of a PC development and manufacturing industry in Taiwan. The first such project started after Apple clamped down on the thriving Taiwanese Apple II cloning industry in late 1982. The industry, then a highly fragmented one with no prior experience with IP protection laws, came to MoEA and ITRI for help.¹³³ ITRI/ERSO already possessed some experience working with Intel processors, and advised them to concentrate on the

¹³² On the Israeli state-supported research consortia program, see also Breznitz 2004a; Breznitz 2004b; Breznitz 2005d.

¹³³ Because the American IP protection laws were revised to include computer codes only in 1980, Apple's lawsuit was one of the first of such suits worldwide.

new IBM Intel-based PC instead of Apple (Noble 1998). The real activity started after February 1983, when Acer approached ITRI/ERSO with a request to develop a PC.

After various halts and requests from other computer-manufacturing companies ITRI/ERSO devised the project as its first multi-client project with the title of MCP-1. A decision was made to limit the number of participants to nine. By the end of 1983, Taiwanese companies had started manufacturing IBM PC clones, hoping to ship them to the US in time for Christmas sales. However, IBM counterattacked, claiming that ITRI's basic input-output system (BIOS) was infringing on its IP.¹³⁴ ITRI/ERSO engineers rewrote the code, but by the time IBM agreed that the new version was legal, it was already May 1984. By then, most of the projects participants either sold their PCs in less IP-strict markets, such as Europe and Asia, or followed Acer and used a different BIOS system (Noble 1998).

Although this project was deemed less than satisfactory, as soon as IBM announced its new PC AT system in August 1984, ITRI/ERSO announced its intention to launch a new multi-client project. This time the participants were limited to three, including Tatung, which used this project as an entry into the computer business. The prototype was transferred by ITRI/ERSO to the companies by July 1985, and soon thereafter the companies started to bring their own products to market (Chang et al. 1999; Mathews 2002; Noble 1998). This project was considered a great success and paved the way to a series of related multi-client projects. From this point onward the projects were run by the newly established Computer and Communications Laboratory (CCL) and were more formally viewed as consortia and not as ITRI's multiple clients research projects.

¹³⁴ The BIOS system was the main, if not the sole, sub-system that IBM uniquely developed for its PC; most of the rest of the PC was built on the basis of open-system from standardized components that could be bought in the market.

By 1990, the Taiwanese industry was firmly established in desktops and other related products; nonetheless, its technological capabilities were still far behind what was needed to succeed in the then-new lucrative market, laptops. This time, ITRI/CCL formally drafted the project as an R&D consortium with the aim of developing a set of key components to become the standard on which the different companies would build and develop their products. The biggest computer-manufacturers trade association in Taiwan was involved and recruited as a joint coordinator. In July 1990, the Taiwan Laptop Consortium with 46 subscribing companies was officially announced with capital of \$2USD million (Mathews 2002). The project was concluded quickly and by the end of 1990 Taiwan achieved the status of the world's leading supplier of laptops. This time, ITRI/CCL not only transferred prototype machines, but also constructed extensive training programs and many of its staff moved to private firms. The main problems of the project were oversubscription and a too tight division of labor. The companies were given an almost complete product that was developed solely by ITRI/CCL, and were unable to differentiate and further develop their products, leading to a relentless price competition between the Taiwanese companies. These lessons were learned and throughout the ITRI-led consortia in the 1990s private companies were given slightly more R&D responsibilities, or at least slightly less finite prototypes. In some of the projects one of the declared aims was the creation of R&D, or at least integrated design capabilities, within the participating private companies.

As the Taiwanese industry has grown to become globally important, many of the leading MNCs happily supported many of ITRI's consortia. The MNCs have hoped to spur the growth of an industry based on their technology, and find it easier to have to deal

solely with ITRI, not separately with every private company. The best examples for such a project was the NewPC project, which was based around the PowerPC processors developed jointly by IBM, Motorola, and Apple (Dedrick and Kraemer 1998; Mathews 2002).

However, in the key area of developing the R&D capabilities of private companies, the research consortia are still far from being successful. For example, during an interview a top official of ITRI's CCL bitterly described the situation as:

“Technology transfer from CCL is very important in Taiwan. The companies use us to train their people, take our technology, and create some products. After which they go to their customers, show them the products as a proof that they can do OEM, sign some OEM contracts, and just do the same things a couple of years down the road. Our aim is to help and spur them to routinize R&D and product innovation. However, the end result is that they do not do it. A main reason being that they can more cheaply rely on technology transfer every time they need to upgrade their skills, which allow them to operate as a pure OEM.” (5/24/2001).

The state also used the research consortia mechanism not only to develop and create new IT products industries, but also to upgrade the Taiwanese electronic components industry, following its strategy from the early 1960s of trying to localize the creation of key components.

One of the most illuminating such projects was the CD-ROM project, which evolved from a MoEA's decision to view CD-ROM as a strategic product in 1992. As a result of this project, by the end of 1999 Taiwan moved from being a supplier of less than one percent of the world's CD-ROMs to supplying more than fifty percent, with almost 49 million units sold (Amsden and Chu 2003. p. 104). This project evolved into a series of consortia and moved on to DVD technology.

From the point of view of our argument about opportunity structure, it is important to note that one key sub-component that none of the consortia managed to

develop was the IC chips. By 1997, the development in the CD-ROM industry, and ITRI's inability to develop the needed IC chips, created an ideal market opportunity for a new IC design company that was just spun off UMC's, MediaTek. MediaTek succeeded where ITRI's consortia failed and quickly developed chips for the CD-ROM industry, breaking the monopoly of Japanese companies in the area. MediaTek's technologies moved together with the industry's, first to CDRW and then to DVD.¹³⁵ In the process, MediaTek became Taiwan's most successful IC design company and the world's fourth largest in terms of sales in both 2002 and 2003.¹³⁶

Nevertheless, even in the IT hardware sector not all of the Taiwanese state's initiatives have been successful. In parallel with ITRI, the Taiwanese government has also sponsored and expanded an even bigger public research institute – Chungshan Institute of Science and Technology (CSIST) – Taiwan's defense technology research institute. Apart from funds received through the defense establishment, CSIST was, as late as 1999, the receiver of the second largest amount of funds from MoEA's Department of Industrial Technology after ITRI (Hsu and Chiang 2001). Not a lot of information is available on CSIST, but while ITRI's efforts resulted in significant commercial success for relatively low investment, CSIST's, many times working on similar technologies with vastly larger resources, did not achieve even one commercial success in the semiconductor industry.¹³⁷ This compares poorly not only with ITRI, but also with Israel's experience. Interestingly the main difference between CSIST and both

¹³⁵ While not being part of ITRI's consortia, after being spun off by UMC MediaTek did subcontract various ITRI's labs for the co-development of specific R&D (Chang and Tsai 2002).

¹³⁶ Interview with MediaTek executives (11/5/2003).

¹³⁷ The full extent of CSIST's resources is concealed as a matter of national security; however, just in terms of manpower during the early 1980s, CSIST employed 20,000 researchers compared with ITRI's ,4000. Today CSIST employs about 14,000 and ITRI 6,000.

ITRI and Israel's RAFAEL is in the fact that CSIST does not maintain close relationships with the private industry and instead prefers to work in isolation under the guise of secrecy.

The Development of the Semiconductor Industry in the 1990s – The Growth of the IC Design Subsector¹³⁸

Of the many subsectors of the global IT hardware industry in the 1990s, the IC design (or fabless) subsector was one of the most innovative and most successful. By the early 2000s, Taiwanese IC design houses companies were the only non-North American companies to reach the top ten position in terms of worldwide sales. As a matter of fact, Taiwan and Israel are the only non-North American countries to have any companies at all in the top thirty companies in terms of worldwide sales, with no Japanese, South Korean, or European firms even making it to the list. By 2003, the Taiwanese IC design industry was already the second largest in the world in terms of sales after the US's. The IC design industry was the focus of attention for the Taiwanese state in the 1990s, and has been key in the attempts of the Taiwanese state to spur more cutting-edge innovational activity.

As can be seen in Table III over the last ten years the Taiwanese IC design industry experienced a remarkable growth. From an industry that consisted of 51 companies in 1991, the industry grew to 66 companies employing 2,109 people in 1996, and to 225 companies employing 11,800 in 2002. This rapid growth, with sales of over \$6USD billion in 2003, made it one of the three biggest IC design industries in the world (ITRI 2003; ITRI various years).

¹³⁸ The next two sections of the chapter are partly based on Breznitz 2005b; Breznitz 2005c.

Looking at the largest ten companies by sales in 2000-2002, in Table II, we see that the industry's skills are quite developed and flexible, as attested to by the ability of Taiwanese IC design firms to excel in almost every subsector of the semiconductor industry. In addition, it is apparent that these successful companies have built their businesses around the opportunity structures offered by the existence of the large OEM/ODM companies in Taiwan and ITRI's efforts to develop local manufacturing of key components. For example, MediaTek's core business has been the PCs' CD and DVD industries; VIA is developing PC chipsets with its customers being the motherboard and PC manufacturers; Ali's main business is laptop chipsets; and Sunplus is catering to the consumer markets, especially to toys OEM/ODMs.

Table I – Top 30 Fabless Companies By Global Sales

2003 ranking	2002 ranking	Company	Country	2000	2001	2002	2003 (f)
1	1	Qualcomm	US	1,215	1,395	1,942	2,510
2	2	Nvidia	US	699	1,275	1,915	1,835
3	4	Broadcom	US	1,096	962	1,083	1,595
4	3	Xilinx	US	1,560	1,149	1,125	1,265
5	5	MediaTek	Taiwan	411	447	854	1,170
6	8	ATI	Canada	520	480	645	1,135
7	10	SanDisk	US	602	317	493	930
8	7	Altera	US	1,377	839	712	830
9	11	Marvell	US	135	275	482	780
10	9	Conexant*	US	-	646	1,942	650
11	6	VIA	Taiwan	909	1,009	729	620
12	12	Qlogic	US	362	357	415	520
13	18	GlobespanVirata*	US	348	265	229	360
14	16	Sunplus	Taiwan	201	195	250	320
15	23	Novatek	Taiwan	121	124	193	311
16	24	Silicon Laboratories	US	103	74	182	310
17	15	Realtek	Taiwan	174	214	265	300
18	17	SST	US	490	259	244	250
19	21	PMC-Sierra	Canada	695	323	213	245
20	20	ICS	US	195	155	228	237
21	19	Lattice	US	568	295	229	218
22	29	Zoran	US (Israel)	68	100	141	213
23	22	Genesis Microchip	Canada	56	126	196	211
24	28	SMSC	US	163	128	145	202
25	-	Zarlink**	Canada	-	-	-	201
26	25	Ali	Taiwan	98	159	176	200
27	13	Cirrus Logic	US	729	534	304	198
28	14	ESS	US	303	271	273	180
29	32	DSP Group	US (Israel)	85	88	125	170
30	26	Semtech	US	215	170	170	160
		Others	-	3,512	2,504	2,210	2,514
		Total		17,010	15,135	16,795	20,640

Source: IC Insights' Mclean Report 2004

Conexant and GlobespanVirata plan to merge in 1Q 2004.

**Became fabless in mid-2002.

Table II Top 10 Taiwanese Design Houses by Sales – (NT 100 million)

Rank			Name	Sales			Main Product Line
2002	2001	2000		2002	2001	2000	
1	2	2	MediaTek Inc.	295	154	129	Optical storage
2	1	1	VIA	252	343	309	PC Chipsets
3	3	5	RealTek	92	73	54	Networking
4	4	3	Sunplus Technology	86	66	63	Consumer
5	6	8	Novatek Microelectronics Corp.	67	42	42	Consumer
6	5	-	ALi Corp.	61	54	31	PC chipsets/DVD Player IC
7	7	9	Elan Microelectronics	40	36	39	Consumer
8	9	7	Elite Semiconductor	34	30	43	Memory
9	-	-	Faraday	34	24	-	Memory
10	8	6	Holtek Semiconductor Inc.	33	32	45	Consumer

Source: *Bandaoti Gongye Nianjian* (The Yearbook of Semiconductor Industry in 2003), ITRI, 2003.

Table III - Size of the IC design sector in Taiwan 1991-2000

	Number of companies	Employees
1991	57	
1992	59	
1993	64	
1994	65	
1995	66	2109
1996	72	2141
1997	81	3349
1998	115	4200
1999	127	6000
2000	140	7600
2001	180	9800
2002	225	11800

Sources: (ITRI 2003; ITRI various years)

Another common trait appears if we analyze the strategy of the leading companies: none of them develops completely new innovative products that are first to the market.

Furthermore, even the most innovative firms, those that manage to develop some brand recognition for their products, such as VIA and ALi, rely on developing secondary innovations on the basis of technologies developed by the leading American MNCs. This tends to leave many of them in a weakened position, where changes in technology or in the behavior of leading MNCs can rapidly deteriorate their market position.

The story of VIA, the largest Taiwanese IC design company in terms of sales until 2002, is a case in point. PC's chipsets are VIA's main product line. As long as Intel's Pentium 3 was the leading PC CPU, VIA gained global market share on Intel's expense, reaching almost 50%, in part because of Intel's decision to stick with the more expensive Rambus technology. With the move to Pentium 4 technology, Intel attacked VIA on multiple fronts: it did not license VIA its P4 technology and it took VIA to court over patent infringement allegations in October 2001. As a result of these moves, all first-tier PC manufacturers, such as Asus or Gigabyte, refrained from using VIA's chipsets, fearing legal action from Intel. VIA counter-sued Intel for both patent infringement and usage of monopoly status, and the legal battle was fought in five jurisdictions. In April 2003, the two companies reached a settlement that includes a patent swap agreement and a licensing agreement. By that time, however, VIA has lost substantial market share and revenues. Moreover, because it agreed to pay royalties to Intel it can no longer retain the profit margins it enjoyed before. If, in 2001, VIA was the biggest Taiwanese IC design house, with about \$1USD billion in sales and control of almost 50% of global market share, in 2002 VIA was only the second largest Taiwanese IC design house, with sales

down to \$729USD million and global market share of less than 25%. In 2003, VIA's sales continued to drop and its sales were only \$600USD million (AFX 2001; FT 2003a; FT 2003b; FT 2003c; Hille 2003; Hung 2002).

Another example of the vulnerability of the Taiwanese IC design industry position within the global production networks is the fact that this legal battle was fought after VIA had already changed its ownership structure to placate Intel's demand. In order to do so VIA separated itself from its main shareholder, First International Computers (FIC). This restructuring was done since Intel viewed the combination of motherboard producer, FIC, and chipset producer, VIA, as a threat.¹³⁹

As can be seen from the rapid growth of the design, or fabless, subsector after 1996, the main impetus for growth had been the establishment and rapid growth of the pureplay foundries. Both major foundries, TSMC and UMC, have taken leading roles in the development of the design subsector. Both established exclusive foundry-IC design house relationships with what they term club members, which they also assisted financially. Many of the top IC design houses such as MediaTek and NoveTek were spun off from UMC when it turned its business model from IDM to pureplay foundry.

Structure, Development, and Business Models in the Taiwanese IC Design Industry

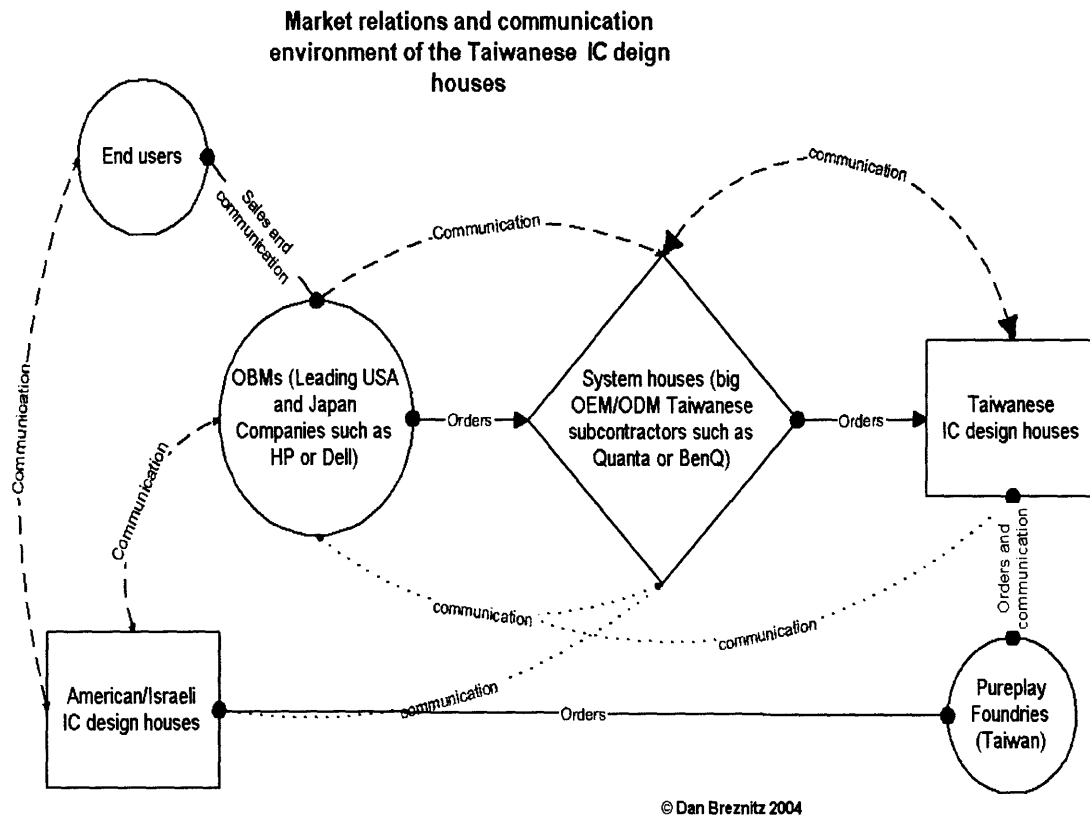
Taiwanese fabless companies employ one main business model, apart from the few cases where a Taiwanese company manages to sell its own branded products to final customers. This business model is based on the utilization of the unique advantage that the Taiwanese IT industry's structure offers: the co-location of both the world's biggest and most advanced pureplay foundries and of some of the largest OEM/ODM companies.

¹³⁹ Interviews with VIA and FIC executives (1/17/2000; 3/24/1999).

Most of the Taiwanese IC design houses employ two variants of the same strategy: to supply the Taiwanese (and more recently the Chinese) OEM/ODMs with the chips they need in order to supply finished products at competitive prices and of sufficient quality to OBM MNCs. The Taiwanese fabless companies rely on the proximity of the world's biggest pureplay foundries. This geographical proximity enables them to produce cheaply and speedily large quantities of newly-designed chips and to inspect and assure quality in almost real-time. All the Taiwanese IC design houses we interviewed specialize in chips based on second-generation technologies with the aim of lowering costs and increasing reliability; they also do some process innovation. Apart from an unsuccessful attempt by ICreate, a subsidiary of Etron, to develop and market advanced chips in a joint venture with the Israeli company Zoran, no Taiwanese IC design house that we interviewed tried to develop original products, new technologies, or products that are based on cutting-edge technology. Figure I below provides a graphic representation of the main differences between the market relation and information and communication flows of the Taiwanese industry in comparison with the Israeli and US industries.¹⁴⁰

¹⁴⁰ For an article that analyzes the relative technological advantages of the Taiwanese IC industry, coming to a similar conclusion, see Hsu and Chiang 2001. Ernst, trying to explain the move of the IC design industry to East Asia, also follows the same argument in regards to Taiwan's relative strengths (Ernst 2004a).

Figure I



The Taiwanese fabless companies' business model has two variants that are not mutually exclusive. In the first variant, the design houses custom-design chips for clients using the clients' specifications (a local OEM with specific contracts with an OBM), test and quality-assure them, and then manufacture and deliver them using a pureplay foundry for fabrication. In the second variant, the IC design house builds "standardized" chips for OEM companies and other customers, manufactures them using a pureplay foundry, and sells them either directly or through distributors. The firms we interviewed claimed that as the market for standard chips is vastly larger, revenues using the second variant with successful products are much higher. However, because custom designed chips have the

advantage of a secure customer and higher profit margins per fabricated chip, a significant number of companies use both business models.

As the custom-made business model also has lower costs and companies can secure quick revenues, until recently it has been the preferred mode of operation for new companies. The story of Sunplus, consistently one of the top four companies in terms of sales since 2000, is illuminating. Sunplus was established by a group of former ITRI-ERSO engineers who left ITRI to join Silicon Integrated Systems (SiS) and left SiS after its restructuring in 1989. The idea of the founders was to focus on the consumer market, especially toys; thus reliability and price have always been much more important than the latest technology and features. Using their own money to seed the company, the founders immediately sought revenues to supplement their capital and started operations with custom-made ASIC designs. In 1994, Sunplus manufactured its first standardized chip, a micro controller for toys with LCD monitors, from which it branched out to other multimedia-related chips. Currently, Sunplus uses the custom-made business model for its entire gift and toy business and the standardized chips business model for the rest.

Most of Sunplus's revenues now originate from its standard chips; however, as there is fierce competition in the multimedia mass market, a large percentage of profits come from the smaller custom-made chip division. Sunplus realizes that even though it does not use cutting-edge technologies, in order to excel, it must keep abreast of new technologies and be able to implement them quickly once their price goes down. In order to do so, Sunplus, in a way similar to many successful Taiwanese fabless companies, employs a few strategies. First, it maintains a close relationship with ITRI, especially with its CCL lab, using ITRI as a channel for new technologies. Second, Sunplus has

established its own investment arm that invests in foreign and local start-ups in fields that Sunplus thinks it might need in the future. Third, Sunplus directly licenses technologies.

The Taiwanese IC design houses do not rely on in-house developed cutting-edge IP to give them market advantage, but on their ability to deliver moderately sophisticated products more speedily, cheaply, and reliably than their competitors. This is true even for companies that pass through the new government-sponsored SBIR program and/or ITRI's incubation center. For example, one interviewee told us: "Our game plan is to focus on the China market. The US is far too technologically advanced for us."¹⁴¹ Another interviewee, a serial entrepreneur, the founder of a company that was then still in ITRI's incubation center added, "The customers we aim to have need good chips but not state-of-the-art chips. They care more about reliability, mass production, and unit costs than cutting-edge technology. They are not looking for new innovations." Two other interviewees, from two of the most technologically advanced communication Taiwanese fabless companies, were even more pessimistic about the status of innovative activities in the industry:

"There is only one place in Taiwan that develops new technology and cutting edge products – ITRI – I sometimes miss being there. The only reason I left is because I wanted to get rich."

"I do not know about any real R&D-based company in Taiwan, apart from ITRI of course. Everybody is interested in revenues and profits. MediaTek is the biggest model of success. The biggest problem for any R&D-based model to work is the stock options/bonus regulations. These pull all the talent into the big manufacturing companies." (Interviews with companies in Hsinchu Park 1/30/2003).

Interestingly, this is also true for all the companies that have been established by returning immigrants from the US, including those that have successfully founded and managed new product-based IC design houses in Silicon Valley. Hence, the decision to

¹⁴¹ Interview with an ITRI incubation center' graduate IC companies (1/28/2003; 1/30/2003).

utilize only the second generation innovation business model has less to do with skills and capabilities and more to do with the institutional structure of the Taiwanese industry and its links with the financial markets.

In sum, the fabless chip sector evolved around a particular business strategy that has relied on the unique institutional features of the Taiwanese IT industrial system as a whole. The main three features are, first, the existence of large OEM/ODM companies that sell in foreign markets, which creates a large demand for chips based on second-generation technologies. Second, the close proximity of the world's largest and most advanced pureplay foundries. Third, the industry is based on an innovation system with a division of labor between ITRI and the private sector that excels in quick technology transfer and second-generation innovation, while continuously infusing the system with the most recent foreign technologies.

Utilizing this strategy, the IC design subsector provides complementary assets to the Taiwanese OEMs and pureplay foundries. First, it supplies the pureplay foundries with a constant stream of orders in a variety of IC designs, helping them to stay profitable and to extend and maintain some of their own technological capacities. Second, in regard to the OEM/ODM manufacturers, the Taiwanese IC design industry is supplying them with the chips they need either to profitably offer solutions for Western OBMs or to compete successfully with western and Japanese OBMs by lowering their cost structure.

The development of the IC design subsector thus enriches the Taiwanese IT industry with positive feedback, strengthening the Taiwanese position as mid-level suppliers within the global IT product networks. Each part of the Taiwanese IT hardware industry, OEM/ODMs, pureplay foundries, and IC design companies, strengthens and is

strengthened in turn by the existence, outputs, and demands of the others. Despite this virtuous cycle, or maybe because of it, the IC design industry is unable to develop alternative business models for capturing the higher rents that come from original innovative designs.

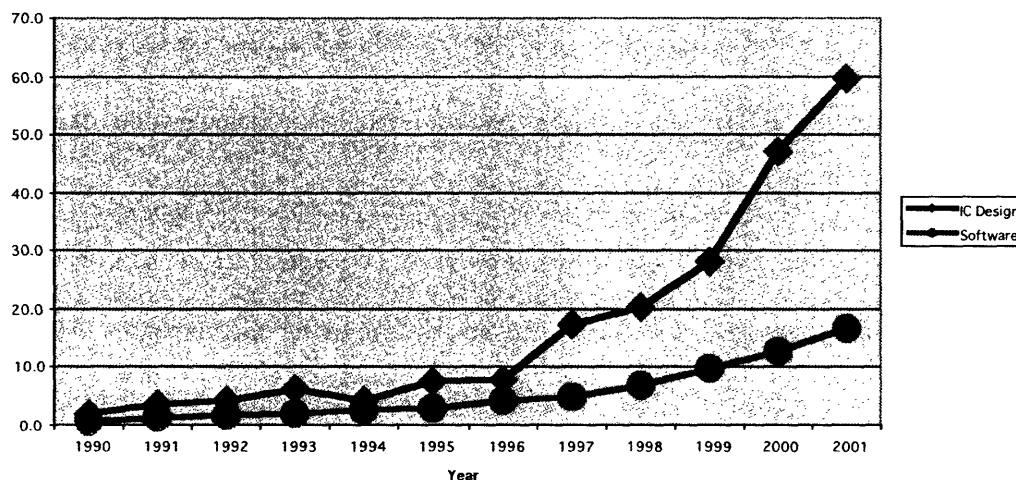
We should not, however, discount the magnitude of Taiwanese achievements in IC design. Taiwan, a small and until recently technologically backward society, developed the second largest IC design industry in the world, far surpassing the South Korean, Japanese, and Western European industries. The industry is not only growing but also enhancing the overall competitiveness of the Taiwanese hardware industry. Whether or not there is a move to innovative products, the industry's growth seems secure in the near future.

The Taiwanese Software Industry

If the story of the hardware IT industry is one of impressive growth and successful policies, the software industry offers a less sanguine tale of industrial policy and growth. Official statistics are inflated, but even they show the one major failure of the Taiwanese software industry: it is mostly a domestic-oriented industry. Official figures present a picture of rapid growth in sales from \$22NT billion in 1991 to \$149NT billion in 2001, but exports in 2001 amounted only to \$16NT billion, or a little over \$490USD million, only 10.73% of total sales. For comparison, the annual export figure for the whole of the Taiwanese software industry is just slightly higher than the quarterly sales of Amdocs, Israel's largest software company. These figures are tiny in comparison with those of the hardware sector, or even with those of the IC design sector alone (for example MediaTek's sales alone are more than twice as large than even the official

exports figures of the software industry). Moreover, the annual sale revenues of two of the three largest Taiwanese software product companies, Ulead and Cyberlink, were around \$30USD million in 2003, too small to put them in the league of medium sized IC design houses in Taiwan, or large software companies in Israel or Ireland. Table IV, compares the rapid growth of exports of the IC design sector, the smallest and latest subsector of the semiconductor industry, with that of the whole software industry, putting this failure in perspective.¹⁴²

Graph I - Annual Exports Software and IC Design



Source: (III various years; ITRI 2003; ITRI various years; MoEA various years)

The relative failure of the software sector is even more puzzling if we take into account the amount of high level software development critically needed by the hardware industry, especially the IC design sector. Thus, the success of the hardware sector in the development of what is usually termed embedded software, coupled with the global

¹⁴² In addition, it is not clear what percentage of the total sales figures should be attributed to foreign companies, and what part of sales are software and not bundled (i.e., hardware and software which are sold together). Furthermore, the official figures include in the definition of the software industry several activities, such as internet service providers, that are usually not counted as software.

success of a few Taiwanese software companies, shows that the cause of this failure cannot be explained by lack of software programming skills in Taiwan.¹⁴³

With this in mind we can understand why a high-ranking official in MoEA mused in one of our interviews,

“Look where we are and where other countries like India, Israel, and Ireland are with their software industry. Nobody heard about them 30 years ago. I must admit that we <Taiwan> are not doing very well with software” (5/30/2001).

In striking contrast to the electronics and semiconductor industries and the positive role played by ITRI, III, the Institution for Information Industry, has no stories to tell of ERSO-like successful spin-offs or any other initiatives spurring the creation of an industry. III has very little to say about its positive role in the development of the software industry. Indeed, III can be seen as one of the main obstacles for the industry’s development.

The impetus behind the establishment of III in 1979 was Dr. K.T. Li’s. The hope of Dr. Li was that III could play a similar role in software to the one played by ITRI in hardware, and he remained influential behind III for some years after its establishment. Thus, III and ITRI were structured in the same way. Moreover, they were established within six years of one another and under the same political leadership. Hence, if the structure of the bureaucracy and its policies is indeed the explanatory variable, we would expect a similar industrial outcome. Nonetheless, the political process of sectoral industry-state co-evolution moved ITRI and the hardware industry, and III and the software industry, on two opposing paths.

¹⁴³ Indeed a critical part of ITRI’s efforts in developing the IC design industry was the development, and subsequent transfer to private IC design companies, of design testing and EDA software tools. The case of ITRI and EDA software tools companies shows that it is quite possible for a public research institution to have positive effects on the private industry by developing and diffusing technologies (Chang and Tsai 2002).

Unlike ITRI, III was created after some of the early leading software firms had been established. The private sector, in contrast to the semiconductor industry, was active in the software sector. The agenda and the funding granted to III by the Taiwanese government were vastly different from ITRI's. First, III was asked to promote the software industry. Secondly, III was given the task of promoting the use of IT and software throughout Taiwan and was asked to help the government with its own computerization. Finally, III was also asked to generate enough revenue to cover most of its activities. The different agendas proved to be contradictory, with the end result that III transformed itself into one of Taiwan's biggest IT consultancies and software houses, and has been competing directly with private software firms.¹⁴⁴

The responses of many software firms to our questions about the role of the state in the industry's development offer the view of III as the biggest hindrance to the industry's growth. The response of a founder of a financial software company is typical: "The state does not have any positive role; as a matter of fact III is our greatest competitor. They also compete unfairly. I need to sponsor my R&D from my revenues. They have all their R&D covered by the state" (1/17/2003). A founder of another software company replied:

"In our 17 years we had direct conflicts with III only once so I am very lucky. However, I do not think III is good for the industry. They get government money to help the industry and nothing happens. III do not really care about the industry – they just talk and talk but do not do anything for the industry. They do not even properly do the more simple and straightforward task of

¹⁴⁴ Again exact statistics are hard to come by. In 2003 the funding III received from the agency that is responsible for the budgeting of Taiwanese research institutions, the Department of Industrial Technology (DOIT), was \$760NT million. DOIT statistics estimate III's 2003 total budget at \$3NT billion, out of which a third is received from projects with other government departments and a third is received in the private market (DOIT 2003). In comparison, the combined total sales of Cyberlink and Ulead, the two leading Taiwanese software-product companies in 2002 were \$65USD million or \$2NT billion (Trend Micro, which is now a Japanese company, had sales of \$364USD million). In a few interviews in 2001 with III's management team, we were told that of III's budget, half originates in sources other than DOIT.

consulting the government on policy issues so policy making is all tangled up. Even in the basic task of changing the perception of the software industry in Taiwan they do nothing. Customers think software and software companies should not be paid because they do not see software as a “real” product” (11/6/2003).

This view of III is shared not only by those we interviewed in private firms and in industry associations, but also by officials of other developmental agencies. One official of an industrial R&D agency responded to a question about the role of III in the software industry’s development, “III is a funny organization. It both competes with and tries to assist the local software industry. On a charitable estimate I would say that they compete at least as much as they assist” (1/29/2003). Another official, a head of a different department gave a similar response, “I agree that III is a very problematic institution. I think that the problem of III is the confusion or the strange positioning that they are in. They try to compete and help at the same time” (11/4/2003).

III is well situated to play a role as a facilitator of collective action and organizer of consortia. However, even in this role both researchers and industry leaders criticize III. Even in the crucial case of agreeing on a standard for Chinese writing input/output and internal conversion, a basic need for the software industry’s attempts to grow, Noble claims that III’s actions fostered distrust and hampered the industry’s efforts to reach agreement. In the end an international body, on which Taiwan had no influence, settled the issue almost a decade later (Noble 1998. Pp. 123-147). This impression of the failure of state efforts is strengthened by our analysis of the software industry. As I describe below, the most successful subsectors are those in which III never intervened.

Structure, Development, and Business Models in the Taiwanese Software Industry

The structure of the Taiwanese software industry reveals a divide between the older companies, focused on the development of software applications for big organizations who fiercely compete with III, and a newer cohort of companies developing software technologies, most of which were founded after the success of the hardware IT industry in Hsinchu Park. This division tempts one to contend that there are in fact two Taiwanese software industries. However, the reality is more complex.

As was mentioned earlier, it is extremely hard to gather precise sales figures on the software industry in Taiwan. Most of the bigger companies, faced with intense competition from III, have branched out into sales and distribution of hardware and even into completely unrelated fields at times of severe need. Even public game development companies, such as Summit, earn much of their revenues from bundled sales – the sales of their products on top of sales of DVD and other entertainment electronics. Estimating software sales in Taiwan is also complicated by the fact that PC manufacturers have been for many years some of the biggest software developers.

Nevertheless, the picture of the industry that emerges is one in which until a decade ago most of the Taiwanese software companies merged both IT consultancy and bespoke development, as well as the sales of specific software systems (such as automation or finance) that were developed as part of earlier work with customers and then packaged. Most of the PC manufacturers were also successful software producers, especially in the 1980s when each manufacturer had its own slightly different version of the Chinese input/output system, and when most of the classic PC software packages from western companies, such as spreadsheets, were unavailable in Chinese.

Because III had captured the big governmental contracts and the big global IT companies were competing directly on big projects, the industry was unable to develop big software houses specializing in customized development. A remark from a founder of one of the companies that managed to survive these times is illuminating,

“Competing with III is like competing with Microsoft. If you compete you get killed on the spot; if you cooperate you get less money and you might be killed later, but at least you get some work. However, III always wins more contracts than they can program themselves, so they then subcontract some of them. They will pay me less than what I would get if I could compete on the project in the free market but I prefer to cooperate with the Microsoft of Taiwan, and not get killed by it.” (11/6/2003).

As a result most of the industry has evolved around a particular market niche that was neglected or considered too small by III, such as international banking or securities trading systems. Today many of these companies are realizing that their future lies with Mainland China. Interestingly it is here that they find that their former relationships as subcontractors of American MNCs in Taiwan are an important asset. For example, a CEO of one of Taiwan’s oldest software companies described his decision to move to China:

“The funny thing is that we never wanted to go to China, but our American MNCs partners asked us to come, both HP and Oracle. The best example is HP. They won the whole IT systems project for a big new plant and they asked us and three other Taiwanese companies to open a China branch and do subcontracting for them. We did that and before we knew what happened Oracle asked us to do subcontracting for them when they won a big Chinese state-owned company contract. I think that without the mainland my company would not have been able to grow at all in the last 3 years. Only because of China we have a chance to survive.” (11/4/2003).

In addition, for the most part the industry has not been able to develop unique products or strong enough brands that guard their own products when the big software MNCs launched Chinese versions of their products. Thus, when Western companies such as Microsoft came around to localize their products to Chinese these companies’ products were wiped out of the market.

The one sector that evolved differently is the PC game industry. Unlike other sectors of the software industry, the video game industry had four tremendous advantages that allowed it to thrive in Taiwan. First, III was not at all interested in this sector. Second, video games, unlike many other software products, benefit from certain cultural traits, and Chinese-born gamers were very keen on playing “Chinese” games. For example, almost every Taiwanese game company has had a strategy or fantasy-role-playing (FRP) game based on the classic tale of the Three Kingdoms. Third, the costs of game development were very low for many years. Most video game companies either started by sponsoring teams of high-school students who develop the games as a hobby on a cost-only basis, or had a mixed development strategy of in-house and semi-independent teams. Fourth, with 7/11 and similar popular chains in Taiwan selling local games on the corner of every block, video game companies have had distribution channels that reached each and every Taiwanese on a daily basis.

It is not surprising that until 2000-1 video games were deemed by many in both the private and public sectors to be the most successful part of the software industry in Taiwan. All the medium and large sized companies such as Softstar, Summit, Gamania (formerly known as Full Soft), Interserv, and Soft-World had gone public on the Taiwanese stock exchange in the 2000-2002 period. Since then, the industry has been hard hit, and in 2003 most of the companies that we revisited had either retreated from original game development or were cutting down their development activities to the bare minimum. Apart from the worsening economic situation in Taiwan, the two changes that transformed the business environment of the Taiwanese video game companies were

technological: the wide diffusion of CD Read and Write technology and the rapid emergence of on-line gaming.

These two technological changes have significantly and swiftly lowered the revenues coming from the sales of PC games, with most but not all, of the leading companies reporting at best sales of tens of thousands of copies of their new games instead of hundreds of thousands of copies. These developments coincide with the maturation of the international gaming industry. The quality and technological sophistication needed to make competitive game titles has drastically raised the costs of development per title. In addition, the Korean gaming industry, for many years the poor and unsophisticated cousin of the Taiwanese industry, was the first to develop on-line FRP games, winning market share and financial backing and overtaking the quality and technological sophistication of the Taiwanese industry at a critical moment. At the end of 2003, all but one of the extremely successful massive-multi-users-on-line FRP games running in Taiwan were developed by non-Taiwanese companies.

The Taiwanese video game industry, without the financial resources of the Korean and Western industries, finds itself technologically backward and stuck with business models that are based on low cost development. It has been unable for the most part to compete. Individually, video game companies do not have the financial resources to regain the technological lead vis-à-vis the Korean industry, and as the industry is widely fragmented it has been unable to coordinate collective action. A few industry leaders approached III and asked for leadership or help, only to be rebuffed until October 2002. A CEO of one of the biggest companies recounted a tale of a failed attempt to cooperate with III in late 2002:

“The worst of the worst is III. A representative of the video game industry approached the president of III, the new one who promised to change III for the better and help the industry, and asked him to help our sector. Mind you, we are the only sector that was really successful in the Taiwanese software industry. After a few talks his answer came back from his secretary – ‘This is not III core business, therefore, we are not interested.’ I ask you: ‘what the hell is their core business?’ They say their goal is to help the software industry, not to make profits, but they do not give a damn about anything but making money” (1/20/2003).

This failure by III is even more surprising because starting in October 2002 the Taiwanese government declared digital content as a high priority technological area, and specifically targeted on-line games as one of the more promising digital content sectors. However, both government officials and industry leaders see the digital content initiative as a failure so far. One of the industry’s representatives in the initiative described:

“This is the latest government fad. They finally realized IP is important. So we sit there for a year, so many important people and so many people from the government and talk and discuss for hours every week and nothing happens. It is running for over a year now and still nothing happened. Elections are coming in six months time so nothing will happen until after the elections because the civil servants are waiting to see who will be their master and are afraid to do anything” (10/30/2003).

This view of the efforts of the digital content initiative in the area of on-line games was also strongly expressed by the responsible Minister of State, who described the efforts so far in regards to the gaming industry, in contrast to government efforts in the hardware sector, in a similar way:

“Nothing much is happening with on-line games. We basically did nothing; we do not even have a budget. We have to admit that a lot needs to be done with software and digital content. However, we <the government> still think that Taiwan’s future is more in hardware” (11/7/2003).

As of the end of 2003, most of the Taiwanese video game companies are fast retreating from game development. From an industry whose leading companies had operations and sold their own published products throughout the greater China region, the industry is transforming itself to an industry whose core competency is game distribution

and resale. This does not mean that two or three of the leading companies will not continue to prosper and grow and develop original games. However, the number of Taiwanese game developing companies is declining sharply with no new entrants coming.

In the last few years, a cohort of software companies with new business models have emerged and succeeded. These companies are much more technologically oriented. Their products either directly deal with software technology itself, or with new applications of IT technology, e.g., anti-virus software, OCR application, or systems recovery. These companies appeared after the success of the IT hardware industry in Hsinchu Park; indeed, many of them are tightly connected to the industry. There are two types of operations: (a) firms supplying the Taiwanese hardware industry with software technology that enables it to add features to its products, differentiating them from the competition, or supplying critical software that the hardware industry would find difficult or prohibitively expensive to get abroad; (b) companies producing software products that are directly associated with the software industry itself, such as anti-virus or application development tools.

One prominent example of a company focusing on software technology itself is Trend Micro, which develops corporate anti-viral protection products. In 2002, Trend Micro became one of the largest software security companies in the world with sales of \$364USD million. Trend was established by Taiwanese, grew in Taiwan, is run by Taiwanese, and still conducts a large share of its activities in Taiwan, but its management felt that it needed to leave Taiwan in order to be globally successful. In 1998 Trend

moved its management team and headquarters to Japan, reestablished itself as a publicly traded Japanese company, and is also traded on NASDAQ.

The two most successful software companies that followed more closely a business model of alliance with Taiwan's hardware manufacturers are Ulead and Cyberlink. In 1989, three friends who worked together at III left the institution to try out their own ideas for software development and established Ulead with finance from the Taiwanese scanner manufacturer Microtek. Ulead's first business was to supply OCR and image processing software to the then-fast-growing Taiwanese scanner industry. The scanner industry was facing difficulties in securing key software from American companies. A few years later, realizing that there was no true color imaging processing editor for the PC (Adobe was selling its Photoshop software only for Mac at the time), Ulead launched its own product called Photostyler. In 1992, Adobe bought the company that held the copyrights for the technology Ulead was using. Since then Ulead has come out with its own product for the mid-range user.

Hoping to use the same OEM model it used with the scanner industry, Ulead wrote software for video imaging for the video capture card industry. The Taiwanese video capture card industry never took off. Ironically, this proved to be a boon for Ulead, which started to work with foreign manufacturers. Today, apart from its image processing products, Ulead also develops video and DVD processing and authoring software. Ulead sells either directly to private users or through OEM agreements with hardware manufacturers. In 1999, Ulead became the first software company to go public on Taiwan's stock exchange. By 2002, Ulead had sales of over \$30USD million and

operations in all five continents. It is striking that one of the three most successful software product companies in Taiwan has total revenues that are so relatively small.

The latest globally successful Taiwanese software company is Cyberlink. Cyberlink is also interesting as it directly employs business techniques its CEO, Alice H. Chang, learned as a top executive at Trend Micro during Trend's rapid growth and IPO period. This is a clear case of learning and economic capabilities' diffusion in the industry. Cyberlink is also the most successful company to be spun out directly from a Taiwanese university lab, attesting to the growing capabilities of Taiwan's computer science academic research.

Dr. Jau Huang, Alice H. Chang's husband, the cofounder of the multimedia lab at National Taiwan University, established Cyberlink in 1994 together with four of his students.¹⁴⁵ Encouraged by Mrs. Chang, then the Executive Vice President of Trend Micro, the team decided to develop a software product instead of a hardware product. In 1995, using self-financing, Cyberlink was formally founded. The company finished developing the first product, a video decoder (VCD decoder), in November 1996. In January 1997 Mrs. Chang stepped in as CEO and embarked on a strategy of OEM sales to Taiwan's VGA card manufacturers, the world's largest.¹⁴⁶ These OEM agreements gave Cyberlink immediate market recognition and the company went on to develop a complete suite of DVD products that now has about 50% of the world market in the DVD PC's multimedia tool niche. Currently Cyberlink sells multimedia management tools and has just started to sell development tools for e-training and e-learning solutions. In 2000,

¹⁴⁵ The story of Dr. Jau Jaung, a graduate of UCLA, marks a very similar dynamic to one commonly encountered in the hardware sector: the growing stream of returning Taiwanese with graduate degrees from leading American universities.

¹⁴⁶ VGA stands for video graphics array, which is a graphics display system developed for the PC by IBM in 1987. VGA has since become one of the industry's standards.

Cyberlink went public on the Taiwanese stock exchange. In the financial year 2002, Cyberlink had sales of over \$35USD million with most of its sales originating with its DVD products done through OEM agreements with PC and notebook manufacturers in the US, Taiwan, Japan, and Europe.

In short, the Taiwanese software industry today seems to have a dual structure. On the one side are the older private companies dealing with business solutions that need to directly compete with III, which has become the biggest business software solutions provider. On the other side are the younger and more successful companies that are much more technologically oriented, developing in market niches in which III has no dealing, with a few of them beginning to have true global reach. Overall, the Taiwanese software industry is still mostly oriented to the domestic market. Only a few companies possess the necessary capabilities and skills to develop products and services for the global market. Hence, relative to the Taiwanese hardware sector or compared with software in countries such as Israel or Ireland, Taiwan's software industry is a stark example of a stage II failure – the inability of the state to change its roles in tandem with the industry's growth.

Government Actions, Institutions, and Market Structure in the Divergent Growth of the IT Hardware and Software Sectors in Taiwan

Using our explanatory framework we can now position Taiwan on it, to gain understanding of the institutional systems in which the Taiwanese industry evolved. First and foremost, we notice that the Taiwanese state has opted to deeply intervene in the IT industry development path by encompassing the R&D creating agents within its bureaucratic structure, as well as by trying to intensely influence the industry's technological development decisions. The Taiwanese state initiated policies with a clear

division of labor between private industry and the public sector. The public sector has been conducting the lions-share of R&D and then diffusing the results, developed to the stage of working prototypes, to the industry. The state also sees itself as the proper loci for making decisions on which R&D projects to pursue and which technologies to develop and obtain. This is almost in direct opposition to the role played by the state in both Ireland and Israel. A recent example is the current “System on Chip” development program (SoC).

The SoC program is the last in a long tradition of technological capability upgrading programs. It is organized in three discrete stages. In its first stage the government focuses on specific products it thinks that the Taiwanese IT industry needs be able to manufacture in the mid-future. In the second stage, the universities and ITRI are asked to give proposals as to which intellectual property and technologies they think are necessary to develop these products, and how they are going to develop these technologies and transfer them to the industry. In the third and final stage, the universities and ITRI will develop the technologies and intellectual properties and transfer them to the industry. Hence, in a way similar to the past, the envisioned role of private industry in this innovation capability development program is limited to one of developing products decided upon by governmental officials using technologies developed by the public sector.

The SoC program also exemplifies the different role for universities envisioned by the Taiwanese state.¹⁴⁷ If in Israel the universities have been, for many years, geared

¹⁴⁷ SoC follows a long tradition of upgrading programs in which various agencies, including the National Science Council (NSC), the Ministry of Education and ITRI, team with universities to develop the capabilities needed to build specific technological fields in Taiwan. The final aim of all these programs is

toward academic research and were given wide academic freedom in defining and pursuing their goals, in Taiwan the universities were viewed mainly as skilled-labor creating mechanisms. This view is especially evident in the new career path and tenure regulations.¹⁴⁸ Recently the envisioned role of the universities has somewhat changed, and the government realizes that the universities should be seen as a key agent in the development of new technological and innovational capabilities.¹⁴⁹ Nonetheless, the overarching technological goals of Taiwan are still defined by the state, and the universities are seen as a subsidiary tool that is used to achieve these aims. The universities, therefore, are urged to develop their faculty and departments in accordance with the state's S&T industrial policies. Part of the SoC program is a detailed development of the technological capability of the university sector, sponsoring eighty-five new faculty positions in pre-defined sub-fields of specializations.¹⁵⁰

Another example of the state's direct intervention in the industry's technological development path is the R&D tax incentive program of one of the main governmental investment vehicles, the Industrial Development Bureau of the Ministry of Economic Affairs (IDB). This program gives tax incentives and other benefits only to companies that make products that are specified in extensive detail by the IDB itself. The products

the creation of a particular industrial sub-sector and products. The expansion of the universities is planned as a derivative of this industrial objective.

¹⁴⁸ As of late 2003 tenure track and career path positions in the Taiwanese universities have been streamlined around the US model (assistant-associate-full professor) with publications being the main criteria for advancement. In the period preceding, publications were not given such a strong emphasis and career patterns were less structured. After the creation of Taiwan as a separate entity under the KMT one-party system, professorships and higher academic administrative roles involved political as well as professional decision-making processes.

¹⁴⁹ Once we take this overarching view of the universities as a factor needed in order to establish the Taiwanese "techno-national" goals, we can easily understand why the NSC, the agency whose main responsibility has been to fund and develop academic research, has also been chosen as the agency to manage and develop the Science-Based Industrial Parks, Hsinchu being the first.

¹⁵⁰ Interview with the Minister of State and S&T policy 11/7/2003.

are gathered in a list based on market research by the IDB every two years. Therefore, the list does not include truly innovative technologies whose market is unpredictable or does not yet exist. Moreover, the program specifies that the tax incentives are to be given only to companies that control the whole production chain, i.e., from the design to the manufacturing and sales, and only with products that an official described as, “are not in niche markets that are so innovative that we cannot predict the future so we cannot really help” (5/28/2001).

There are various other government programs to finance industrial R&D. In fact several of our interviewees from the major developmental agencies complained that Taiwan has too many small agencies and programs, each with its own bureaucracy, with the result a policy hodgepodge and confusion. Of these programs the three that have been most relevant to the IT industry are the SBIR, the Technology Development Program (TDP), and the Leading Product Development Program (LPDP), all of which are sponsored by MoEA Department of Industrial Technology (DOIT). Aside from SBIR, most programs mainly assist in the development of products that are based on some R&D effort, disregarding whether they are new to the world markets or not. Most of the grants to IT hardware companies assist them in pursuing second-generation product innovation, and do not provide incentives for a riskier approach.

Moreover, although DOIT has been leading the way in fostering more R&D activities in the private sectors in the last three years, it started to channel grants directly to private companies only in 1998. DOIT started to channel these resources directly to industry only after intense lobbying of the industry convinced the government to channel a small percentage of the funding that was formerly given to the public research

institutions (ITRI and III) directly to the private industry.¹⁵¹ Both the SBIR and the TDP are staffed with ITRI personnel who are seconded to the programs. Indeed, according to our interviewees around 1/3 of the IT companies that are funded through SBIR also have contract research relationships with ITRI.

These constraints are still more severe in the case of software R&D. For example, thus far software is not even included in the IDB's tax incentives scheme. During the interviews many software companies complained that apart from a brief period in the late 1990s, before the latest government budgetary cuts, they have not been able to get any grants. In addition, the Taiwanese state policy of focusing on specific niches is not appropriate to the current state of the Taiwanese software industry as its outcome is to deny many promising software companies access to R&D capital, while hardly promoting the creation of new companies in the targeted niches. Software companies that did manage to secure a state grant complained that the bureaucratic regulations forced them to spend more money on getting the grant than the grant itself. Those that did get the grants in the late 1990s though, did tell us that, as other sources of financing were lacking, these grants were critical in helping them to finish their first R&D projects.

In sum, even today government policies define a strict division of labor in R&D between state and industry. The state assumes control of research and development activities from screening the technological development path to the creation of prototypes of specific products. Furthermore, the state focuses on specific technologies up to the level of particular product specification. Our theoretical approach suggests that the likely

¹⁵¹ The amount DOIT channels directly to the private industry started at about 1% of total DOIT budget in 1998 with \$200NT million, and under the new head of DOIT it has been growing steadily both in size and as a percentage of budget to \$2.8NT billion out of a total budget of \$17.2NT billion in 2003. For more about DOIT activities and programs until 2000 see a paper by Chiung-Wen Hsu and Hsueh-Chiao Chiang, then of ITRI and DOIT respectively (Hsu and Chiang 2001).

influence of such policies is that private companies have little incentive or scope to develop innovative R&D capabilities. The end result is the continuation of the same capability development trajectory that the Taiwanese IT developed so far, focusing on second-generation innovation, integrated design, and process and manufacturing innovation.

Analyzing the ways in which the Taiwanese state regulated and interacted with the financial markets, our theoretical approach suggests that these also strengthen the tendency of the Taiwanese IT industry to focus on developing only a narrower set of innovational capabilities. There are two main financial constraints on IT companies that wish to develop new innovation-based products in Taiwan, one in the beginning of a firm life, and one toward the end of its development stage. The first constraint is the almost utter lack of finance in the beginning stages of firms' development process for technologically cutting edge R&D. The second constraint derives from the fact that the Taiwanese stock-option system gives enormous advantages to companies that have already gone public, not only granting them stronger financial capabilities, but also giving them an almost total stranglehold on hiring the best engineering graduates.

The main cause is Taiwan's employees' stock-option regulations. These prohibit companies, both public and private, from giving stock options to employees (one of the main attractions that a cash-starved start-up can offer to entice new employees in the US, Israel, and Ireland). However, the same regulations allow already-public companies to give actual stocks (i.e., not an option on the stocks but the stocks themselves) to their employees at a sharply discounted rate under the "profit sharing system," where the stock is treated as profit sharing. Moreover, the stock-bonuses are taxable only at the time of

sale and only on the nominal par value (set by law at \$10NT per stock no matter what the stock's market price is), which gives the employees an enormous and tax-free financial bonus. For example, according to TSMC's annual reports, the average profit per employee received by TSMC employees through stock per year was more than \$1.5NT million in 1996 and reached more than \$2.5NT million in 1998; engineers with a masters degree earned much more than the average. A CFO of a leading IC design house calculated that after four years, an engineer with a masters degree will get an annual bonus worth about \$300,000USD; a good annual salary for the same employee stands today at \$18,000USD (IPC interview with IC company's CFO 11/5/2003). Hence, a graduate of a good university with an advanced degree who wants to become well off needs only to join an already public company to be virtually assured of reaching that goal in a few years. Not surprisingly, new private companies find it very difficult to recruit graduates of the top engineering schools.

Consequently, the regulations regarding employees' stock options in Taiwan motivate new companies to seek the shortest and surest route to an IPO. In order to go public on the main exchange, a company needs to display five years of disclosure statements showing constant profits.¹⁵² Hence, most Taiwanese IT companies use a business model that assures quick revenues, in contrast to one employed by innovative-product-based firms that involve incurring a few years of heavy losses during their R&D

¹⁵² In an effort to induce younger IT companies as well as software companies to list, new regulations allowing listing in the secondary exchange were put in place. Some software companies have indeed opted to use them. However, the young hardware companies and some of the more established software companies interviewed regarded the use of this option as giving a negative signal to the market, preferring instead to use the old regulation and list in the main market. In addition, even under the new regulations the same laws regarding stock options apply, hence, the effect of the new listing regulation is mostly in letting IT companies go public faster.

phase before sales. In addition, the state puts significant restrictions that dissuade companies from having an IPO on a foreign stock exchange.

The VC industry was created as part of an initiative of Dr K.T. Li who viewed VCs mainly as a missing pool of finance, and not as a distinct industry.¹⁵³ Moreover, Dr. Li's and subsequent governmental initiatives have taken great care to make sure that the Taiwanese VC industry stays Taiwanese, devoting all their attention to motivating local investor participation. The main policy with which the state spurs the creation of the VC industry and maintains its existence are tax credits. In the beginning the industry was heavily regulated and many of the main VC funds had ties to various KMT investment vehicles such as Kung-Kwang and Century. As of the end of 2003, according to the Taiwanese VC association, foreign capital still amounts to less than seven percent.¹⁵⁴

Looking at private VCs we found that, unlike their Israeli, and even more than their Irish counterparts, most of them prefer to invest only in the later stages of development, and only after firms have already proven their success by becoming profitable. There are several institutional reasons for the conservative behavior of VCs. First, by law VCs in Taiwan must be registered companies, not limited partnerships.¹⁵⁵ This limits their ability to invest in young companies in two ways: i) as a registered company a VC is not allowed to invest in a venture that is not already registered, ruling out true seed funding; ii) as a registered company the VC (that is, the person who acts as a VC, who in the US and Europe is called the general partner) must submit all his or her

¹⁵³ On the importance of this distinction, see Avnimelech and Teubal 2003a and Chapter Two of this dissertation.

¹⁵⁴ Interview with TVCA's secretary general, 11/3/2003.

¹⁵⁵ The establishment and the specific laws regulating the VC industry are another brainchild of Dr. K.T. Li, who, after being exposed to the American VC industry, decided that a local VC industry was a critical component for the development of Taiwan's IT industry in the early 1980s and masterminded its creation (the industry's official birth year is 1983).

investment decisions to the board of the VC firm, thus making the VCs more conservative.

Taiwanese VCs also are more reticent because of the sources of their capital and the education of the VCs themselves. Most VC funds have strong ties to one individual or company and operate in accordance with the sponsor's investment strategy, which is usually more risk-averse and tends to select firms with established business models that the sponsors can easily understand. This is especially evident in software where most VC companies do not invest at all.¹⁵⁶ The VCs themselves are drawn mostly from the financial industry or the traditional industries. Hence, they do not have intimate knowledge of IT, and prefer less risky endeavors.

Lastly, but at least as importantly, we must remember that VCs' main aim is to make profit on their investment in a limited amount of time. The structure and listing regulations of the Taiwanese Stock Exchange, where most of the exits take place, favor companies that are already profitable for a few of years.¹⁵⁷ This, in turn, motivates the VCs to invest in companies with a business model that is focused on achieving large sales figures without a long loss-incurring R&D phase. Even when Taiwanese VCs do invest in young Taiwanese companies, they usually prefer companies that follow the well-trodden path of producing products based on second-generation technologies with the prospect of near-term revenues.¹⁵⁸

¹⁵⁶ Interview with the Taiwanese VC association, 11/3/2003.

¹⁵⁷ The regulation involving the fixed nominal par value of a stock applies also to private companies. While this does not prevent investors from investing in companies based on changing valuations as they progress through their business plan, in theory this might increase the transaction costs and the risk associated with VC investment in Taiwan. Our interviewees, however, did not regard this as an obstacle.

¹⁵⁸ Exit refers to the change of ownership in which the VC sells its share in a company and "exits" it.

The industrial institutional system and the opportunity structure it gives companies was heavily influenced, on the hardware side, by the explicit Taiwanese S&T industrial policies aiming to develop an industry supplying critical components and design and manufacturing services to MNCs. The current innovation system of the IT industry motivates new companies to pursue known business strategies, and limits the ability of companies that tries to truly innovate. The Taiwanese system, with the existence of world leading OEM/ODMs and pureplay foundries, supplies virtually infinite opportunities for small new companies that follow either the second-generation innovation or OEM/ODM models. Furthermore, the economic and management skills that are needed in order to profitably run those kinds of operations are abundant. To use different words, the Taiwanese industrial system is richly endowed in the “specific economic competencies” needed to succeed in second generation innovation-based design and OEM/ODM operations (Carlsson 1995; Carlsson and Eliason 1994).

The whole Taiwanese system of innovation is primed to give private companies constant access to new technologies from abroad. In the last few years this kind of technology channeling became one of ITRI’s main roles. ITRI, especially its computer and communication lab (CCL), has changed from being the leader and initiator of the industry, especially in semiconductor, into being a supporting actor in the 1990s, mostly as the main R&D services provider in the industrial system as well as an important channel for foreign technology. For example, the answer that each and every IC design company interviewed gave to the question of whether there is any company that conducts technological cutting-edge R&D was that the only organization in Taiwan involved in these activities is ITRI and its CCL lab. Top officials of CCL attest to the fact that CCL is

only too aware as to the affect that its technology transfer programs and this division of labor has on the incentives of private industry to develop original product innovation capabilities.

On the other hand, a company that wants to innovate faces significant obstacles, from the lack of finance, the difficulty in recruiting highly skilled personnel, and the relative scarcity of business and management skills to run a Silicon-Valley-like operation. All of these problems are also augmented by the fact that if geographical proximity to both their customers and suppliers helps companies to either sell to, or become an, OEM/ODM company, their distance, both physical and cultural, from their main market for innovative products, the US, makes their operation more complex and more expensive.

In software the unsuccessful approach of III and the industry's stagnated growth have strengthen our hypothesis that unlike the preaching of the old development school, a too heavy handed intervention by the state without a dialogue with private industry will not lead to industrial growth. The Taiwanese software sector shows that in the case of RIB industries attempts by the state not only to lead the industry, but also to be the industry are doomed. III is a clear case of not only wrong positioning of the developmental agency, but of a failure of the developmental agency to manage the co-evolution processes and the unavoidable diminishing of its own power with the growth of private industry. The divergent paths of the software industry and III, and the hardware industry and ITRI, strengthen our argument that structure and timing alone are not the explanation: the sectoral politics of co-evolution are.

However, while III has played an inhibiting role in the development of the software industry there are also other reasons for the particular development path taken by this sector.¹⁵⁹ First, one of Taiwan's main industries has been PC manufacturing, and each of those companies was also busily producing software for its own machines, and hence, preventing the development of a large standardized market that could support independent product-oriented software firms. Second, until the early nineties, partly due to internal competition within the state apparatus and III failure, there were no standards for Chinese input/output and internal conversion (Noble 1998). This spurred many companies to produce Chinese programs of the equivalent popular English packages, all of which were practically wiped out as soon as the western companies published a Chinese version of their package. The third reason is that neither the private hardware industry nor the government saw software as an independent industry but as a service component needed by other industries. This handicapped the industry in two ways: first, software has never been on an equal footing with hardware in the competition for government budget and grants; and, second, software companies had difficulties selling pure software solutions for reasonable prices in the market.

The software industry has also suffered acutely from the lack of capital. Until the advent of the Internet, VCs were unwilling to invest at all in pure software companies unless they were already well established. Even today software has a more difficult time securing VC finance than does hardware, as many interviewees in the VC industry, the Taiwanese VC association, and software companies pointed out. As for public finance, for many years pure software product development did not receive any grants. Even

¹⁵⁹ Indeed in a remarkable contrast to ITRI, apart from the two companies that are direct and official spin-offs of III, our research did not find a software company that regarded III as even somewhat helpful.

today, software is not included in the IDB's tax incentive scheme. For these reasons many of the older software companies, facing virtual exclusion from big projects, have branched out into other areas of operation, some of which have nothing to do with software such as the distribution of gift packages. Thus, unlike their counterparts in the IC design subsector, many of the Taiwanese software companies have suffered from a lack of focus and an inability to concentrate enough resources, management and capital, on R&D. The one subsector that proved to be nimble, innovative, and successful during the 1980s and 1990s was video games.

Starting in the late 1990s, with the rapid growth and growing sophistication of the IT hardware industry in Hsinchu Park, III activities dissuading new companies from working on big business applications, and the growing skill base and sophistication in computer science in Taiwan, a new cohort of companies that are much more technologically oriented has appeared. Some of these companies have already managed to become global competitors in their niches and a few more seem poised to do so. These companies and the video games sector have had very little to do with III. In sum, the software industry, unlike the IT hardware industry, has not been able to transform itself into a successful exporter and a global competitor. What has been achieved has taken place in spite of, rather than because of, the government's main agency, III.

Conclusion

This chapter analyzed the development of the Taiwanese IT industry. The analysis showed that there have been major differences in both the development and state-industry interactions between the hardware and the software sectors of the industry. The IT hardware sector developed rapidly and successfully. In some specific subsectors and

stages of production, the Taiwanese industry has either become the world's leader or number two after the US. In contrast, the software industry growth was stagnant. There is no subsector, production stage, or even product niche in which Taiwan's software industry is considered to be a major global player.

The differences in state's policies and state-industry co-evolution occurred even when, from the formal structural perspective, the Taiwanese state followed a very similar pattern in its sectoral policy in both cases – the creation of a public research institution as the focal R&D and policy coordination vehicle. Nevertheless, in the hardware sector in both the case of the creation of a new industry, semiconductor, and in the case of upgrading an existing industry, electronic OEM/ODMs, ITRI's behavior was an almost ideal case of state-industry co-evolution. In software, however, ITRI very quickly moved into an adverse relationship with the private industry, a position it holds to this day.

In both cases, semiconductor, and electronics OEM/ODMs upgrading, ITRI at first took a leading role and then slowly but surely divested itself from it and assumed the role of a supporting actor giving the industry more decision making scope to manage its own future. ITRI, on the other hand, rapidly, by and large because of the conflicting agendas given to it by the government, moved to secure itself as the biggest software house and IT consultancy in Taiwan. From this position, ITRI could not but view the private industry as a competitor, rather than as the community it strives to serve. In addition, due to its conflicting interests, ITRI has never been able to play the important role of research consortia coordinator and convener. These adverse relations with, and inability to see, the private software industry as its real customer remains to this day, when ITRI itself realizes that it needs to change under mounting pressure from both

government and private industry. The inability of III to envision its role as a supporting actor for the private software industry is vividly demonstrated in the remark given by one of III's top executives when asked about the future of III, "Our new goal is that we aim to be the Accenture of IT of Taiwan, not to code the projects by ourselves."¹⁶⁰ Thus, III still views itself as a for profit consultancy looking for projects on the national level, not as a public research institution helping the private software industry to develop.

The role of the Taiwanese state in the development of the IT industry, in both hardware and software, strengthens our hypothesis about the ways in which the state can successfully promote RIB industries. It also strengthens our main contention about the new developmental state theories. It is not the state that is either a neo-developmental or not; the story of the Taiwanese IT industry shows that the same state can be both. The answer lies in the politics that decides the particular ways in which the state tries to implement its vision for the creation of a new innovation-based industry, and in the politics of state-industry relations and co-evolution processes that evolve as the industry grows.

If the state's responsible agencies, as in the case of ITRI and the hardware industry, have as their main goal the development of the private industry, and are able to manage the transformation of their own positions as part of the state-industry co-evolution process, then the state can successfully play a key role in the development of the industry. If, however, as in the case of III, the state's responsible agencies, even when organized in a structurally similar way and managed from above by the same leadership, do not see the development of the private industry as their primary goal, and are not

¹⁶⁰ Interview with III executives 11/7/2003.

willing to relinquish their leading position, then the same state that so successfully developed one industry can be one of the main causes for the stagnation of another.

Looking on our second set of arguments on R&D capability creation, the decision of the state to build public research institutions as its main policy vehicle crystallized a specific division of labor in R&D between public agencies and private industry. In this division of labor the public agencies focus on R&D and the private companies focus on final development and integrated design. It is important to note how deeply this division of labor runs and how much the R&D scope of Taiwanese companies is limited. From the most basic levels of R&D-related decisions it is the state that took responsibility for screening and capabilities development decisions. State officials compile detailed lists defining products up to the level of feature specifications, and only companies willing to develop them will be entitled to R&D incentives. State officials also make decisions about future research fields. In case of national projects, such as SoC, once decisions about research and specific products have been made, it will be the public research institutions that will develop technologies and the first prototypes and only then transfer the results to the private industry.

In such a system both the scope and the resources granted to private firms to conduct R&D are limited. There are no incentives for private companies to develop their own sophisticated R&D, technological screening, or product innovation skills and capabilities. Companies in the Taiwanese IT industrial system are by and large motivated to specialize in final product development and integrated design. The scope that the state grants for private companies to participate and develop skills and capabilities in

applicative, not to mention generic or basic, research is extremely restricted.¹⁶¹ As a result the private industry in Taiwan developed limited R&D and technological screening skills, with almost no attempt to develop new-product innovation capabilities.

These effects have been reinforced by the behavior of private investors in Taiwan. The conservative behavior of private investors and venture capitalists in Taiwan limit resources available to firms that try to employ extensive product R&D business models and channel large amounts of capital to firms that follow a second-generation innovation or OEM/ODM business model. This is a direct result of two things. The first cause is the way in which the VC industry was created and regulated in Taiwan. Of particular are: the needs of VC funds to register as companies, and be regulated as such, and the fact that almost all of the funds are raised in Taiwan. The second cause is the way in which both public listing of companies and stock options are regulated. Taken together these supply strong incentives to follow investment strategies that limit risk and uncertainty, and consequently, the scope of R&D. Accordingly, the institutional settings of the financial system in Taiwan do not support business strategies that necessitate high level of original R&D to be taken by private firms.

In addition, the business structure of the Taiwanese industry, specifically the relationship between MNCs and local companies, presents both established companies and entrepreneurs with an extensive opportunities to supply the global IT production network with components as well as manufacturing and integrated design services. On the other hand, it does not present companies that wish to develop original innovative

¹⁶¹ It is important to remember, though, that overall industrial R&D resources, in contrast to the resources channeled to original product innovation R&D activities of private firms, are relatively high in Taiwan even if prioritized by governmental decisions. Hence, overall resources are much higher, for example, than in Ireland.

products with the same. Again it was the state that constructed these relationships with the MNCs and employed a strategy of developing the local industry as a supplier of components, manufacturing, and design services. This strategy was employed from the early 1960s, and continues to be employed today. The state R&D efforts have all been aimed at the creation of an industry with exactly these capabilities.

In sum, in analyzing development of the Taiwanese IT industry we found our theoretical approach to assist us in giving a comprehensive explanation of the Taiwanese IT industrial development experience. We can now understand the industry's position in the global production networks, its successes and failures, and its unique strengths, weaknesses, and limits.

Chapter Four – A Misunderstood “Miracle” – The State and the Growth of the IT Industry in Ireland

“Trying to induce private entrepreneurship in Ireland during the 1980s made me feel like I was part of the old lobster joke: A young man goes to the beach, he sees an old fisherman with two untied lobsters in a very low bucket. He comes to the fisherman and tells him, “Sir, your lobsters are not tied and the bucket is very low, you have to tie them or they will run away.” And the fisherman answers, “Dear lad, do not worry, these are Irish Lobsters! As soon as one of them almost makes it to freedom the other jumps and drags him back down.”

A former executive of the IDA’s Enterprise Development Plan.

Introduction

If there has been a great transformation in international perception of national economic performance in the 1990s it has been the case of Ireland. As late as 1995, the common perception of Ireland’s economic performance was one of a continuous failure, which dooms Ireland to always be the basket case of Europe (Guiomard 1995).¹⁶² Less than four years later, sick Ireland seemed to have become the roaring Celtic Tiger (Breathnach 1998; MacSharry and White 2001; O’Hearn 1998; Sweeny 1999). Irish software companies such as Iona in middleware, Smartforce and Riverdeep in education, or Trintech and Baltimore in data security not only achieved global success, but also made their founders and many of their employees rich when they publicly listed on NASDAQ. This success made software the first industry in Irish history to create such a virtuous cycle of entrepreneurship, and helped to transform even the Irish perception of themselves.

Indeed, Ireland has become the most invigorated economy of Western Europe, a model for the EU’s new entrants, and one of the world’s most successful IT industries. This achievement has been attributed largely to the Irish developmental agencies that promoted this accelerated growth utilizing a series of industrial and S&T policy

¹⁶² As late as 1989, Ireland lost 1.1% of its population to emigration. Indeed, even today the Irish population is still less than 50% of the eight million strong it was before the great famine of 1845-1850.

initiatives. Moreover, this impressive feat has been achieved while both politicians and bureaucrats have strongly adhere to a neo-liberal interventionist ideology; a development ideology significantly different from Israel's or the Taiwan's.

However, even a brief analysis of the Irish IT industry reveals dissonance between the operations of the foreign multi-national corporations (MNC) and the indigenous industry. On one hand, the MNCs, a cornerstone of Irish industrial policy since the 1950s, are thriving and delivering great economic growth. Dell, an American MNC, has just surpassed Microsoft, another American MNC, and became the biggest Irish exporter, single-handedly responsible for 5.8% of Irish GDP in 2003.¹⁶³ This is an impressive statistic, and shows that even with rising costs, Ireland is still central to the global strategy of leading IT MNCs. However, both Dell and Microsoft, together equaling about ten percent of Irish GDP, have very few high added value activities, such as R&D or product design, in Ireland. This leads many commentators to suspect that behind the impressive Irish GDP and trade figures lies even more impressive showmanship of transfer pricing accounting, utilizing Ireland's low corporate tax regime and the availability of well-educated labor force.¹⁶⁴

On the other hand, in the indigenous sector, it is the software industry that has reached global prominence, not the hardware and electronic manufacturing sector favored by the Irish FDI-based policy. Furthermore, while the state claims great credit in sponsoring the growth of the software sector, it has started to sponsor it systematically only after a few Irish-owned companies achieved global success. Lastly, these state

¹⁶³ At around \$8 billion, Dell's 2003 annual revenues alone equaled the combined value of the Irish tourism and agriculture sectors.

¹⁶⁴ Transfer pricing refers to the internal trade accounting techniques that MNCs use in order to record most of their profits within units/subsidiaries situated in the most favorable corporate tax regimes.

programs appeared to suffer from a slight misconception in regards to their goals and methods, especially in the last four years.¹⁶⁵ The result is that the industry's growth was brought to almost a complete halt since 2001, with almost no new companies managing to shore up annual revenues of more than \$2 million.

Nonetheless, Ireland's state-led transformation from a country in which, in the 1950s had the least educated workforce in Western Europe, to one of the world's top IT producers in the end of the 1990s, is nothing but miraculous. What are the causes behind this transformation? What enabled Ireland, the laggard of Western Europe, to become the EU's IT industry "shining light" in the time span of one generation? Lastly, what are the weaknesses, strengths, and generalizability of the Irish experience?

This chapter analyzes and explains this transformation utilizing our theoretical framework. Throughout this analysis I make the following arguments: first, both the IT industry and the Irish S&T industrial policies evolved within a political system in which the state has had one overarching goal – job creation – a significantly different circumstance than in Israel and Taiwan. This led to a specific process of state-industry co-evolution with markedly different outcomes, than these of Taiwan and Israel, in terms of the IT industry's capabilities, structure, and position within the global production networks.

The focus on job creation led the Irish state, following an ideology of "neo-liberal interventionism," to develop an FDI-based industrialization policy. The Irish neo-liberal interventionist ideology is based on two conflicting principles around which the

¹⁶⁵ One significant result of such missteps is the fact that in 2001, with the Irish VC industry managing record levels of capital, there were only three seed investments, which together equaled \$750,000USD. Hence, at the same time that state-led efforts increased the amounts of IT-designated funding to their highest levels ever, the formation rate of new IT firms dropped to almost zero.

Irish state has been formulating its economic and industrial policies since 1958. On one side, the state, in both the government and the developmental agencies levels, possesses a strong free-market ideology. On the other side, it also sees a large role for government in enhancing the competitiveness of Ireland and strategically managing its growth. This ideology is radically different than Israel's and Taiwan's where the state's ideology, until very recently, was a variant of market-socialism.

The state, led, from the late 1950s until the early 1990s, by the specifically created autonomous governmental agency – the Industrial Development Authority (IDA) – was focusing its attention on bringing MNCs to open manufacturing plants in Ireland and on upgrading the physical and educational infrastructure. Throughout this period the Irish state paid relatively little attention to the development of industrial R&D activities in general and indigenous IT industry in particular.¹⁶⁶ Moreover, the state, true to its neo-liberal ideology, did not apply pressure on the MNCs to embed with the local industry.¹⁶⁷ This lack of interest in the particular needs of rapid-innovation-based industry, coupled with only minimal attempts of the IDA to nurture, embed itself, and network with Irish-owned industry, hurt the early development of the Irish IT industry, in particular the hardware sector.

¹⁶⁶ The autonomous IDA, building on its ability to lure MNCs and its domain over what was widely perceived as a key issue – job creation – grew to wield immense power of policy formulation and implementation over all issues of industrial and economic development until the 1990s. Hence, between the 1950s and the early 1990s, the IDA was a true pilot agency with sway over the actions of many other agencies Chibber 2002; Johnson 1982.

¹⁶⁷ As will be discussed later, in the early 1990s the structure of the developmental agencies was changed and after several reorganizations IDA, or IDA-Ireland, is now the acronym of Industrial Development Agency Ireland and no longer of the Industrial Development Authority. IDA Ireland is an autonomous government agency responsible solely for FDI industrial policy. Hence, it is a very different and much less powerful agency than the original IDA in its heyday. Currently the structure of industrial developmental agencies consists of Enterprise Ireland (EI), which is responsible for the indigenous industry, and IDA-Ireland, which is responsible for the FDI-based industry. Both agencies are nominally under the auspices of Forfas, which is responsible for strategic planning in regard to industrial development. The three are semi-autonomous public agencies under the Ministerial Department of Enterprise, Trade, and Employment.

Even in the 1980s and 1990s, after the IDA and its successors, Forfas, IDA-Ireland, and Forbrait/Enterprise Ireland, started their active involvement in the creation of the indigenous IT industry, they were neither technologically savvy or deeply embedded within the IT industry, nor, for many years, did they view indigenous IT industry development as a particular problem of creating rapid-innovation-based industry. Industrial policy has been planned as a derivative of the goal to enhance employment through the creation and growth of enterprises broadly defined. Only in 1991, when industry pressure and the availability of EU funds led to the creation of a new specific sub-unit within the IDA, the National Software Directorate, whose employees were recruited directly from industry, did the state start to pay continuous attention to the particular needs of R&D-based IT industry. Yet still the policy focused almost solely on software.

Accordingly, my second argument is that the case of the indigenous IT hardware industry in Ireland has been a clear case of stage one failure – the inability or unwillingness of the state to facilitate and participate in the growth of the indigenous hardware sector and its networks.¹⁶⁸

Interestingly, software was the recipient of focused state policy specifically because it was defined as a tradable service and not as an industry. During the 1980s, with Ireland once again in severe economic crisis, the IDA changed its policies in a few critical domains. One of the changes was to step up the indigenous-industry-oriented activity with the creation of the Enterprise Development Program (EDP). The second change was to create a new focus on tradable services on both the indigenous and FDI-

¹⁶⁸ The National Software Directorate was moved into Forbrait and then Enterprise Ireland after the two agencies were created. It is now called the National Informatics Directorate. An ill-fated predecessor, called the National Software Center, operated on a much smaller scale within the IDA from 1984-1988.

based sides of its operations, with software quickly becoming the prominent sector of this new policy.¹⁶⁹ However, seen as a service, these policies did not take into full account the particular needs of the software sector as an R&D-intensive industry. S&T industrial policies were enacted only after the industry achieved worldwide success.

In this chapter, I present the history of the co-evolution of Ireland's S&T industrial policies, the particular growth pattern of the industry, and the state role in this growth. I first give an overview of Ireland's early economic history as a background. It is important to show how the development of the IT industry was profoundly influenced by the nature of the Irish bureaucracy, the historic relationships with Britain, the continuous economic crisis and large emigration, and the development of the neo-liberal-interventionist ideology. The next section analyzes the decisions that led in the 1950s to the creation of the IDA, the IDA's early years, and its policy changes in the early 1980s. Following this account, I examine the growth of indigenous IT industry, first hardware and then software, by evaluating the intricate co-evolution process between state policies and industry's development, the changing roles of the various developmental agencies, as well as the particular division of labor that evolved between the local and the global industry, and between public research institutions and private firms. The last section investigates the industry's development in the 1990s, the influence of a new set of policies and bureaucratic structure, the ways in which these policies, in turn, were influenced by the industry's evolution, and the industry's current strengths and weaknesses. The chapter ends by offering several conclusions about the current and future state of the Irish IT industry.

¹⁶⁹ Consequently, as will be described in detail, the indigenous hardware industry, never the focus of targeted policies, continues to face severe disadvantages vis-à-vis both the indigenous software companies and the hardware MNCs.

Historical Background and the Beginning of the IT industry

After gaining independence, the Republic of Ireland passed through two almost complete U-turns in its industrial policy, and a subtler, but arguably at least as important transformation since the beginning of the 1990s. Starting with its independence in 1921 and for the first decade of its existence, after conceding to England most of the industrial base, which was concentrated in the Northern counties around Belfast, the Irish republic was almost solely an agriculture-based economy. Led by William T. Cosgrave of the Cumann Na nGael party, the newly established republic followed an economic policy focusing solely on the agriculture sector, and was fiercely free trade in its economic ideology. Patrick Hogan, the then Minister for Agriculture, is famous for describing this policy as “helping the farmer who helped himself and letting all the rest go to the devil” (Haughton 2000). The main elements of this policy were: free trade, parity of the Irish currency with the English Sterling, low taxes, and low and modest government spending and intervention. This policy gave the Irish an almost unbeatable claim to the title of the most conservative revolutionaries in history.¹⁷⁰

In 1932, in the midst of the global depression, staging a major political transformation in Ireland, Fianna-Fail – the republican or nationalist party – won the elections.¹⁷¹ Fianna Fail, led by Eamon de Valera with Sean Lemass serving by his side as Minister for Industry and Commerce, made the first complete reconstruction of Ireland’s economic policy and devised a highly nationalistic policy based on the ideal of

¹⁷⁰ For more on the Irish economic history see, Haughton 2000; Kennedy 1989; O'Gr'ada 1997.

¹⁷¹ Two center right parties have been dominating the Irish political system: Fianna-Gael and Fianna-Fail. The main difference between the two has been that Fianna-Fail, the Republican Party, until very recently did not officially accept the political separation of the Irish Island. Since 1932, Fianna-Fail has managed to secure its position as the largest party and has been in power for most of the period. This makes Ireland a one-party dominated political system for most of the period of its early industrialization, similarly to Israel and Taiwan.

an autarkic market. Free trade was abolished, high tariffs were put in place, and a proxy economic war was waged for a very high economic price against England over land annuities. While some debate still exists on whether these economic policies were truly damaging to Ireland or only slightly so, one fact remains clear. The economic gap between Ireland and the UK grew, and so did the gap between the North of Ireland and the Irish Republic. Moreover, net emigration continued at an alarming pace and an overall pessimism about the future of the republic as an independent state was deeply felt.¹⁷² At that time, at the request of Sean Lemass, who became Prime Minister – Taoiseach – after de Valera, Ken Whitaker, Ireland’s most prominent civil servant and the general secretary of the Ministry of Finance, published in 1958 Ireland’s first comprehensive economic policy document – the celebrated *Economic Policy* (SO 1958a).

In this report, Whitaker devises the main points that continue to shape Irish economic policy to this day: export-oriented industrial policy tied with free trade and conceptualization of Ireland’s main economic threat as severe unemployment leading to alarming large net emigration.¹⁷³ The publication of Whitaker’s *Economic Policy* also marks the crystallization of the Irish neo-liberal interventionist ideology. The main goal of the first economic program and of all those that followed has been job creation. Since 1958, there have been three basic elements in Irish economic policy: provision of economic incentives and low corporate tax rates to induce industrial development and

¹⁷² By 1961 the Republic population was only 2.8 million, compared with 3.1 million in 1921 and 8 million before the great famine of 1845-50.

¹⁷³ Emigration was so severe that it led the Irish government to organize special committees on the subject, and some observers, most notably John O’Brien in the edited 1953 volume, *The Vanishing Irish*, questioned at the time the viability of Ireland as an independent state (O’Brien 1953). In the 1958 economic program which followed Whitaker’s report the government described Ireland’s main problem: “Production has not been increasing fast enough to provide employment and acceptable living standards for growing number of our people; *large-scale emigration* has been accompanied by a high level of unemployment. *Emigration will not be checked* nor will unemployment be permanently reduced until the rate of increase in national output is greatly accelerated” (SO 1958b. Italics added).

investment, transition to free trade, and – the main cornerstone of Irish industrial policy until the mid 1990s – attracting MNCs (mostly American) to locate export-oriented manufacturing activities in Ireland. The most important vehicle for institutionalizing this policy was the strengthening of the IDA, the Industrial Development Authority, as an autonomous agency responsible for job creation through industrialization. The IDA mandate was to create more jobs with the aim of decreasing the cost per job created through time.

While not focusing on the MNCs sector in its inception, FDI-based industrialization quickly became the main focus of the IDA and the Irish industrial policy. Using the yardstick of job creation, one can understand the lure of bringing large corporations that could promise the almost instantaneous creation of substantial and quantifiable number of jobs, a situation in which employment creation-tied grants make sense to both parties.¹⁷⁴ The IDA rapidly grew in its importance and influence throughout the years and transformed itself into a full “one-stop shop” for attracting and locating MNCs.

In doing so the IDA utilized a double strategy. On one side targeting and approaching MNCs, employing a wide array of techniques to befriend their senior executives, the IDA operated as a marketing agency that sold “Ireland” to MNCs, especially in the USA. The IDA quickly established a network of foreign offices whose job was to create long-term relationships with companies (many times when these

¹⁷⁴ The IDA, and Enterprise Ireland after it, have been using employment grant mechanisms as one of their main vehicles for direct financial aid. The agency and its client corporation agree on the number of jobs to be created and the agency awards the corporation a specific amount of capital per new job. The almost obsessive attention with which job creation and destruction has been followed in Ireland is evident reading Irish newspapers. The exact number of jobs created or discontinued still appears in the title of all articles dealing with the fortune of foreign (and many local) companies, even if the main thrust of the article deals with other issues.

companies were still in their early growth phase) that would eventually result in these companies opening their European facilities in Ireland. The IDA quickly moved to target sectors and internally employed a set of targets based on the number of jobs created and companies moved in each sector.

On the second side, the IDA was busily orchestrating the construction of the infrastructural and financial benefits Ireland could offer to the incoming MNCs. Ireland, like Taiwan, claims to be the first state to open a duty-free export processing zone, in Shannon in 1958. Moreover, soon thereafter many of these tax incentives were applied to the whole republic. In 1958, the Export Profit Tax Relief provided 100% tax relief on export profit growth, i.e., 100% for new export-oriented facilities. In the beginning, these policies were similar to Taiwan's. However, in 1964, the neo-liberal-interventionalist ideology of Ireland sharply moved Ireland down a different path. All restrictions on foreign ownership and repatriation of profits were eliminated, no pressures were put on MNCs to source locally, and the idea of demanding, or even asking, MNCs to transfer knowledge to local component suppliers was not even floated.

As part of making itself into a one-stop shop for MNCs, the IDA became the biggest industrial land developer and owner in Ireland, and took it upon itself to cater to the needs of the MNCs even after they had already moved to Ireland, representing their interests within the Irish state. Unlike local enterprises, MNCs coming to Ireland have been offered land, complete factories, and one centralized agency that represents the MNCs in all their dealings with other state and local agencies.

The IDA reached the zenith of its power in the 1980s. Not only was the IDA formally semi-independent (defined as a public agency, it was not part of the civil

service), which allowed it to act as a bridge between other governmental ministries and departments, but its policy domain also included everything that related to industrial development broadly defined. Its strong political connection to MNCs and responsibility over local industry gave it an immense political clout. This was especially true in the period until the early 1990s when the IDA was seen as effective in job creation – the national mission at the time.

The fact that the IDA was: i) responsible for the recruitment of MNCs; as well as ii) one of the largest landowners in Ireland was especially important. In the context of the Irish electoral system, a single-transferable-vote system where Ireland is divided into districts each electing three to five members of the Dail, the IDA was perceived to have significant influence on MNCs' ultimate location decision within Ireland, and accordingly, was seen as able to shape the economic future of specific districts. To further enhance its political muscle, the IDA was actively organizing the local managers of the MNCs into coherent lobbying group around its policy initiatives (O'Riain 1999). The IDA also benefited by having internal cohesion and extremely high-skilled personnel. The agency recruited the top high school graduates into a long career pattern within it, in which they were also given opportunities to acquire higher education. Hence, it was stuffed with highly-skilled, very motivated, and extremely loyal personnel who were able to use the IDA's semi-independence to make the agency into a crucial policy-entrepreneur, by utilizing the structural holes of the Irish bureaucracy to connect different organizations with weak social ties, and through which, to attain the IDA's own goals (Burt 1992; Granovetter 1973).

This policy turnaround, coupled with the MNC-focused industrial policy, followed by membership in the European Community since 1973, and entry into the European Monetary System in 1979 led to relative economic growth until the 1980s. However, while manufacturing output growth was quite stable throughout the years, employment growth stayed slow and even took a dip in the 1980s. Moreover, the aggregation of macro-level figures hides a negative facet of Irish economic performance until the 1990s: the huge jobs' turnaround, i.e., number of job lost, especially in Irish-owned firms.¹⁷⁵

Building the Human Infrastructure – The Build-up of the Irish Education System

At the same time Ireland was passing through a much more subtle transformation, a change arguably at least as important as any for the future growth of the IT industry. Within two generations Ireland went from being the West European country possessing the least educated workforce to a nation with one of the most highly educated workforces in the world.

Until 1966, less than 50% of the Irish population enjoyed education above the 6th grade. However, that situation quickly changed after the Minister of Education, Donogh O'Malley, following a heated debate started by a 1965 OECD sponsored survey, *Investment in Education*, decided by decree that second level education was to be given free to all Irish children. While publicly Lemass conveyed utter surprise at the O'Malley's move, some argue that O'Malley had the blessing of Lemass who wanted second level education to be granted to all Irish youth and knew that he better circumvent

¹⁷⁵ For an assessment and historical description of Ireland's industrial policy, see O'Sullivan 2000a; O'Sullivan 2000b. For a critique of Ireland's FDI-oriented industrial policy now and then, see (O'Hearn 1998).

a public debate in which the Ministry of Finance might delay or prevent this change from taking place. In an interview, Ken Whitaker strengthened this assumption stating how he, representing the Ministry of Finance, felt a need to protest only to find that Lemass was not only approving of O'Malley's "surprise" decree, but was quite prepared for it.¹⁷⁶

The OECD influence was also critical in the early 1960s in the establishment of the regional technical colleges – which have been recently upgraded to Institutes of Technologies (OECD 1965; OECD 1969). This was the first in a series of changes that overhauled the Irish higher education system, first in the 1960s and continuing in more vigorous fashion in the 1980s after the IDA included education policy in its overall view of the supply side of Irish industrial policy.¹⁷⁷ In the 1950s only 33% of Irish school leavers finished secondary education and only 10% had any experience of third level education.¹⁷⁸ By the mid-1990s these levels grew to 80% and 50% respectively, and the percentage of under 28-year-olds attending college in Ireland is one of the highest among OECD countries (Breathnach 1998).

The role of the IDA in this transformation was immense. In the 1980s, when its FDI-attracting focus changed from manufacturing activities to more technologically-advanced activities in general and the IT industry in particular, the IDA realized that Ireland needed a much more technologically-skilled workforce in order to attract the MNCs it targeted. Using its influence, the IDA first managed to bridge the gap between the universities and the government that delayed the improvement of the higher education system, especially research, for more than a decade. This feud between UCD and Trinity,

¹⁷⁶ Interview with Ken Whitaker 9/3/2003.

¹⁷⁷ For a detailed account of the development of the Irish Higher Education system, see White 2001.

¹⁷⁸ Higher education in Ireland was such a rare opportunity in the 1960s, that virtually none of the civil servants in the Ministry of Education dealing with higher education policy was a university graduate (White 2001. Pp. 41-42.)

the two prominent Dublin-based universities, and the Irish government, began in the 1960s. The government tried to force the merger of the two institutions and to establish a firmer control over the merged entity. The plan was quickly abandoned but animosity between the political elite and the two leading Irish universities remained until the 1980s. In retrospect, this bungled move by the government was one of the most important to the creation of the Irish software industry. Immediately after the government announced the plan, under which Trinity's engineering faculty was to disband and move to UCD, Trinity moved to counter it by creating and rapidly expanding a new engineering department of Computer Science in 1969. UCD followed suit by expanding its own Computer Science program located in the sciences. These two departments became crucial to the development of the Irish IT industry in later years.

Secondly, the IDA also managed to accelerate changes that upgraded the whole education system. Within a decade and a half the regional technical colleges became full-fledged academic establishments, the National University of Ireland system was expanded, and a few more higher education institutions became full-fledged universities (White 2001).¹⁷⁹

There were major differences between the Irish education system and policies and these of Israel and Taiwan. Education in Ireland was seen as an economic supply-side issue, and consequently the system's main aim was to create high-skilled labor that could work for the incoming MNCs.¹⁸⁰ Indeed, even today if a regional college wishes to open a new degree course, it has to show that the industries around it not only want these

¹⁷⁹ In addition to opening the new facilities and institutions, the state has also been using its control of university slot allocation to steer students toward engineering and technology courses.

¹⁸⁰ A spell as interns in various workplaces is still often an integral part of the education in the RTCs/RITs and other, non-university, parts of the Irish higher education system.

skills, but also approve the specific curricula offered. Many of the managers of the large MNCs interviewed, such as Intel, Digital, or Ericsson, talked at length about the involvement of their corporation in the development of the nearby colleges' course of studies.¹⁸¹

In one important respect, academic research, Ireland is still far behind, Israel, Taiwan, or most OECD countries only very recently does a small positive change appear to have occurred.¹⁸² In the 1970s the state supplied, at about £27 million, very minimal resources for academic R&D, but during the financial crisis in the 1980s even that amount went down sharply to almost nothing. EU grants became the main source of capital. Only in the mid-1990s with the looming future expansion of the EU did policy makers and politician realize that Ireland must upgrade its R&D capabilities if it were to compete with the Eastern-European countries for MNCs.

These developments triggered the establishment of Science Foundation Ireland (SFI) and the Programme for Research in Third-Level Institutions (PRTLTI) in 1988.¹⁸³ SFI has been built on a similar basis to the American NSF. Indeed its director general, William Harris, an American of Irish origin, was formerly a director of one of the NSF divisions. SFI was envisioned as a five-year targeted effort to create high-quality research in the areas of biotechnology and ICT, but this focus was somewhat expanded. The SFI also continues another reoccurring theme of Irish economic policies: there is an intentional bias to award grants for teams who are led by foreign-based internationally renowned researchers. The argument behind this partiality has been that Ireland needs to

¹⁸¹ For a paper trying to measure the economic effect of the expanding education system, see Durkan et al. 1999.

¹⁸² See, NSB 2000. Figures 6-55 to 6-61.

¹⁸³ Interview with Don Thornhill Chairman of the Higher Education Authority 2/4/2002.

attract high-quality researchers if it wants to conduct top-level research. While Ireland has the advantage over Israel and Taiwan of being a highly developed English speaking country with high-quality of living that can attract foreign talent, others argue that this move symbolizes the inability of the Irish state to trust its own citizens. As of 2004, SFI budget for its first period of operation, 2000-2006, is €646 million (SFI 2004).

PRLTI is the twin effort of SFI and its main aim is to enable the building of the necessary research infrastructure within the university system. PRLTI allocates its funds on a competitive basis. As of 2004 the PRLTI had three multi-year funding cycles. It was envisioned as a state-industry initiative. As of 2004, not including private contributions, €605 million were allocated (HEA 2004).

By establishing these two programs in 1998 the Irish state indicated its seriousness about transforming the academic research infrastructure. However, there are still many caveats as to the continuous state support for SFI and its medium and long-term influence. Moreover, even when finally moving to upgrade the Irish research apparatus, the Irish state still employs an FDI-orientation, for example in its insistence on the participation of foreign-based scientists. Hence, questions remain as to whether the goal of the SFI is a genuine attempt to change the Irish economy capabilities toward rapid-innovation-based industrialization, or just the last stage of supply-side policies to create MNC-attracting human capital.

Thus, although the development of the Irish education system is unprecedented in Irish history and has greatly helped to propel Ireland along the track of high skilled IT industrial development, it appears that the strategic view behind these developments treated the education mainly as a way to produce high skilled labor, and not innovation

and research. Only in the last five years policies with a vision of making the Irish higher education system more research-oriented have been implemented.

Seeds of the IT Industry – From the 1960s to the Early 1980s

Throughout the same period the seeds of the future IT industry in Ireland were planted. In both the public and the private sectors, computerization activities that would eventually give birth to the Irish-owned IT industry were taking place. The official beginning of computerization in Ireland was in 1958. In that year Suicra – the Irish Sugar Company (a state owned enterprise) – decided to computerize its operations and brought the first computer to Ireland.¹⁸⁴ Throughout the 1960s and early 1970s, big public and private companies and organizations were the main loci of professional IT training and knowledge diffusion, especially as formal third-level education was beyond the means of most young high-school graduates at the time, and most universities didn't offer computer-science degrees.¹⁸⁵ Barry Murphy, the first director of the National Software Directorate and before and after CEO of a few leading Irish-owned software companies, such as Insight, Openet Telecom, and Netsure, echoed the claims made by many that these institutions are the unsung heroes of the industry:

Those big companies were the only institutions that were actually training people at the time; these companies were the likes of the banks and insurance companies. They gave superb training to cohorts of young people, which they all lost in five to seven years' time. These companies made an immense contribution to the Irish software industry (Interview with Barry Murphy 11/6/2000).

¹⁸⁴ For accounts of the development of the Irish software industry, see Arora et al. 2001; O'Riain 1997; O'Riain 1999; Sands 2005; Sterne 2004. For an account based on cluster theory, see O'Gorman et al. 1997.

¹⁸⁵ For some years, Cara, the computing subsidiary of the national airline, Aer Lingus, was the biggest software company, data processing center, and exporter in Ireland. With its ticket ordering system and remote terminals, Cara was the first to introduce distributed software systems into Ireland and later also successfully sold hotel management systems in Europe.

The early Irish IT companies were established in the 1960s and 1970s. Most, due to the high cost of computers at the time and the capital constraints in Ireland, concentrated either on consulting and services or out-sourcing of IT services' business models.¹⁸⁶ The first Irish software company was System Dynamics, founded in 1968 by a team of former IBM Ireland employees, and focused on software consultancy services. System Dynamic was also important for three other reasons, first, the spawning of a few of the biggest Irish software consultancies, such as Chaco or Delphi, which in turn spawned others, such as Enovation.¹⁸⁷ Second, System Dynamic's founder Tom McGovern was key in raising the profile of the Irish software industry and creating its identity as a distinct socio-political group within the Irish industrial landscape. Lastly, McGovern, in a way similar to other successful early IT entrepreneurs, such as Michael Peirce of Mentec, played a crucial role as the early financier of other, more product-oriented, companies. As other sources of finance did not exist, and as the Irish banks were not even willing to extend overdraft facilities to many software companies until the early 1990s, such a role cannot be underestimated.¹⁸⁸

The Irish IT companies in that period, unlike the MNCs, had to surmount extensive difficulties in order to commence and maintain operations. Not only was there no source of funding nor entrepreneurial financiers such as the Israeli Tolkowsky and

¹⁸⁶ Interestingly enough, some of the local managers of MNCs' subsidiaries claim that the existence of these IT out-sourcing services companies in Ireland granted the Irish subsidiaries a comparative advantage versus other foreign subsidiaries when competing for more activities in the corporate headquarters (interview with former managers of the Irish subsidiaries of telecommunication MNCs 7/17/2001).

¹⁸⁷ Michael Purser, an employee of System Dynamic who left to become one of the first Computer Science faculty members at Trinity, founded Chaco. Chaco was created partly in an attempt by Purser to help his own students find employment. The company was considered the more technologically oriented of the Irish software companies in the 1970s before it merged with Baltimore, another company that Purser co-founded together with Jim Mountjoy. A few more service-based companies that later transformed into product companies appeared in that period. The most notable of these were GC McKeown and AMS.

¹⁸⁸ McGovern's two most important investments were done in conjunction to his relationship with Jim Mountjoy, the co-founder of Baltimore in 1984, and Euristix in 1990.

Discount Investment, but also banks were not even willing to extend loans or simple credit facilities to indigenous IT companies. The result has been that these few individuals still daring to be entrepreneurs typically needed to mortgage their own houses to secure working capital. As a result of these constraints, most of these early IT companies stayed financially fragile and collapsed at the slightest change to their monthly cash flow. Moreover, unlike the MNCs, local NTBFs were not offered land and offices in the IDA's industrial estates, and many property owners turned out to be as conservative as the banks, and were unwilling to rent space for software companies.¹⁸⁹

Slowly but surely, the first Irish companies moved on the backs of their customers to product development. Timing and the movement of the MNCs into Ireland were important catalysts in this development. In the 1970s, the MNCs led the progress in Ireland away from the mainframe platform into minicomputers. As the opening of the new and smaller Irish MNC subsidiaries coincided with the rise of minicomputer technology, relative to its population Ireland became one of the worlds' heaviest users of minicomputers.

Mini-computers were: i) a different platform, and hence, did not use the same software employed at the MNCs' foreign headquarters; and ii) a new platform, and hence, did not have an established base of software. As a result, many local companies managed to get development projects that could easily be packaged (a new concept at the time) into software products. The more successful of these packages quickly secured a few more sales in Ireland and the UK. However, a second and much more important

¹⁸⁹ As many of the commercial space problems relates directly to the Irish-British tradition of renting commercial propriety only for long-term leases (5 to 25 years), even in the 2000-2003 period many interviewees complained about the unwillingness of landowners to rent their offices to newly established software companies.

transformation of the local software industry happened when the computer manufacturers, such as Digital, IBM, and ICL, invited some Irish companies to market their products together as a bundled solution.

Kindle, one of the first Irish software companies to reach successful constant overseas sales, is an example of this model of organizational development. Kindle, founded in 1981 as Triple A Systems, first developed banking systems on the ICL platform.¹⁹⁰ ICL sold its computers around the world, especially in former British colonies, and did not have many banking packages that ran on its platform. It added Kindle to its official list of ICL software vendors as a banking package specialist. Soon thereafter, Kindle got orders from all of the former British colonies. In the second part of the 1980s, Kindle converted its products to other platforms. Kindle is now owned by a British company, and is a 500-person software house with a global sales and support network. However, its main locus of activity and R&D is no longer in Ireland.

The early 1980s saw an overall maturation of the Irish software industry. This process concurred with the beginning of the changes in the IDA view of the indigenous IT industry and the tradable services industries. With the establishment of the Enterprise Development Program by the IDA the agency started to become more proactive in assisting local IT NTBFs, however, on a very low scale and with relatively small amounts compared to the aid given to MNCs. Furthermore, the IDA and many leading politicians developed a relationship of mutual distrust with the indigenous IT industry, a state of affairs that continued to the mid-1990s.

Apart from Kindle, two other software companies whose rise and fall changed the way the IDA and subsequently Enterprise Ireland manage their R&D grant schemes were

¹⁹⁰ ICL was a leading British computer company that merged into Fujitsu.

Insight Software and Real-Time Software (RTS). The two companies, in particular RTS, were different from earlier Irish-owned companies in being product-based companies from their inception. They were also representative of the particular profile of the Irish software industry at the time: the products of both were based around Maapics. Maapics was the main software suite for manufacturing facilities offered by IBM as part of its own foray into the minicomputer arena.¹⁹¹ Both companies grew out of the relative strengths of the Irish industrial base in the early 1980s – manufacturing facilities that were world leaders in utilizing the new minicomputer technologies.

Insight was originally the name of a package for financial reporting and analysis built to work on top of the Maapics package by a product-oriented venture of AMS named Vector Software. Insight was sold by AMS, which also financed all the development efforts from its IT consulting revenues. AMS started to directly sell the Insight packages around the world in 1980, and changed its own name to Insight Software in 1983. The company reached record product sales for an Irish company in the early 1980s, and by 1988 was poised to sell its more advanced software package for the IBM AS/400. However, the company started to suffer from severe cash flow problems. These were caused by a series of factors: i) the need to financially rely solely on its own revenues; ii) its use of a business model that necessitate a costly international direct sales operations; iii) the fact that Insight, with Vector acting as its R&D center, still maintained both the product line and the consultancy business; iv) the added difficulties in moving into the higher priced software package on a newly launched platform brought. In the end

¹⁹¹ The Maapics package was introduced to Ireland together with IBM's System/34. IBM launched System/34 in April 1977 as its own approach to minicomputers. System/34 was a low cost distributive data processing system modeled on the IBM 5340 system.

the founders were glad to sell Insight to the Hoskyns Group, a publicly listed British software house in 1988.¹⁹²

Real-Time Software (RTS) was given more attention by the IDA, mainly as it was perceived to be the first technology-based spinout to form from a subsidiary of foreign MNCs and as such was celebrated as a political success story. The company was founded to develop software packages and tools around the Maapics software. Its seed finance came from its co-founders, one of whom then proceeded to sell his services as a consultant to finance the initial product R&D. Starting by offering multicurrency modules, RTS developed a whole suite of financial packages. By 1985, the company had revenues of a few million dollars and a chain of foreign offices. However, it still did not manage to secure investment anywhere in Ireland and even with the relatively small amount of capital RTS raised in the US and the UK by the end of 1985, it was clear that its better funded American rivals were winning market share. In 1986, the company suffered heavy losses that brought its founders to sell it to the American company MSA. Soon thereafter MSA itself faced difficulties and closed down its Dublin operations in 1988.

¹⁹² In 1988, Hoskyns also bought CBT systems' – Computer Based Training – first incarnation. With the sale of Hoskyns to Cap Gemini in 1990 the remaining product-based activities of the former Insight were discontinued. Barry Murphy, the then CEO of Insight left to become the first Director of the NSD. CBT was established by Patrick (Pat) McDonagh in 1983. Its first product was a training kit for money market dealers. The domain knowledge, as well as some of the financial backing, came from Dermot Desmond. Dermot was the first private financier to invest significant amounts of capital in the software industry (Dermot's most known software investment was the backing of Fran Rooney's transformation of Baltimore into a data security company in the late 1990s). In 1987, McDonagh sold the company to Hoskyns only to buy it back in September 1991 after Cap Gemini bought Hoskyns. Under the management of Bill McCabe the new CBT concentrated its effort on the American, and not the European, market. Within three years CBT, selling software user training products, mainly for Lotus Notes, reached revenues of \$18 million before becoming the first Irish software company to list on NASDAQ in 1995. CBT later changed its name to Smartforce before merging with Skilsoft in 2002, and is now trading under the Skilsoft name. Using the money he earned from CBT's public listing Patrick McDonagh financed Riverdeep, in 1995, another educational company selling multimedia school courses. Riverdeep also publicly listed on NASDAQ in 2000, making McDonagh, a school teacher by training, the most successful software entrepreneur in Ireland.

In the same period many politicians as well as other parts of the IDA aired concerns that the EDP was investing too heavily in risky indigenous software businesses without generating enough employment. In the three years between 1986 and 1989 these concerns were strengthened when many of the leading software companies went bankrupt. In addition, as the result of the foreign M&A of RTS, Insight, and CBT, some of their founders made what was considered in Ireland at the time a small fortune. The fact that these entrepreneurs made this fortune by selling their companies, which was perceived to entail the destruction of jobs instead of the creation of jobs, triggered severe resentment. Both the public and the politicians, only too willing to spend millions on MNCs, saw the newfound riches of the software entrepreneurs who benefited from IDA grants not as a sign of success but as socially unfair gains. Moreover, with the growing number of bankruptcies there was a wariness of the chances that a local industry would ever be able to achieve continuous and sustained growth.¹⁹³ In the end a decision was made that state aid should be constructed to share the upturn of businesses it invested in and not just their risks. Direct pressure from the then new Minister of Finance, Albert Reynolds, brought the IDA to introduce a small, later to be proved significant, change to the conditions of its grants: starting in 1988 the Irish state started to take equity stakes in return for financial aid.

The tales of these three companies also show the most significant difference between the Irish and the Israeli software industry. The Israeli software industry grew within an innovation system already focused on R&D. As a result, many of the products of its software companies were software development tools. The Irish software industry

¹⁹³ As one interviewee from the former IDA remarked: “in that period <1986-9> we joked that in Ireland the best way to create a small Irish software company was to establish a big one and wait” (interview 3/10/2001).

followed a different track, developing software applications for particular business domains such as finance, insurance, or manufacturing control. Only with the rise of university research in the early 1990s would Ireland manage to grow successful software companies with a focus on developing software technology itself. However, when one such company, Iona, was listed on NASDAQ, it epitomized the new international success of the industry and completely changed its perception in Ireland.

An almost forgotten fact about these early years of the Irish IT industry is that the first IT companies that truly reached sustained global success were hardware, not software, firms. In the mid-to-late 1980s the Irish IT hardware industry briefly enjoyed unprecedented success. The two prominent companies of that period, whose development stories also explain why there were only a few Irish hardware companies until the mid-1990s, were Lake Electronics and Mentec.

Harry Lynam set up Lake Electronics in the end of 1976. Lynam, a physicist, worked for many years in the engineering part of the Post and Telecommunication Ministry where Jim Mountjoy, another important entrepreneur, also gained his first experience. In 1976, Lynam became fascinated by microprocessors, and decided to sell his house and move with his family to his in-laws to secure the seed finance for Lake Electronics. Luckily for Lake in the same period the IDA established the EDP and Lake became one of its first clients. A few of the early employees of Lake described the effect of this state help as critical:

“More than anything else at that period in Ireland it <the IDA backing the company> was the psychological affect. We were frowned on, seven adults with families leaving good secure jobs to start some adventure in a technological area nobody understood. The fact that the esteemed and all powerful IDA thought that we were making something useful gave us the mental strength to continue” (interview 7/9/2001).

That injection of capital from the IDA also transformed the way in which the banks treated the company and together with a first project with Lynam's former employer, the Ministry of Post and Telecommunication, Lake managed to develop its first product: an MP controlled PBX.¹⁹⁴ Lake secured a critical alliance with British Telecom (then a state-owned enterprise) in 1979. Building on its first major international sale Lake soon expanded worldwide and by 1983 grew to become a 200-person strong company with revenues of £10IEP million. However, the company suffered from lack of management skills and encountered reoccurring cash flow problems. The result of these unstable times was the sale of the company in 1988 to Landis & Gyr, a Swiss engineering MNC.¹⁹⁵

Thus 1988, the year in which the remains of RTS' Dublin operation closed down and Insight Software and CBT's first incarnation were bought by Hoskyns, became the year in which the first generation of international successful Irish IT companies suffered heavy setbacks and the image of the indigenous sector was tarnished.¹⁹⁶

Mentec's creation story has many similarities to Lake's. Mike Peirce, who was a lecturer in Trinity's engineering faculty at the time, founded Mentec in 1978. Peirce's expertise was the use of computers in manufacturing. In 1978 together with one of his graduate students he went on a study trip in Japan to see the use of robots in manufacturing. The trip proved to be the needed trigger and Peirce and his student-

¹⁹⁴ PBX stands for Private Branch exchange, a private telephone network used within a specific organization. Users of the PBX share a number of outside lines for making telephone calls outside the PBX.

¹⁹⁵ Lynam also become seriously ill in 1988 and retired from the industry. In 1990 he came back and established Klas, a telecommunication hardware company, together with his wife and son Henry.

¹⁹⁶ Landis & Gyr ran into difficulties in 1991 and closed down its Irish subsidiary. Out of its Irish operations two new Irish-owned IT companies were created by MBOs. The first was Lake Communication, which is still managed by several of the old management team of Lake Electronics who stayed on with Landis & Gyr. The second was Peregrine Software, a financial data security company that flourished for a few years before being bought in 2000 by Trintech, one of the three Irish software companies that are still listed on NASDAQ in 2005.

turned-partner mortgaged their assets to secure seed financing in the form of a bank loan. Fortunately for them the IDA's EDP not only agreed to match their funds but also to guarantee 50% of a £100,00IEP bank loan. The fact that the IDA agreed to assist the company at the time was critical and an interviewee working for Mentec at the time described it:

“We could absolutely not get started without the IDA, the banks were unwilling to talk with us before the IDA chipped in. As a matter of fact we probably would not have even tried. When we floated the idea of opening a company, almost all the people we knew told us that we are crazy and that to leave secure respectable careers at Trinity is madness. Many reminded us that we have families and children to think of” (interview 6/10/2003).

With the IDA's backup, Mentec approached the banks. However, the banks insisted that Mentec buy “real assets” worth £50,00IEP to secure the 50% of the loan not covered by the IDA. Hence, Mentec's first activity was the building of its own offices. The banks were pleased, but Mentec was left with no working capital and no way to finance R&D activities.

At the time the biggest IT MNC in Ireland was Digital Equipment of Massachusetts, which had large facilities around Galway. Mentec first focused on projects to develop custom hardware solutions around Data General's computers, but switched allegiance to Digital in 1979. Digital, unlike the other MNCs at the time, had an active and developed OEM partnership program and was looking for suppliers to develop bundled solutions for its PDP computer line. In order to help its smaller suppliers it granted them complete and open documentation of its systems. Mentec soon became Digital's most important OEM supplier in Ireland. Focusing on product development, Mentec created its core product in 1982, a single board computer/controller based around Digital's J-11 CPU to be used in manufacturing control systems. This basis led to many

other developments around Digital's and Mentec's own chips that were fabricated by Texas Instruments. In its prime, Mentec had revenues of ten of millions IEP and employed more than 200 people in Dublin and a few score more in the US and England. At one point sixty-five of Mentec's employees worked on R&D, a unique feature in the Irish IT industry of those days. Mentec also enjoyed the fact that it became an official partner of Ireland's foremost MNC and the IDA gave it more than a few R&D grants throughout the years.¹⁹⁷

The stories of Mentec and Lake Electronic exemplify the difficulties that Irish hardware companies had over and above the significant obstacles that software companies were facing. Not only is hardware product development a much costlier endeavor than software, but also the opportunities for consulting projects, especially these that can ultimately lead to product development were scarce. In addition, at that time both software and hardware companies had to face a hostile social environment that either saw technological entrepreneurs as risk takers when they failed, or resented them when they succeeded. Thus, where in Israel and Taiwan, the pioneers of the IT industry were seen to advance the national dream - soldiers in the war for national growth and glory – in Ireland, *under the political context of job creation* the same pioneers were seen as unstable and untrustworthy gamblers.¹⁹⁸ Banks and other financial institutions not only were unwilling to invest in the industry, but also refused to extend even the minimal

¹⁹⁷ Mentec and its founders, especially Mike Peirce, became crucial to the continued development of the Irish IT industry. Peirce invested in and was the chairman of Parthus, an Irish IC design house established after the demise of Digital's facilities in Galway that became the only Irish hardware company ever to be listed on NASDAQ. Peirce and Mentec not only encouraged a few spinouts, such as, Eurologic and AEP, but also became their key early investors. In addition, in 2001 Peirce, together with the former director given to Mentec by the IDA, opened Mentor Capital, a small VC fund.

¹⁹⁸ John Sterne, a historian of the Irish software industry, remarked that even as late as 1995, a Minister of the State, Pat Rabbitte, decided that it would be politically expedient to use a joint conference of the Irish and Massachusetts software associations to chide the Irish software industry for "paying too much for their employees" (Sterne 2004. Pp. 86-87).

necessary financial services to IT companies. Only those founders willing to risk everything they had by mortgaging their own property managed to secure enough capital to open their businesses. Accordingly, the financial backing of the IDA, even if limited, was absolutely critical.

Even in the relatively simple issue of finding office space, indigenous Irish IT companies have been facing severe difficulties and discrimination compared with the MNCs and traditional businesses. Regulation and tradition in regards to commercial space in Ireland have led to a system in which private property owners prefer to lease almost solely for long multi-year terms. Furthermore, almost none of them were willing to lease their offices to NTBFs, which they perceived as too risky. Thus, if on the one side the IDA was busily developing purposely built industrial estates for its MNC clients (hence, probably lowering the profitability of developing industrial commercial spaces for private property developers), on the other side the indigenous companies faced immense difficulties in securing even a small office space. Many of my interviewees as late as 2002 still argued that finding office space was one of their most difficult obstacles, even for well-funded companies.

The experiences from the creation of the IT industry in Galway after the closure of Digital's facilities in the early 1990s are exemplary. The founders of both Storm and Toucan, two of the most successful companies to be created by former employees of Digital after its closure, quickly found out that even with state and regional agencies backing their efforts, and even at a time in which their success was deemed crucial for the economic future of their communities, no one was willing to rent them office space. In the end the only way in which they managed to secure space was by the IDA allowing

both companies to build their own premises in one of its industrial estates. A solution that forced both firms to spend a large percentage of their limited resources. Last but not least, while throughout this period MNCs were offered a wide array of tax incentives, the indigenous IT companies, like all Irish businesses, had to pay the full, and high, corporate taxes rates.

State Policies and the Discovery of IT and Tradable Services – the Evolution of State Policies in the 1980s and Early 1990s

On the IDA's side, the late 1970s were the years in which the agency started to appreciate the potential of the IT industry. If in the 1950-60s the IDA was broadly recruiting MNCs, it became much more focused in the late 1970s, especially with the 'growth-without-jobs' socio-economic crisis of the 1980s. The IDA's biggest coup in the 1970s was attracting Digital Equipment. Digital, then and throughout the 1980s one of the world's top IT companies, opened its facilities in Galway in 1971 and soon became the biggest MNC in Ireland. Together with Erickson, which has large facilities in Athlone, Digital has also been one of the first MNCs to move more advanced R&D operations to Ireland.

By the late 1970s, the IDA started to focus on the tradable-services industries and on high-technology electronics. This process was soon accelerated when it became clear in the 1980s that manufacturing MNC subsidiaries preferred to increase their investment in capital equipment, not in expanding their headcount. Thus, while overall production grew, the number of jobs did not.

In 1975, the IDA established the International Services Program (ISP) that through political lobbying extended the incentives formerly given only to the

manufacturing sectors to the service sectors. In the beginning software was not considered to be the main target, but by 1981 it became one of the ten designated sectors of internationally traded services to which tax incentives were fully extended. The IDA pushed for and succeeded in getting incentives, approval, and recognition for a rainbow of tradable-services industries, from English-language-schools, to software, finance, and film. These incentives and the actions of the IDA to both bring MNCs and create local enterprises in these areas developed the institutional framework in which the perception of service industry firms gained in reputation and legitimization.

At the same time the IDA institutionalized its support to indigenous companies in 1978 when it created the Enterprise Development Program (EDP). The main goals behind the creation of the EDP were to: a) increase employment; b) lower Ireland's reliance on FDI by growing indigenous companies; c) create of a set of suppliers to attract more MNCs; and, d) change the attitude against entrepreneurship and local enterprises in Ireland. The focus was on all sectors, both traditional and technological.

Interestingly the officials running the MNC-focused International Services Program were also given the responsibility over the EDP. Thus, unlike the case of the indigenous hardware industry, which was continuously treated as an extension of the already established MNC-oriented policies, the birth of indigenous software industry concurred with changes within the developmental agencies that institutionalized their interest and focus around the industry.¹⁹⁹

The two programs, ISP and EDP, were not focused on the IT sector in particular or on NTBF promotion in general, but on promoting any kind of entrepreneurial activity

¹⁹⁹ During the interviews, executives of the EDP all remarked that electronics was always considered manufacturing. As a result it was not firmly on the new agenda of indigenous enterprise building and new tradable-services industries.

in Ireland.²⁰⁰ However, processes related both to state activities and to the activities of private entrepreneurs, coupled with changes in global demand for IT, propelled the software sector as the first sector in which indigenous companies achieved worldwide success. This success, in turn, refocused most of the attention of the newly created state agencies on the IT sector, specifically enhancing the software industry and aiding its continuous growth since the mid 1990s. Indeed two different executive of the EDP program strongly insisted that:

“There was no aim to create science-based industry at the time, the program <EDP> evolved in a case by case process. Slowly it became clear that services are the main beneficiary, and that in reality we were mainly dealing with software. This is why we quickly added software to the list of sectors to get the full tax benefits and why later policy was constructed around software. But we had no ideal of creating a technological industry in Ireland at the time. We just aimed to create more enterprises and jobs” (interview 3/14/2001).

The EDP became crucial not only in the funding of companies but also in actively convincing potential entrepreneurs to start their business. At least as importantly, the EDP’s actions granted some legitimacy to technological entrepreneurship and risk taking. The latter might have been the most important accomplishment of the EDP considering Ireland’s ultra-conservative business and financial landscape at the time. In addition, on the FDI-oriented policy side, the new policies and the actions taken by the ISP culminated in major software companies opening subsidiaries in Ireland. A consensus evolved that the future of Irish industry did not rely solely on the manufacturing sector.

The first major software MNC that arrived in Ireland and transformed it into the world capital for software localization was Lotus in 1985.²⁰¹ Unlike the indifferent

²⁰⁰ Interviews with former executives of EDP and ISP (3/10/2001; 7/16/2001), and the first CEO of EI, Dan Flinters (2/5/2002).

²⁰¹ There were many smaller foreign software companies that arrived to Ireland prior. However, Lotus’ move, in the time it was considered one of the premier software MNCs, had the effect of legitimizing

reaction given by the political establishment to the activities of local companies, the political and social elite attended the opening ceremony of Lotus' Irish operation and the company gained the goodwill of both the Irish developmental agencies as well as leading politicians. John Sterne argues that the main reason why Lotus was greeted with such esteem is specifically because it did not conduct any R&D activities in Ireland but concentrated on localization, packaging, and logistics. Therefore, Lotus was seen as a real manufacturing company with sensible well-understood operations (Sterne 2004. Pp. 101-108).²⁰² Following Lotus almost all of the top software MNCs, such as Oracle, Symantec, Coral, Novell, and Microsoft opened localization, packaging, and logistics operations in Ireland during the 1990s. Microsoft soon became Ireland's top exporter and the sales attributed to its Irish subsidiary are single-handedly responsible for making Ireland into the world's biggest software exporter.

In the 1980s the commitment of the state expressly to the software industry was further strengthened with the establishment of the National Software Center (NSC). The NSC was the first failed attempt to create within the IDA a subunit stuffed with industry experts to promote the growth of the software industry. In 1983, two competing proposals for a National Software Center were put forward. One, proposed by a coalition of the Science and Technology Board, the Higher Education Authority, and representatives of the indigenous industry, envisioned a non-profit center providing the industry with wide range of services. The second proposal, of the IDA, was focused on the MNCs sector and envisioned the NSC as a self-financed operation giving services to the industry for a fee.

Ireland as the "place to be" for American software MNCs. A very similar effect that DEC's move to Galway had in the 1970s, and Intel's in the 1990s.

²⁰² Localization is the programming activity of taking a software working in a specific culture/language and translating it into different cultures/languages.

Unlike the Science and Technology Board and the Higher Education Authority, the IDA did not bother to consult with the indigenous industry (O'Riain 1999; O'Riain 2004; Sterne 2004).

In another example of the IDA's power at the time, although the local industry supported the competing plan, the NSC was created on the basis of the IDA's proposal.²⁰³ Brian Dugan was recruited from a position of VP in Standard and Poor's in New York to become the NSC's first director. The NSC's first board of directors also consisted solely of MNC representatives. However, the NSC very quickly focused more on the indigenous industry. By 1987-88 the NSC became one of the main institutions in which the state and the indigenous software industry were collaborating. On the other hand, the NSC's need to become self-financed ultimately led to conflicts as well as perceived and real competition with industry. In addition, its focus on the indigenous sector cost it its IDA support. By June 1988 the NSC was closed down.

Before it closed down the NSC managed to complete the first survey of the industry. The result of this survey shows how different from the Israeli, and how similar to the Taiwanese, the Irish software industry was in the 1980s. If in Israel the leading companies at the time were focusing on solutions to R&D and software programming processes, in Ireland most of the companies either imitated already established packages of foreign companies on new platforms, or focused on industry specific applications with very little in terms of R&D or innovation. For example, in 1984 there were twenty four

²⁰³ O'Riain, reporting on the view of the indigenous industry on that period, cites their position as reflected in its main publication of the time – Irish computer: "If the interests of the indigenous computer services industry companies are safe-guarded and promoted, and if there is a proper structure within which they can influence the new body in the interest of their members, then it <NSC> will have the association's <ISA then called ICESA> support. If they are not met, in the word of a member of the ICESA executive committee, it will be '*total opposition*'" (O'Riain 1999. P. 214, Italics added).

companies selling packages for insurance agents, eighteen with software for lawyers' offices, and twelve selling applications for TV rental stores (Sterne 2004. P. 17).

By 1988, the political landscape in Ireland was changed, and the further development of the indigenous software industry was very much on the agenda. As soon as the NSC was closed down two proposals for centers to replace it were immediately put forward. The first, focusing on skill development, resulted in the ultimately ill-fated PAT university-industry linkages centers established with EU funds. The second, developed together by the Ministry of Industry and Commerce and the indigenous industry resulted in the creation of the National Software Directorate within the IDA in 1991.

In a symbolic move, very different than the IDA's choice of an American to be the NSC's first director in 1984, an Irishman, Barry Murphy, was chosen to become the NSD's first director. Murphy, Insight Software's CEO and a member of the board of ICSA, has been one of the most vocal and prominent leaders of the indigenous industry.

The NSD became crucial on three fronts. It was the first organization to chart the size and scope of the software industry on Ireland in a comprehensive and regular basis, finding it in the words of Murphy, "to have more companies than anyone thought at the time" (interview with Barry Murphy, 11/6/2000). Following that initiative, the NSD became the main center devoted to collecting, processing, and publishing data on the software industry. Secondly, the NSD became the main promoter of the movement toward the product-development business model and away from the consulting business model. Last but not least, using EU financing, the NSD became one of the main initiators of the high-tech-oriented venture capital industry in Ireland.

At least as important, however, was the effect of the NSD within the Irish developmental agencies. Unlike any other sector, software companies now had a direct line and a voice within the Irish developmental agencies, first the IDA and then Forbriat and EI. With the NSD pushing for more resources to be channeled toward the indigenous software sector and with its people sitting in the grant-giving committees of the EI, software soon became the pilot sector around which Ireland's S&T industrial policies, focusing on the indigenous-industry, were planned and implanted.

The Restructuring of the Developmental Agencies

Even with the IDA's new programs and focus in the 1980s, the "growth without jobs" crisis coupled with the failure of fiscal expansion policies left Ireland in a dire situation. Emigration reached new heights with 44,000 or 1.1% of population leaving Ireland in 1989 alone, many of those from the young and highly educated segment of the population. This turn of events together with a growing public resentment of the IDA's focus on MNCs, started subtle but important changes in Ireland's industrial policy, which, in the end, refocused it around the high technology sectors in the 1980s and 1990s.

The last restructuring of Irish industrial policies around the high-technology industries started during the latest Irish economic crisis. In the early 1980s, major policy and social upheavals started the realignment process of Ireland's institutional system along the path of NTBFs-oriented industrial development. In the socio-political arena resentment toward what was seen as the excessive focus of IDA on MNCs with much smaller amounts of resources channeled into the indigenous industry, coupled with the severe crisis of Irish industry, culminated in the Telesis report.

The report, commissioned by the National Economic and Social Council (NESC), hence with substantial political support behind it, argued for an almost complete renovation of Irish industrial policy. The report concluded that Ireland's economic growth should have a "double engine" of FDI and Irish-owned companies. The report also argued for the building of national champions, and contended that the level of organizational and management capabilities of Irish firms was too low for them to succeed without a hands-on industrial policy. Thus, the report called for a break with the traditional neo-liberal-interventionist industrial policy. Nevertheless, the report itself did not give any conditions whatsoever as to how national champions and winners should be selected nor to how the state should employ direct intervention to strengthen the management and organizational capabilities of Irish-owned firms.

The Telesis report was published in February 1982 and a heated debate about industrial policy followed. However, in the 1984 White Paper on Industrial Policy, the Telesis report recommendations were mostly ignored (O'Sullivan 2000b). Nevertheless, the report's long-term impact was larger than it seemed at the time. It both started and lent legitimacy to a long process of refocusing industrial policy around the indigenous industry. This process culminated in another committee report, the 1992 Culliton Report.

The Culliton report's most important recommendation was that the state should direct its assistance into fixing general financial market failures, i.e., helping companies in every sector that were deemed too risky by the existing conservative financial institutions to be granted finance.²⁰⁴ Moreover, the Culliton Report envisioned a restructuring of the development agencies' organization.

²⁰⁴ Again the contrast with Israel is apparent, where in Israel the state focused its energies around market failures associated with R&D activities and not with general financial market failures.

As a result of the Culliton report, two waves of bureaucratic reshuffling occurred. In the first, under the Industrial Development Act of 1993, the IDA was restructured into two main agencies: Forbairt took charge of the indigenous industry development and the Irish Science and Technology Board (Eolas). The IDA, still influential but with reduced power, was renamed as the Industrial Development Agency-Ireland, and given the mandate over the MNCs and FDI-related activities. In addition, on top of these two agencies a strategic, coordination, and advisory agency – Forfas – was created. In 1998, the reshuffling was completed with Forbairt merging with the Irish Trade Board and parts of FAS (the training agency) into one agency with capabilities and responsibilities for promoting Irish-owned industry in both Ireland and abroad. The merged agency was renamed Enterprise Ireland.

This period also strengthened Ireland's particular neo-liberal-interventionist ideology. These bureaucratic reconstruction efforts progressed side by side with the establishment of a neo-corporatist regime by the new right-center government. In a stark difference to both the US and the UK, in Ireland when a new center-right government gained power from a center-left one in 1987 it opted not only not to crush the labor unions, but also to enhance their power by structuring an encompassing neo-corporatist framework – the social partnership agreements. This framework led to a series of ever more comprehensive three years agreements, which are part of the backbone of Irish industrial and economic policy to this day (Hardiman 2000; Hardiman 2002).

Thus, Ireland, led by an ideologically center-right government, possessing an industrial base consisting mainly of American MNCs, and under strong pressure from the IMF and the World Bank, decided and successfully implemented a neo-corporatist

framework. Moreover, the Irish Fainna-Fail government accomplished this feat at exactly the same time that their ideological contemporaries and partners, Thatcher in the UK and Reagan in the US, were busily dismantling union power. Thus, the end of the 1980s and the beginning of the 1990s brought major policy changes to Ireland. These policy changes, taken together as part of a major restructuring of the Irish industrial policies, have been very different than those taken in Taiwan and Israel in the same period.

The Rise of the Software and the Continues Stagnation of Hardware – Development and State-Industry Co-Evolution in the 1990s

By the latter half of the 1980s, the success of the Irish product-oriented software houses together with the PC revolution started to change the Irish IT industry's landscape, and a growing number of software companies were founded around specific product ideas. Nevertheless, as the stories of the first few years of even the most successful Irish companies like Iona, Aldiscon (now Logica-Aldiscon), and Smartforce (formerly CBT and now part of Skillsoft) attested to, the industry's main problem remained the acute lack of capital.

An example for the difficulties of the indigenous companies in these years is the story of Glockenspiel. Glockenspiel is also important for the development of the Irish software industry for three reasons: first, it was the first globally successful Irish company that utilized the path common to the Israeli software industry – development and sales of software tools to developers. Moreover, Glockenspiel pioneered in Ireland a particular strategy for doing so: the quick implantation of the latest international standards of a particular software development technology, with the company becoming the first to the market offering a workable product based on these standards. This is the exact strategy executed later by Iona, Ireland software industry's flagship company, and

since then by many of Iona's spinouts. Second, Glockenspiel became famed for operating a high-technology firm in one of the roughest neighborhoods in Dublin's inner city. This, while irritating some, also gave the indigenous software industry in general and Glockenspiel in particular, some political goodwill. It later became an integral goal of the Irish state IT development schemes.²⁰⁵ Third, the story of the rise and fall of Glockenspiel portray the very ambivalent way in which the IDA was treating the indigenous industry. The IDA's treatment of the company when it faced crisis became a focal point for the growing resentment of the agency by the software industry.

John Carolan, an Irish software programmer with extensive knowledge and networks with research institutions and developers outside Ireland, founded Glockenspiel in 1984. At that time, Carolan became involved with the new technologies of object-oriented programming and the new C++ language standard. Glockenspiel utilized his knowledge of the C++ standard and became the first software company worldwide to develop a C++ compiler for the PC platform. In its first years Glockenspiel financed its product development mainly from C++ consulting.²⁰⁶

In 1988, the same year in which many major Irish IT companies succumbed to financial difficulties, Glockenspiel reached a point in which most of its revenues came from export sales of its products. Very quickly Glockenspiel taught the Irish software industry the lesson already well learned by the Israeli one: software development tools which are sold directly to engineers and developers need no localization and can be sold all over the world without costly modifications. Moreover, the customers for these

²⁰⁵ The latest of which is the project to create an R&D-based multi-media/digital hub/cluster in the Liberties (around the old Guinness Brewery) that brought MIT's Media-lab as its anchor tenant.

²⁰⁶ A compiler is a program that decodes instructions written in a specific programming language, such as C, Pascal, or Basic (also called higher order languages) and produces an assembly or machine language program that can then be executed by the computer.

products, being engineers and programmers, are more sophisticated than the average consumer; hence products that are too complex and crude in their user interface to be sold to the consumer market can still be sold to these highly skilled customers. Building on its C++ expertise, Glockenspiel started to offer a wider range of RAD tools for C++ development. The company's deep technical knowledge enabled it to develop award winning products and both IBM and Microsoft promoted their sales.

However, in Ireland, this technology-development-oriented business model was so different from any other Irish company ever to exist that it led both the IDA and the financial institutions to treat the company with suspicion and mistrust. In 1991, Glockenspiel achieved record sales and was the second top indigenous software exporter after CBT. In 1992, however, its American distributor went bankrupt. Almost immediately its bank in Ireland informed the company that it had to pay its overdraft facility in full and the IDA did not agree to extend any aid. Shortly thereafter Computer Associated bought Glockenspiel out of receivership and the IDA, in a move that further installed distrust within the indigenous industry, demanded that every grant the company ever received should be paid back in full (O'Riain 1999; Sterne 2004).

By the early 1990s, the software industry had notably grown and apart from being well organized, a growing number of product-oriented companies attained global success. For the first time, Irish software companies managed to successfully cross the Atlantic and thrive in the American market. Furthermore, the Irish software industry became much more technologically savvy. One of the most important factors in enabling this development had nothing to do with the Irish state, but a lot to do with the Irish university sector and the EU.

Starting in the end of the 1980s, and with growing importance in the 1990s, the Irish universities, in particular Trinity, started to participate in the EU research framework schemes. In a short period of time, Trinity's Computer Science Department became one of the largest recipients of ESPRIT grants for computer science in Europe. These grants enabled Trinity not only to expand its computer science research activities, but allowed several research group to form and then spinout as already established companies with working products and strong IP.²⁰⁷

The most important software company to rise out of these particular institutional settings was Iona. Iona had its origins in Trinity getting an approval to offer the first undergraduate computer science degree course in 1979. Trinity needed to expand its faculty very quickly and enrolled as lecturers many of its graduate students, among them both Chris Horn and Sean Baker. At the time there was very little money for research in Ireland. However, in 1980, one of the senior lecturers in the department, Neville Harris, came back from a sabbatical at Stanford bringing with him in his baggage four Sun Microsystems' processors and a 3mb per second Ethernet to establish the Distributed System Group (DSG). In 1983, the coming of the ESPRIT program suddenly changed the research landscape in the department. ESPRIT allowed for applicative research groups to apply for funding on a multiple year basis. In 1984 the DSG group, then consisting of four lecturers, managed to get their first multi-year project. This allowed the group to expand, and joined by Chris Horn, who came back from Brussels after being part of the EU team forming the ESPRIT program, the group quickly managed to get enough

²⁰⁷ The continuous important of ESPRIT and other EU framework programs to the research activities in Ireland is evident when one realize that as late as 1998 more than third of the research budget of Trinity's, at the time Ireland's university with the biggest research budget at €20.3, came from these programs (Grimes and Collins 2003).

funding to make it the biggest and richest computer science research group in Ireland. By 1985, the DSG group grew to encompass six lecturers and about 40 graduate students. At that time the group was already run almost as an independent financial entity, a unique and novel experience in the Irish higher education system.

In 1991, a group within the DSG led by Chris Horn, Sean Baker, and Annari O'Toole decided to open Iona, a campus company based around their knowledge of distributed systems.²⁰⁸ By that time, Horn and Baker were already active in a new international standard group, the Object Management Group (OMG). The founders saw a window of opportunity utilizing a strategy similar to Glockenspiel: being the first company to offer products that implant OMG's new middleware standard.²⁰⁹ However, in 1991, no one in Ireland was willing to invest in a company with such extensive R&D-based business plan. From 1991 to 1993, the company was financed from consulting revenues including the fees the founders earn for teaching C++ and system analysis, two ESPRIT projects, and some savings. This financial situation allowed Iona to start product development only in June 1992. By that time Iona also managed to get an IDA employment grant of £150,000IEP for which the IDA took a 7% stake of the company.²¹⁰

By June 1993, Iona became one of the first companies to offer a product implanting the new CORBA standard with C++ compatibility. This raised the interest of Sun Microsystems. In December Sun offered to invest \$600,000USD for 25% of the

²⁰⁸ Colin Newman was Iona's fourth founder.

²⁰⁹ The specific standard was ORB, which stands for Object Request Broker. ORB is the component in the heart of the Common Object Request Broker Architecture (CORBA) middleware standard. Middleware is the general name for software whose main task is to allow programs written and operated on different platforms to exchange information and work together.

²¹⁰ A former executive in Iona argued when interviewed that at that period in order for an indigenous company to be approved for the lower tax regime (automatically given to MNCs) the IDA needed to give its consent. The only way to get the IDA approval was to agree for a grant scheme in which the IDA took 7% stake in the company.

company. This offer from a leading MNC transformed the reputation of Iona in Ireland, transforming it from an untrustworthy R&D-based IT operation into a legitimate and promising company. It was here that the development agencies' misconception of the software industry proved to be a hurdle. The inward looking development agency, by then restructured as Forbrait, and Trinity, refused to be diluted by Sun's investment. Only when the founders threatened to close down the company did the two institutions back down and the IDA agreed to give a matching funding to Sun's to keep its stake from being diluted.²¹¹

Very quickly the new relationship with Sun, in a very similar way to Sun's alliance with the Israeli Checkpoint or to Amdoc's alliance with SBC, opened the doors of the US industry for Iona. By 1995, both Boeing and Motorola were using Iona's products and in February 1997 Iona became the second Irish company after CBT to go through an IPO on NASDAQ. Since by that time Sun had decided to sell its entire 25% stake in Iona, the IPO became the fifth largest software IPO on NASDAQ up to that point.²¹² The sums involved and the large publicity helped to transform the perception of the indigenous software industry both within and outside Ireland.²¹³ Software had become the jewel in the crown of S&T industrial policies in Ireland. This was especially true as EI's growing portfolio of Irish IT companies' stocks soon made it the most profitable

²¹¹ Financial resources for R&D in Ireland were so constrained even after the IDA approval, in 1994, for its second grant, Iona decided to hire a former graduate student of Horn and Baker's to a fulltime position of applying for ESPRIT funding.

²¹² Sun had two reasons for selling its stake: i) by that time Sun decided abandon the CORBA middleware standard and concentrated its efforts on its own self-developed Java technology; ii) Sun Microsystems preferred as a corporation not to hold large stakes and board directorship positions in other public companies in order to prevent the legal risks involved.

²¹³ Iona also had one other key influence. Led by former lecturers at Trinity the company was the first Irish company to hire entire cohorts of Irish computer science students to conduct R&D work in Ireland. In this Iona helped to transform the perception of Irish computer science students about what should, and can, be done in Ireland.

Irish venture capital organization. Nevertheless, as will be discussed below, the growing fixation of EI on profitable investments has by now become an obstacle to the industry's continuous growth.

The DSG group and Iona, also offered a development paradigm for the evolution of other research groups, many of them turned into commercial spin-offs in Trinity's computer science department. Some examples of these have been Wilde Technologies, another a spinout of the DSG group focusing on software design; Prediction Dynamics, which develops financial modeling software and was founded by Professor Padraig Cunningham and Dr John Carney, based on Carney's Ph.D.; and, Havok, which is the commercial reincarnation of the Graphic Users Group. In addition, EU programs and the incentives they supplied to organize the research into semi-independent applicative technology research groups gave rise to some of the relatively few successful Irish hardware companies in the late 1990s, such as Haptica and MV Technologies. As Trinity, even under the constraints of miniscule research budgets, has spun-off many other companies both before and after, including another two of the only six Irish software firms ever to go public on NASDAQ, Baltimore and Trintech, one wonders why in Ireland the universities' research effort are seen to have failed to positively effect the growth of the industry. This is especially remarkable as other universities, including UCD, DCU, and UCC, were also the breeding ground for many software companies throughout the years, if not to the same degree as Trinity.

Iona itself was also critical for the development of the industry, in its role being the educator as managers for a whole cohort of computer science students. These students joined the company before its IPO and passed through its rapid growth phase. Many of

them left the company after 1999 to establish their own companies. There are now over a dozen direct Iona spin-offs. In one of which, Cape Clear, not only did Iona invest, but also two of Iona's founders, Colin Newman and Annari O'Tolle, left Iona to join and manage it.²¹⁴

Accordingly by 1994-95, the time of the restructuring of the development agencies and the NSD initiative to develop a high-tech oriented VC industry, the landscape of the indigenous software industry was already transformed. Smartforce/CBT had become the first Irish software company to become public on NASDAQ, Iona secured major partnerships with Sun, Motorola, and Boeing, and by 1995 Aldiscon was the market leader in the new mobile phone technology of Short Text Messaging (SMS).²¹⁵ In short, by the time the industrial policy restructuring process had begun in 1994, the indigenous software industry was already established as the leading and most successful export-oriented sector in Ireland.²¹⁶

Many product-oriented firms had to support their R&D efforts by offering services and consulting, a fact that not only slowed their R&D efforts but limited their ability to develop large-scale, complex, R&D-based products. This situation started to change only after the reconstruction of Irish industrial policy and the refocusing of a more significant portion of that policy on the indigenous industry. The formal creation of Forbrait, the forerunner of Enterprise-Ireland, in 1994, increased state support for Irish-owned software companies.

²¹⁴ However, later the relationship between Cape Clear and Iona turned sour and Iona took Cape Clear to court in 2002 over hiring issues (Daly 2002).

²¹⁵ In 1996, Aldiscon was also the first company to secure major investment from the EI sponsored ICC software fund. In 1997, in the middle of an IPO process, Aldiscon was sold to Logica for £90 million in cash and is now the division that generates most of the revenues and profits for Logica-Aldiscon.

²¹⁶ At the time the software industry was the only successful indigenous sector in Irish history apart from agriculture and tourism.

In the hardware sector, however, there was no significant improvement. The two prominent hardware companies that became major exporters in the 1990s were Silicon and Software Systems (S3) and Parthus, both IC design houses. The circumstances involving their establishment were so unique that they made them the exception rather than the rule. In 1986, S3 was founded and has been managed since as an independent company by professor Maurice Whelan of Trinity. However, S3 was established as part of efforts to convince Philips to open a subsidiary in Ireland by Whelan, a former researcher of Philips electronics, and the IDA's. These efforts culminated in Philips agreeing to open S3 as a joint venture with Whelan where Philips owns 90% of its shares.

Parthus was established as Silicon Systems in 1993 when Brian Long, then the chief design engineer of Digital in Ireland, decided not to move with Digital to Scotland after the closure of Digital's operation in Galway. Instead, Long, with the help of the IDA, which also matched him with Peter McManamon, Parthus financial co-founder, established Parthus as part of the efforts to reconstruct the IT industry in Galway with the closure of Digital. However, what allowed the company to start operations and grow was a combination of financial backing and aid from Michael Pierce of Mentec, seed financing and stream of orders from STMicroelectronics, obtained through Long's industry contacts, and Long's and McManamon's savings. Only after securing these financial resources did Parthus obtained a matching grant from the then newly established EI. Parthus was started as a service IC design house, mainly for STMicroelectronics, which supplied Parthus with over 65% of revenues in its first three years. However, luckily for Parthus, the contract with STMicroelectronics stated that the IP developed was to be owned by Parthus.

In 1998, building on the already established reputation of the Irish software industry, Parthus changed its business model to an IP licensing, utilizing what has been one of the biggest investments by Goldman Sachs in an Irish IT company, \$16 million. In 2000, Parthus became the first and only Irish hardware company to be publicly listed on NASDAQ when it double listed on the London Stock Exchange and NASDAQ. In 2002 Parthus was bought by an Israeli company, DSP group, and was merged with DSP's own IP licensing division to be re-floated as Parthus-Ceva; in 2003 the name was changed to Ceva.

Thus, the stories of S3 and Philips, Parthus and STMicroelectronics, as well as the earlier relationship of Mentec and Digital, show that in the context of the Irish innovation system with its dearth of both capital and a semiconductors industrial eco-system, such as Taiwan's, only with a rare combination of long-term support of an MNC and the development agencies could a successful hardware NTBF grow. With the development agencies focused as they were on the indigenous software sector, treating the indigenous hardware sector only as a derivative of the MNC-focused policy, it is not surprising that stories of successful Irish hardware companies are few and far in between.

The venture-financing situation improved significantly after 1995. NSD, by then a part of EI, led an initiative to distribute EU-backed finance in an attempt to spur the establishment of high technology oriented venture capital funds. This effort, coupled with the proof for profits by the publicly listed companies and some high-profile M&As after 1995, culminated in a small but vibrant local VC industry. For the first time in the history

of the industry starting in 1999, local software entrepreneurs could reasonably expect to find enough investment capital to startup a product-oriented-only company.²¹⁷

The first government initiative to create a VC industry in Ireland was not at all aimed at the high-tech sector. In 1994, realizing that financial institutions in Ireland were overly conservative, unwilling to grant working and growing capital to new enterprises in any industry, the government, using a policy of veiled threats, persuaded the big pension funds to make available up to £100IEP million, to venture capital very broadly defined.²¹⁸ Using this finance, three VC funds were established: Delta, Act, and ICC. The three invested most of the funds in later-stage development of businesses, mostly in traditional companies, and not in IT.

In 1995, the NSD initiated the first attempt to spur a high-technology oriented VC industry. The NSD VC initiative, using EU money from the Operational Program for Industrial Development 1994-1999, distributed €43.9 million to establish 16 funds under a scheme in which half of each fund's finance was granted by the state and the other half was raised in the private market.²¹⁹ The state position in all these funds was that of a regular general partner. This created the ironic situation in which in Ireland, where, unlike Taiwan and Israel, the state specifically chose policy vehicles with the aim of limiting its direct intervention in the market, representatives of EI, often the same people, sit on the boards of the VC funds, the boards of companies in which EI invest, and EI investment committees that decide in which companies to invest.

²¹⁷ Good statistics are lacking but using multiple resources we can ascertain that starting in 1999 a major upgrade of the Irish VC funds occurred. About €700 million were raised by Irish IT oriented VCs in 2000-2001, with actual investment in IT of €62 million in 1999 and €162 million in 2000. Sources: M.O.P 2000; PriceWaterhouseCoopers 2000, and the Irish Venture Capital funds' websites.

²¹⁸ Unlike the US, in Europe almost any capital involved in the growing or the restructuring of a business falls under the rubric of venture capital. In effect the European use of term VC is very similar to the American definition of private-equity firms.

²¹⁹ In the end only 15 funds actually started operations.

The Irish state, much like the Taiwanese, saw VC as a missing pool of finance, and not as a separate industry with specific capabilities to be developed. Hence, while one of the declared aims of the policy, similarly to Israel's, was to enlarge not only the pool of finance but also the pool of financiers, the state opted to cooperate with local investors, who lacked specialized high-technology VC knowledge and background, and not with foreign VC-skilled institutions.²²⁰ The first fund to be established was the ICC software fund I. ICC fund I started operation in 1996, and Maurice McHenry, an old NSD and EDP hand, relocated from the NSD to become the fund's manager. Aside from one large and recent VC fund (Cross Atlantic) and a few semi-institutionalized funds of successful entrepreneurs (Mentor, Oyster, and Island are the prominent ones), all the VC funds operating in Ireland were created as part of the NSD initiative.

In 2002, Enterprise-Ireland announced another VC initiative, this time more regionally and sectorally-oriented and fully funded by the Irish government. Under this new initiative the Irish government distributes €95 million to ten funds, most of which are the new funds of the same management companies of the first initiative, with the hope of stimulating the commitment of a total of €500 million to these funds' management.²²¹ It is the ironic result of the inherent conflicts of Ireland's neo-liberal interventionist ideology, that the state's attempts not to interfere with the market's price-setting mechanisms ended with Ireland, the only nation out our three cases to fully subscribe to free-market principles, becoming the one case where the state is not only the biggest VC in itself, owning shares in all of Ireland's promising IT companies, but also the biggest

²²⁰ On the distinction between the two VC industry creation policy types, see Avnimelech and Teubal 2003a.

²²¹ Interview with Denis Marnane 3/7/2002. For more information on the distribution of the first EI VC initiative, see EI 2000.

investor in the VC industry. Accordingly the state also has a claim to a large stake of the VC industry's investments and a significant role in shaping its decision-making.

The VC initiatives of the Irish government through Enterprise-Ireland and the NSD bore some fruit. Starting in 1999, Irish entrepreneurs could reasonably expect to be able to raise enough capital to enable them to start NTBFs focusing solely on new product development. However, as of 2004, especially in comparison to Israel, the Irish VC industry is smaller, less professional, and still intimately linked to established Irish financial institutions. If in Israel, many of the VCs are former technological entrepreneurs, in Ireland most of the VCs are former accountants and management consultants. Moreover, the Irish VC industry is less internationally connected than the Israeli one, with the sources of its financing and its connections concentrated in Ireland and Europe. Thus, especially in the software industry where the US is the main market, the VC industry in Ireland is still lacking.

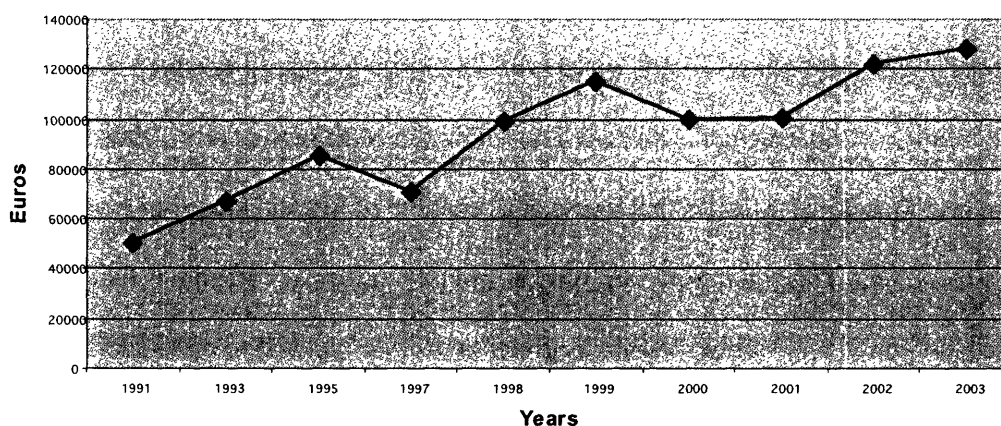
On the other hand, it might be that some of these features, principally the close connection with local institutional investors, and the fact that Ireland possesses very developed institutional pension funds, made it very attractive to Irish firms to double-list on both the NASDAQ and the Dublin (or another European) Stock Exchanges. This double-listing option is one that all the Irish IT companies listed on NASDAQ followed, and it probably diminishes the need to transfer more and more activities to the US.²²² The greatest concerns regarding the Irish VC industry today are: i) its ultra-conservatism and lack of will to invest in seed stage companies; and ii) its continuous reliance on the state for both its investment decision making and financing.

²²² In 2001, Israel had acknowledged that problem and changed some of its regulations to make it easier and more attractive to Israeli firms to double-list. However, it remains to be seen how widespread will be the effects of those measures.

In the late 1990s the Irish software industry enjoyed its greatest success so far. Six software companies, CBT/Smartforce, Iona, Trintech, Baltimore, Datalex, and Riverdeep listed on NASDAQ. Together with a few large-scale M&As, these high-profiled success stories helped to change the perception of the industry both within and outside Ireland. In 1998-2001, the new generation of NTBFs also enjoyed, the advent of the VC industry and could raise enough financing to utilize product-R&D focused business models. In addition, many established companies, such as SoftCo or Fineos, transformed their business model into a product-based one, often using VC financing to accomplish it.

However, as can be seen from Graph I, the average sales per employee in the Irish indigenous sector, while vastly improving from a low of \$45,000 in 1991, is still only 40% of the average of the Israeli IT industry. This seems to imply two points: first, from an optimistic perspective, there is still a lot of room for improvement; second a larger percentage of the Irish industry is still focused on the less profitable activities of service, consulting, and bespoke development.

Graph I - Sales per Employee: Indigenous Software Sector



Source: (NID 2005)

Enterprise-Ireland has also been intensifying its own grant giving mechanism.

Since 1994, Enterprise-Ireland has directly given companies an annual average of £16 million Irish.

Table I – EI Support and Profits all sectors 1998-2004

Year	Capability Building	Equity and VC Funds	Funds Gained by EI from Equity
1998	€ 58 m**	€ 14 m**	€ 14.3 m**
1999	€ 68 m**	€ 33 m**	€ 12 m**
2000	€ 65 m**	€ 38 m**	€ 49.56 m**
2001	€ 51 m**	€ 72 m**	€ 101.58 m**
2002	€ 31 m**	€ 38 m**	€ 34.3 m**
2003	€ 26 m**	€ 38 m**	€ 14.6 m**

Source: EI annual reports.

Notes: Capability Building is defined as an investment in R&D, training and new market development, thus it includes, but not solely consist off, R&D grants. Equity and VC Funds are financing channeled to the private VC industry. Unlike Israel, funds gained by EI are delivered to the exchequer and are not channeled back into the industry.

However, the grant-giving mechanisms of Enterprise-Ireland highlight the different underlying objectives of the Israeli and Irish industrial policies, and intensify the main obstacle that still exists for many Irish entrepreneurs – the acute lack of very early and early stage financing for NTBFs. EI financial aid packages for new companies consist of both a hodgepodge of grants, some of which are the remnants of older grant schemes mixed with some new ones, and equity-based investment. In order for companies to get special tax benefits and qualify for R&D grants, EI needs to approve them as “fast-growing start-ups,” an idea devised by the NSD in the early 1990s. Fast growing start-ups are companies that are seen as capable of reaching sales of €2 million within a few years. There are, however, only a limited number of companies that can be approved, and only very limited resources given to the NSD and EI to conduct the necessary analyses. Hence, a bottleneck develops specifically in this critical development stage where the firms are in their most dire need for state-aid.

This situation is further complicated by the equity-base of the EI grant giving mechanisms. EI, in one of the most paradoxical twists of the Irish neo-liberal-interventionist ideology, claims on the one hand that the state can and should take large stakes in private companies. However, adhering to neo-liberal principles on the other hand, EI wishes to avoid a situation in which a government agency determines the market capitalization evaluation of a private company. This creates a situation in which the firms seeking EI aid must find private market investors that would resolve the evaluation process. Only then would EI join the investment round on the same valuation basis. Many investors, though, agree to invest only in companies that have already received EI's seal of approval. This seeming "Catch 22" situation is even more complex when we realize that EI is also the single largest financier of the Irish VC industry itself. Hence, in many cases, EI actions make the Irish VC industry even more conservative in its investment decisions than what it is already.

This process, in effect, makes it impossible for most early stage IT start-ups to get sufficient financial aid from the state. As early stage investment is riskiest with the uncertainty being the highest, EI investments do almost nothing to solve the most intense market failure inherent in new technology development. In addition, it can be argued that EI financial aid packages, as they are organized now, help more in lowering the risk for the VCs than they help NTBFs to secure larger amounts of capital than they could without this venue.²²³ These shortcomings are readily admitted by EI. Accordingly, EI's then CEO Dan Flinters mused: "I agree with some of what you say, especially with the fact that we are still lacking a good mechanism to finance seed and early stage

²²³ As EI finance is conditional on VC funds' agreement to invest, and as Irish VC funds usually make their investment conditional on the NTBF securing EI financing, EI packages are in a sense complementary finance, which otherwise the VC fund would need to supplement.

companies, on which we are working, but considering our goals and resources I think we have the best working scheme” (Interview with Dan Flinter, 2/5/2002).

Indeed, considering that the goal of EI is not to generate the maximum amount of R&D but to maximize the number of successful indigenous businesses that supply the highest number of jobs for the lowest cost to the taxpayer, EI mechanisms are sufficiently well suited. Nevertheless, the continuous crisis of the industry since 2001, and the fact that there have been almost no seed investments by Irish VC companies since then, raise the question of whether EI policies and grants answer the needs of the indigenous industry, or whether they have in fact become an obstacle to its growth. This sentiment was voiced not only by many companies but also by former EI executives. One can indeed defend the Irish record by arguing that since 2001 there has been a global crisis of the IT industry in general and VC financing in particular. Nevertheless, this does not explain why does Ireland fare so much worse than either Israel or Taiwan, especially as Ireland has just culminated a major policy effort, including VC creation, whose main aim was specifically to set in motion more NTBFs formation, not less.

For example, a founder of a very successful company in the 1980s reflects on EI’s changing policies:

“When we opened our first company, EI, then the IDA, was crucial. They also proved very very helpful throughout the years and early 1990s. Now they just become too conservative. They are no longer that helpful, especially to new young firms” (4/18/2001).

A few founders of younger start-ups concurred:

“In the past EI were very helpful to young companies. Now, after they suddenly made money, the only thing they do is to play ‘king of the lake’ games. Meaning that if you are already very successful EI will come and grant you both money and help. When you actually need them, though, they just ignore you.”

“The part of EI that deals with helping you to set offices and meetings abroad is superb, not so within Ireland. In the beginning we were desperately looking to get grants from them and they turned us down. Now after our success and after getting some VC money they <EI> are running after us trying to convince us to take their money. They think they missed our boat and that they could have made money on us... I really wonder if EI is at all capable of making decision to invest in truly innovative, hence, risky, new IT companies.”

“For two months I was trying to get money from EI, and then I finally understand that this is a waste of money and time to go to EI. To get good money <large grants> from EI you must already have a good VC deal in your packet.”

“The funny thing is that I found out that EI is much more aggressive than the VCs themselves asking for big chunk out of companies. This, and they are so utterly slow and bureaucratic. I truly do not understand why they do it, because on the other hand they are the nicest and friendliest people I ever met. I think that the real problem is that they become omnipotent, you now must have EI approval in order to get anything in Ireland and they are talking with you under so many hats that sometimes I wonder if the person in front of me knew which role he is supposed to be playing now” (interviews with company founders 1/7/2001; 3/13/2001; 3/20/2001; 4/20/2001).

Lastly one of the IDA’s former executive who took part in planning the equity-based grant giving mechanisms argued for a radical change of EU grant-giving mechanisms:

“At the time it is was a good idea, we had two problems we needed to deal with. First, there was political pressure after politicians became concerned when, on one hand, many software companies who got grants went bankrupt, and, on the other hand, a few were sold to MNCs with the founders making a large profit. The second was the need of technology companies that do R&D to get a large quantity of capital upfront, which we could not do with employment grants, especially as new software start-ups just do not create that many jobs. Thus, equity-based grants seemed like an ideal solution for both and could be worked within existing regulations. I also must say that in the beginning, when we did not make any profit, it worked like a charm. The problems started when EI holdings in a few companies were suddenly worth millions. The more EI turned into the most successful VC organization in Ireland, the more profits become a yardstick, with the result that investment decisions are becoming more and more conservative and profit-oriented. EI is now so obsessed about making money and does not care enough about the overarching goal that the state should have – the development and growth of the industry” (interview 3/10/2001).

However, the most telling example of the acute lack of true seed capital might be the political battle the ISA led to prevent the cancellation of the Business Expansion Scheme (BES) and the Seed Capital Scheme (SCS). BES and SCS are tax schemes under

which a group of private investors pool capital of up to the amount of €250,000 to invest in exchange for stocks in a specific enterprise under special tax discount procedures. The two, in particular the older BES, have been a crucial source of capital for all newly established enterprises, especially IT NTBFs. Almost all of the Irish IT companies have used the BES as their main, and sometime sole, source of seed financing.

The two schemes were supposed to phase out in the end of 2003. The Ministry of Finance argued that the with Irish technology-oriented VC industry having the largest ever amount of capital under management, and with EI help, the two schemes, which need a special approval from the EU competition commission, should be scraped. However, with the Irish VC industry and EI in effect reaching a deadlock over seed investment, the importance of the two schemes to the industry rose even more after 2000. In the end after extensive lobbying by the ISA the two schemes were prolonged until 2006 and their maximum amount was raised to €1 million. It is symbolic of the current missteps and misunderstandings of the Irish state-industry co-evolution processes that the chairman of the ISA, Cathal Friel, who has also been a top manager the Irish VC and corporate finance industry, described the schemes as the only source of funding available for start-ups in the software sector, apart from EI aid (O'Halloran 2003; Smyth 2004a; Taylor 2003).

Hence, it seems that even with all the new initiatives and the greater amount of finance designated for investment in the IT sector, the actual situation of the Irish IT industry in 2004 is not that much different than that of the Irish IT industry in the beginning of the 1990s. This, again, hurts the IT hardware industry more than it hurt the software industry. The main reason for this disadvantage is that hardware product R&D

phase is both longer and more expensive; therefore the risk associated with hardware R&D is higher. The reaction of two leading VCs and hardware entrepreneurs to questions about the lack of investment in the hardware sector are revealing:

“It is obvious why there are almost no new hardware companies. The risks are a lot higher than in the software sector, so we prefer not to invest in them.”

“There are no hardware followers to us because there is no money, you need a lot more money in hardware than in software and when there is almost no money period, then software companies, which can also generate revenues through consultancy and bespoke development, will be the only ones that survive.”

“Hardware investment is just too risky for Irish VCs, the development phase is long with no revenues, the costs are an order of magnitude higher than software, this is just too risky. Even in software we dislike investing in companies with no source of revenues. You want to know what was the best VC investment of the year in my opinion? It was this lovely company, three ex-Iona founders, they already generated €3 million in consultancy fees, and now they talk about a product. They do not really know what the product is going to be, just that it is going to be in middleware in the mobile domain. You see? Three trusted veterans, a constant stream of revenue, and low risk that they will go belly-up. These are the kind of investments we like to take part in, not some haphazard idea for some hardware product development” (interviews 6/10/2003, 2/5/2004, 2/4/2002).

This crisis in new company formation coincides directly with the culmination of the most extensive initiative to expand the Irish technology VC industry. Moreover, it also coincides with the most extensive efforts ever to create significant academic R&D activities, with the aim of fostering the continuous growth of the IT industry in Ireland. In sum, it seems as if the co-evolutionary process of state-industry relation in Ireland is now out of step. With EI’s centrality in each and every point of the system and with its new zeal for profit-generating investment, one must wonder if the future development of the indigenous software industry in Ireland is now in danger of suffering from a stage II

failure – the inability of the state to relinquish its own power over the sectoral industrial system.²²⁴

The crisis in the formation of new firms is not the only crisis the Irish indigenous software industry is facing. Internal reports done by the ISA strategic vision group in late 2003 showed that only 24 of the total of 700 Irish software companies reached the very low barrier of €2 million in annual sales. These findings suggest that even established software firms find it very difficult to expand their activities under the current conditions. Moreover, less than 30% of surveyed companies in 2004 were even willing to look for VC funding; this is a sharp decrease and another indicator of the growing mistrust between industry, investors, and the state agencies (ISA 2003; ISA 2004; McManus 2002).

The one sector of the Irish IT industry to which this crisis is irrelevant is the MNC sector. MNCs not only extended their R&D activities in Ireland by buying Irish IT firms for their technologies, but also, in the last five years, moved to open their own in-house R&D operations. Both Intel and IBM announced the opening of new R&D facilities, and the MNCs' participation in the new Science Foundation Ireland schemes is growing, compared to the almost insignificant participation of the local software industry.

Accordingly, it seems as if without some changes in policy the end result of the new S&T industrial policy initiatives, aimed at least partly to diminish Ireland's over-

²²⁴ One measure of the new passion for profits and EI self-congratulatory mode, which is in part created by the adherence to the neo-liberal interventionist ideology, is the farewell interview, Dan Flinter, EI's first CEO gave the Irish times before his departure in September 2003. Flinter was quick to point out that Enterprise Ireland realized about €250 million in the 1999-2003 while investing "a sinfully small amount!" Flinter also forcefully defended the status-qua, arguing that EI activities are getting the balance exactly right (O'Keefe 2003).

reliance on the MNC sector might end up by increasing it (ISA 2004; IT 2003a; IT 2003b; Lillington 2003a; Lillington 2003b; Smyth 2004b).

Conclusion

This chapter analyzed the development of the IT industry and the co-evolution of state-industry relations in Ireland. In particular, it inquired into the different ways in which the state acquired its technological and scientific skills, the industry's evolution, and the interdependencies between state policies and the industrial development. The chapter evaluated policy vehicles as well as the amount of control the state attempted to have over the IT industry's technological development path. Furthermore, it analyzed the role of the state in fashioning the indigenous industry's relationships with the global markets.

Since the 1950s, the Irish state developed its economic and industrial policies adhering to the inherently conflicting ideology of neo-liberal interventionism. This ideology let Irish policy makers to devise and implement economic policy on the basis of two opposing ideals, a neo-liberal free market principle and the opposing strong interventionist ideal granting the state massive scope to construct, structure, and restructure the Irish society for the common good. The main goal around which this ideology, and consequently all Irish industrial policy, crystallized was job creation. With the severe economic crisis and vast immigration bringing the leaders of Ireland to fear for its survival as an independent state, job creation became the highest national objective and the people and organizations that were designated to achieve it were granted immense power and influence.

The strong focus on job creation led the IDA, the industrial development agency responsible, to develop an MNC policy orientation, a successful application of which brought an almost constant stream of MNCs to open manufacturing facilities in Ireland. Each such opening, created, as if by magic, a specific and usually large number of jobs. The focus on MNCs and manufacturing also allowed for the utilization and growth of employment-tied grants to become the main legitimate mechanism with which direct financial aid was channeled to private companies.

Hence, the Irish IT industry developed within a very different system than that of either Israel or Taiwan. Unlike both, the development of an indigenous IT industry was not for many years the goal of the state. Moreover, the Irish bureaucracy, structured as it is in the English flavor of Weberian ideals, was not deeply infused with scientific and technological skills as the Israeli and Taiwanese. Moreover, none of Ireland's leading politicians were engineers or scientists, nor did any of them attach any value to science and technology as such. In fact, in the political context of job creation the local IT industry was actually viewed with suspicion for many years.

The skills and policies that were developed were designed mainly around the core goal of MNC-bringing industrial policies, and the realization that in order to continuously bring and retain them Ireland needs to develop a highly skilled and technologically savvy labor force. It is in the context of this industrial and innovation system that we can now understand the specific development path of the Irish IT industry. The Irish software industry's orientation toward the development of products of mid-sophistication, developed in environment were not only were these the solutions that its main customers needed, but also what the severe financial constraints allowed Irish software firms to

develop. This is no more apparent than in the rise of the first globally successful Irish software companies around the new mini-computer technology. This was a technology in which Ireland, with its concentration of MNCs manufacturing subsidiaries, became a global center of using.

However, it is precisely because of those particular circumstances that the effect of the IDA's and later EI's initiatives were so immense. Not only were the EDP's grants many times the sole source of financing, but also the fact that the powerful IDA was willing to invest in these companies granted them a much needed legitimacy, both commercially and financially, and at least as importantly socially. Nevertheless, while the indigenous software sector became the main recipient of the new policy initiatives, the hardware sector was left behind and still remains mostly unattended. The changes in policies together with the economic crisis of the 1980s and the growing success of the software industry focused Ireland's industrial policies toward two new pillars: internationally tradable-services and Irish-owned enterprises. The S&T industrial policies developed in this context again made software the main beneficiary of these changes. This was especially so with the NSD, staffed with veterans of the software industry, becoming the main IT policy unit within the IDA and EI throughout the 1990s.

Toward the end of the 1990s, with the efforts of EI and the establishment of SFI and PRLTI, coupled with the successful state actions to create and grow a local, and locally financed and managed, technologically-oriented VC industry, it seems as if the Irish IT industrial innovation system has been finally transformed. However, the particular way in which this system evolved and the devotion of the Irish developmental agencies to the two contradictory ideals of the neo-liberal interventionist ideology still

prevent the indigenous industry from enjoying most, if not all, of these newfound riches. With their resources and knowledge and their new interest in moving more R&D activities to Ireland, the MNCs are much better poised to utilize the growing academic R&D infrastructure in Ireland. Already American MNCs are by far the largest patent issuers in Ireland, and with the inability of the indigenous industry to successfully grow firms, it is extremely vulnerable vis-à-vis the MNCs in two fronts. Hence, without extensive changes in the indigenous-focused science and technology industrial policy, the new move of Ireland into high level R&D, hailed as a way for Ireland to become less dependent on FDI, would end up making the Irish economy even more dominated by MNCs than before.

EI central position in all nodes of the IT industrial development networks is now doing more to inhibit the continuous growth of the Irish IT industry than to aid it. With EI representatives involved in each and every major decision of an NTBF life: its seed and feasibility venturing, its designation as a “high-growth potential,” the VC financing rounds, the composition of its board of directors, and many of the times the establishment of its first international offices, EI is significantly more important to the industry than it ever was before. Moreover, since EI is the largest single investor and shareholder in the Irish IT industry, both directly and as the chief investor in the Irish VC industry, the agency now wields immense power over the future and present development of both the Irish IT and VC industries. This situation rises two questions: i) is it advisable for the state to wield these powers in such an advanced growth stage of a RIB industry? And, ii) does EI specifically uses these powers wisely and in accordance with the proper yardsticks. Our analysis suggest that the answer to these two question is no.

In short, the growth story of the Irish indigenous IT industry and the particular mode of its development, side by side with Ireland's growth as a site for IT MNCs manufacturing and logistics center, shows the utility of our theoretical framework. Helping us to analyze the development of rapid-innovation-based industry in Ireland, our framework pointed us to key areas of inquiry, and assisted us in understanding them. Our analysis enabled us to inquire into both the considerable strengths and the weaknesses of the Irish IT industry. Ireland is now well into becoming not only an MNC-led powerhouse, but also an innovative indigenous IT industry powerhouse. However, it is still an open question whether the Irish state can amend its neo-liberal interventionist ideology, a doctrinal anchor that served it so well, to accommodate for the building of the risk-taking, privately managed, financial and services infrastructure this industry is yearning for.

Conclusion – Comparing Choices and Consequences in Rapid Innovation-Based Industrialization

Choice: *The act or opportunity of choosing; suggests the opportunity or privilege of choosing freely*

Consequence: *Something produced by a cause; as a result*

Merriam-Webster's Dictionary 11th edition

Introduction

This dissertation has been motivated by two puzzles. First, what is the role of the state in the development of RIB industries in less developed economies, under the conditions of intensified globalization and fragmented production? Second, does the fact that the IT industry's very different development paths, in particular in Israel, Ireland, and Taiwan, suggest that multiple developmental choices are available to emerging economies?

The dissertation shows that emerging economies do have the ability to craft and select different paths in nurturing the growth of successful RIB industries. In my case studies I elaborated on how diverse S&T industrial policies distinctly shaped the development of each IT industry. In so doing, this dissertation dispels theories that solely attribute the explanatory power to either the timing of industrialization or to specific states' structures. The stories of Israel, Ireland, and Taiwan suggest that four factors are crucial in order for a state to spur RIB industrial development.

First, the state needs to actively engage with industry to solve the fundamental market failure in industrial R&D. Otherwise, the inherent characteristics of industrial R&D, its indivisibility, inappropriability, and high uncertainties, all of which are accentuated in the case of emerging economies with their lack of technological capabilities and finance, would lead private investors to allocate sub-optimal amounts of resources to research.

Second, state action is also of crucial importance because the innovation process itself is an inherently collective endeavor. As such, innovation is iterative and cooperative in nature; therefore, there is a significant role for public actors in facilitating, enhancing, and maintaining innovative activities.

Third, the state must actively link the local industry with global markets, both production networks and financial markets.

Lastly, in each specific industrial sector, the state and industry need to be able to manage constant change. State actions and policies that prove successful in early stages of the industry's development might prove harmful in later stages. Specifically, the development agencies need to be able to manage the political reality of their own diminishing importance as the industry grows.

The theoretical framework presented in the first chapter offers a specific understanding of the different consequences and final outcomes of the diverse choices taken by Israel, Ireland, and Taiwan. First, our theory argues that specific industrial R&D, dynamic economic capabilities, and business models are more suitable for certain stages of the production process. Secondly, the analysis of the dynamics of production stage specialization and economies of scale and scope indicates that industrial systems specializing in specific stages of production tend, if successful, with time and effort, to become ever more competitive and innovative in these specific stages. Consequently, to understand the different evolutionary processes of RIB industrial growth we must: (a) comprehend how industrial R&D and dynamic economic capabilities are created, improved, and maintained in each of our cases; (b) follow the growing utilization of certain business models in each of our cases; and (c) understand the development of

specific relationships that the local industry has with the global industrial and financial markets.

In short, our framework motivated us to a specific analysis of how different behavior and structure of the state influences the development of the IT industry's R&D capabilities in each of our cases, by looking at a few critical domains. The first domain is state decisions on necessary R&D skill acquirement. The second domain is state decisions on the degree of control it attempts to have on the technological development path of the industry, including decisions of how, and whom, to finance. These decisions affect both the R&D resources available to the industry and the scope of R&D activities. The third domain is, state efforts to build the early local leading companies, and state decisions concerning the involvement of foreign firms and investors within its national borders, as well as decisions concerning whether to enhance specific relationships between local and foreign companies outside the state's national borders. These decisions, shape the resources, the particular feedback and information the industry gets from its main customers, as well as the diffusion and development of specific innovative capabilities.

We anticipated that private firms in the high technology industry of emerging economies would have more limited R&D capabilities if the state tried to control the industrial R&D development path, encompassed the R&D conducting agents within its structure, supplied only limited resources, refrained from urging foreign companies to conduct R&D activities within its borders, and limited the involvement of foreigners as financiers. Throughout the three empirical chapters, this framework proved to be effective in enabling us to comprehend how the particular choices of the three states led

to the specific industrial outcomes in each case. Moreover, unlike other theoretical frameworks, our framework proved helpful in understanding not only successes and failures, but also the specific strengths and weaknesses of each industry. In short, the theory helps not only in explaining results in the aggregate level but also in comprehending the true nuances and consequences of the choices made and the actions taken. Accordingly, by showing the plurality of actions and choices that emerging economies have in order to develop their RIB industries, and by analyzing their particular consequences, both positive and negative, this dissertation emphasizes the importance of politics – the process of crafting, debating, deciding, and acting on different alternatives.

This concluding chapter takes a more comparative approach to this last point and shows how political debates, on both the national and sectoral levels, influenced key decisions about the critical variables of our framework. This chapter presents detailed comparisons on three issues: R&D market failures, MNCs, and venture financing. Together, these examples not only strengthen our arguments on how we should reformulate our thinking on RIB industrial development, but also strengthen our arguments on the role of politics at both the national and sectoral levels in defining the very diverse economic growth paths emerging economies can, and should, follow.

Dealing with the “King Kongs” – The Politics of MNC-focused Policies

One of the critical factors in understanding the diverse development paths of the IT industries in Israel, Ireland, and Taiwan is the different ways in which the state has linked the local industry with the global industry. Nowhere are these differences more apparent than in the diverse policies that the three countries employed with regard to MNCs. This is also a crucial political choice as decisions with regard to MNCs are: i)

decisions about the nationality of the ownership of local production, and hence, decisions about the level of dependency on the international system and markets that the local economy is willing to sustain; and ii) decisions that intimately attest to the national perception of the local industry's current and potential capabilities as well as status. Therefore, various policies followed by the three countries reflect the diversity of their national identities as well as their perception of the world system.

Looking at the political context in which these policies developed, we find that, in 1950, Ireland was a country brought to the brink of poverty by two decades of extreme nationalistic-autarkic industrial and economic policy, aimed at severing its dependence on the UK. In this political situation, job creation became the national mission and a significant social backlash spread against the ideals of national economic independence and industrial isolation. Consequently, local industry was thoroughly discredited and its capabilities and motives were suspect. The fact that the IDA's MNC-focused policies were quickly perceived as effective in large-scale job creation, while the local industry continued its downward spiral, strengthened this political atmosphere. Only by understanding the socio-political context in which Ireland's first industrial policies evolved, can we understand why, until very recently, the main aim of Irish S&T and industrial policies was to maximize inward FDI and bring more MNCs to open labor-intensive manufacturing facilities in Ireland, and why the local industry, specifically the IT industry, was treated indifferently and its leaders regarded with doubt.

On the other hand, we have Taiwan, a state that, while much more willing to create dependencies on international markets than its neighbors in North Asia, Japan and South Korea, was much keener to see the nationality of the ownership of a significant

percentage of the Taiwanese industry stay Taiwanese (Fuller 2002). Taiwan, in the context of its growing political isolation, was actively trying to link its local industry as a strategic supplier and partner to the world's leading MNCs. However, to accomplish this vision, Taiwan still needed to create a critical mass of local industry, specifically locally owned, in the context of a political system distrusting the concentration of power in big multidivisional conglomerates, and within a financial system designed to prevent the use of large-scale long-term debt. Only by taking account of these political constraints and wishes, can we understand why the Taiwanese state at the same time tried to lure MNCs into Taiwan, employing tactics similar to Ireland's, and pressure these MNCs to source a significant percentage of their components locally as well as to transfer to Taiwanese companies the necessary know-how to manufacture them.

Lastly, Israel conceptualized its economic future not in terms of job creation, but in terms of the creation of a "science-based" industry. Hence, the policy goal was to maximize a certain set of activities and to build an industry whose main activities in Israel would be the creation and development of new products and technologies. Moreover, in the political context in which Israel has operated since 1967, with the Arab embargo, cooperation with MNCs was perceived as a significant international achievement, especially convincing these MNCs to locate activities of strategic importance in Israel. This is especially true since the vision of a "science-based" industry, unlike the Taiwanese industrial vision, does not inherently necessitate national ownership of the organization conducting these activities.

Looking at the behavior of American IT MNCs in the three preceding chapters, we saw that these diverse national policies translated into marked differences in the ways

in which MNCs linked with the Israeli, Irish, and Taiwanese industries, as well as in the activities the MNCs located in the three countries. In contrast to the way American IT MNCs have been operating in Ireland and Taiwan, In Israel many, if not all, of the MNCs first activity was to open R&D centers, or to buy Israeli NTBFs and transform them into R&D centers, moving only later, if at all, to manufacturing activities. These diverse MNC behaviors translated into the different outputs MNCs supplied to the local industrial system, and the different inputs they sourced from it. Accordingly, these differences translated to different incentives for capabilities development as well as different resources and opportunities available in pursuing them for the local IT industry.

Two examples of the different paths pursued by two leading MNCs, Intel and 3Com, in Israel and Ireland serve as a way to highlight these differences and their impact. In 1974, Dov Frohman, a senior Israeli researcher in Intel's California headquarters, decided to return to Israel and accept a professorship in the School for Applied Physics at the Hebrew University of Jerusalem.²²⁵ As Intel wanted to retain the services of Frohman, the company agreed to open its first design and development center outside the US in Israel, with five employees.²²⁶ In doing so, Intel pioneered a mode by which many MNCs started operations in Israel.²²⁷ Over the years, the Intel center was highly successful and continuously enlarged its R&D activities. By 2002, it encompassed seven centers. In 1985, Intel Israel also pioneered the first movement of Intel toward silicon chip

²²⁵ In 1971, shortly after joining Intel in 1969 and after the first 1kbit DRAM was released, Dov Frohman invented the UVEPROM, an electrically programmable memory that holds the programmed values until erased by intense ultraviolet light. Frohman invented, developed, designed, and fabricated the first UVEPROM.

²²⁶ One must note, though, that opening a small SC design center is not as capital-intensive a high-risk decision as is opening a fabrication facility; total investment in the Israeli center was \$300,000 (1974 terms).

²²⁷ Over the years, Israeli senior R&D managers in other American MNCs have followed this pattern and returned to Israel to open R&D operations for their MNCs. National Semi-Conductors and KLA are two prominent examples.

fabrication activities outside the US when the first Intel fab in Israel started operations in Jerusalem. In 1999, Intel started the operation of its second fab in Israel. In 2000, following the acquisition by Intel of two companies with major R&D centers in Israel, DSPC and Dialogic Israel, Intel's R&D activities evolved into two more product platforms. Beyond these, the activities in Israel of Intel Capital, Intel's venture capital arm, are the most comprehensive in terms of investment outside the US. During 2002-03, Intel Capital was the most active foreign investor in Israel.

Throughout the years, Intel Israel R&D has been responsible for some critical components in Intel's global strategy, including the 8088 (IBM's famous pick as a CPU for its first PC) and the Pentium MMX technology. In 2000, Intel Israel had revenues of \$2USD billion and employed 4,000 people; as of 2002, Intel Israel was responsible for the development of the next generation's laptop-oriented CPUs, 3G mobile network products, and a few other critical components of Intel's global R&D strategy, such as the development of the latest technologies for optoelectronic chips' manufacturing.

In 1989, Intel decided to start manufacturing operations in Ireland. The main reason behind Intel's decision to locate in Ireland was the company's fear of an imminent creation of "Fortress Europe" by the EC (now EU) in 1992. A year after the first box assembly operation began, Intel decided to open a full-scale fab, making Ireland the only other place apart from Israel with an Intel fab at the time. Within a few years, Intel realized that "Fortress Europe" was not an imminent danger and the box assembly line was closed. However, fabrication activities continued. Moreover, local management, spurred by the shock of the closure and helped by an Israeli who became the fab developer and manager, and using his experience in Israel started low-profile R&D

activities aimed at the creation of a center of excellence in specific technologies in Ireland. Intel Ireland also managed to lobby Intel HQ to create a special position for Intel Capital in Ireland, which started operations in 2001 and has already invested in a few local start-ups.²²⁸

3Com's involvement in Israel enlightens the second and newer route used by MNCs' starting operation in Israel. In 1994, 3Com bought NiceCom, an Israeli company that developed local area network ATM switches.²²⁹ NiceCom was then transformed into the NiceCom division inside 3Com, responsible for the development of all ATM technology in 3Com, which enlarged its Israeli NiceCom R&D center through a few more M&As, and ended with a critical mass of 300 people in Herzelia. At the end of the 1990s, 3Com became a large complex company and suffered from growing financial difficulties. As a result, 3Com started a process in which it spun off, among others, Palm, its handheld division; its modem division under the old US Robotics brand (which it bought with the acquisition of US Robotics, another company with an R&D center in Israel); and, in February 2000, Atrica, a new Israeli start-up developing urban optical networks and headed by none other than the old NiceCom executive team. As of 2004, Atrica inherited all of 3Com's R&D activities in Israel and has been considered one of Israel's most promising start-ups, managing by the beginning of 2005 to secure more than

²²⁸ The history of Intel in Ireland and Israel is based on interviews with five executives of Intel and Intel Capital in Israel and Ireland, and email communication with Dov Frohman. See, also Dror 2/6/2002, *Wired Magazine* "Tech New Promised Land," 1/17/2000, also available on line, <http://www.wired.com/news/infrastructure/0,1377,33537,00.html>, and Intel Israel and Intel Ireland websites: <http://www.intel.com/il/> and <http://www.intel.com/ireland/>.

²²⁹ Asynchronous Transfer Mode (ATM) is an international standard for cell relay in which multiple service types (such as voice, video, or data) are conveyed in fixed-length (53-byte) cells. This makes ATM a fast data transmission protocol as fixed-length cells allow cell processing to occur in hardware, thereby reducing transit delays.

\$160USD million in investment. Moreover, the former CEO and now chairman of 3Com and CEO and Chairman of Palm, Eric Benhamou, serves as Atrica's Chairman.

For reasons similar to Intel's "Fortress Europe" strategy, 3Com started its Irish operation in 1992 by opening a plant in Dublin. Over the years, the Dublin operation became the best in quality and yields, and 3Com opened a small R&D center in Dublin. It is an interesting fact that even as 3Com was reeling from 18 months of downsizing in 2002, the Irish R&D center was still operative when all others were closed or spun off, and that, although 3Com has outsourced all of its manufacturing activities, mainly to Flextronics, and closed down all of its other plants worldwide, the Irish plant was the last to close. According to 3Com, the reasons behind this decision have been a mix of the high quality and yields for the Dublin plant; the Irish tax regime; the fact that Ireland is part of the EU; the excellent infrastructure for European deliveries around Dublin; and last, but not least, the excellent relationship with the Irish government.²³⁰

Thus, the story of Intel and 3Com exemplify the very different ways in which their national IT industries are embedded in the MNCs' global production network. Israel has always been first and foremost a location for high-level R&D activities, while Ireland was mainly deemed a strategic location for manufacturing. These different relationships brought leading American MNCs to locate very different activities in each location, creating very different relationships with, demands from, economic incentives for, as well as opportunity structures and resource availability for, the local IT industry.

²³⁰ Sources: interview with Eric Benhamu, former CEO and Chairman of 3Com 1990-2000, and current Chairman of 3Com, Chairman and CEO of Palm 2/13/2002, Asis 2/20/2002; Harmony 2/14/2002, and the company's website www.3com.com.

Facilitating Industrial R&D – The Politics of the State as a Researcher

A second critical component in understanding the different development paths of the Israeli, Irish, and Taiwanese IT industries is the ways in which the three states devised different solutions to the problem of industrial R&D market failure. Of particular importance is the question of the location of the R&D generating agents within the industrial system, public versus private. In all three countries this debate was intimately connected to the national perception of capabilities, status, and identity, as well as to the politics and the bureaucratic structure of knowledge. Taiwan and Israel are the two cases between which a deeper comparison is most revealing.

Looking at Israel in 1968, with a total of 886 R&D workers with academic degrees in the whole civilian industrial sector, one might wonder how the Katchalski Committee came to the conclusion that the growth of science-based industry should be the core of Israel's S&T industrial policy goals. However, even more interesting, and easily forgotten, is the fact that the committee's recommendations, which were transformed to specific policies, viewed state-run *public research institutions as the main vehicle for this socio-economic transformation*. Hence, between 1968 and 1973, Israel undertook major steps toward following a development path very similar to Taiwan's. Nonetheless, by 1974 the reliance on public research institutions was quickly curtailed, and the system refocused around a policy regime viewing private companies as the main agents for industrial R&D and technological development. Thus two questions arise: why did Israel, unlike Taiwan, choose to change course? And what enabled Israel to do so with such speed and without any significant political backlash?

The answers to these two questions are intimately related to these two countries' different politics of technological knowledge, perception of national identity, state-

industry relations, and the political-bureaucratic structure of power. First, let us look at the question of each country's political context of state-industry relations and the politics of technological knowledge. In Taiwan, the ruling party, the KMT, while viewing the growth of private industry as the ultimate end, at the same time mistrusted private entrepreneurs and their motives and was actively pursuing policies to prevent the growth of competing centers of power (Cheng 1993; Fields 1995; Gold 1986; Hong 1997; Wade 1990; Wu 2001). In Israel, on the other hand, the ruling labor party actively tried to grow a strong private industry and was pursuing policies to limit the power of the public and semi-public sectors (Levi-Faur 1998; Levi-Faur 2001). Accordingly, if at the starting point in both societies, the existing infrastructure of industrial R&D consisted mainly of public research institutions, in the political context of Taiwan such a system would have offered an optimal solution to competing political goals. In Israel, on the other hand, a system focusing on public research institutions not only clashed with the ultimate goal of building private science-based industry, and hence, an industry with significant R&D capabilities, but it also clashed with the political-economic goal of the ruling Labor party to strengthen the private sector at the expense of the public sector.

However, at least as important in facilitating the Israeli course change were the different politics of knowledge in the two states. Here the bureaucratic structure of knowledge and power as well as the perception and structure of the academic system, were of key importance. In Taiwan, the decision to create ITRI and later III was the personal undertaking of two prominent KMT leaders, Dr. Y.S. Sun and Dr. K.T. Li. As a consequence, the two public research institutions were under the direct patronage of two leading politician-bureaucrats, who had direct interest in their continuous development.

From the mid-1970s onward, K.T. Li devoted his career and considerable power to the development of the Taiwanese IT industry through ITRI and III.

In addition, the high echelons of the Taiwanese bureaucracy consisted of engineers. Therefore, the view of a state deeply involved in charting the technological development of its industry and locating the R&D agents within the state structure, was accepted not only as natural, but also as politically prudent, and helped to directly enhance the power and status of the two patrons of ITRI and III. Lastly, during that period, the university system in Taiwan was thoroughly controlled by the KMT, with virtually all the professors and administrators nominated by the KMT and members of stature in the party. Academic freedom was not a widely held value, and the goals of academic research were intimately tied to the national aims of improving Taiwan's economic and political power.

In Israel, the situation was almost directly opposite. No leading politician had any direct interest in Israel's public-research institutions. The political leaders who decided the fate of Israel's S&T industrial policies did not possess Ph.D. degrees, nor did they personally undertake the development of the IT industry. S&T industrial policy in Israel was always deemed to be a professional domain. Values of academic freedom and "pure" basic research were strong. Until the late 1970s, developing the research capability of strictly academic institutions was a high national priority, sometimes even higher than national security and the growth of the defense industry. A case in point is the story of the transfer of a whole department to the Weizmann Institute of Science from RAFAEL, the public research institution for the development of armaments. This was done in order to enhance the national academic research infrastructure, and against the wishes of

RAFAEL that invested significant resources into the development of this department and viewed it as critical to its future R&D plans (Mardor 1981. Pp. 113-117.).²³¹

Consequently, after the 1973 war, when the government of Israel decided to give higher priority to the development of industrial R&D and science-based industry by recruiting a prominent and strong-willed professional, Itzhak Yaakov, to head the OCS, he was given the power to transform it into an active agency, and had authority to formulate and implement policies. Coming from within the military, and possessing strong international connections and education, Yaakov was ideologically opposed to public research institutions. In an interview he concluded:

“My second guiding principle was that a state cannot guide the industry. The state cannot come and say from now on we will develop engines for helicopters, this is a complete dead-end. Successful industrial R&D comes from the people themselves. Therefore, the problem of the state is to give the entrepreneurs who think they know what they are doing the ability to do so. The key to understand is that we cannot control the consumers; accordingly good ideas have to come from the market, not from the state. These are the reasons why in my second year I decided to cut the budget of the public research institutes by 70% and transfer the finance directly to industry” (interview 9/28/2000).

The combination of the different national political contexts, ideologies of development and science, political patronage for the public research institutes, and the bureaucratic structure of power, were the main reasons why in Israel, once Yaakov decided to dismantle the public research institution-based S&T industrial policy, he could do so in matters of days, while in Taiwan, this option was not even considered.

These decisions have had decisive long-term consequences on the development path of the IT industries in Israel and Taiwan. In Israel, the focus on the enhancement of

²³¹ Indeed the social status of academia in Israel was so high in these early years that RAFAEL viewed it as critical to win a political battle to grant its R&D employees recognition as academic personnel, giving them the same wage agreements and similar career pattern as those of university professors and not of engineers (Mardor 1981. Pp. 88-92.)

technological cutting-edge R&D activities of private firms has propelled IT companies to develop capabilities that facilitated novel products innovation based on the latest technologies, the newest technologies themselves, or new applications of these technologies, and has led Israel's IT industry into its position as a supplier of new technologies to the global IT industry's production networks. Nonetheless, the source of the industry's gravest Achilles' heel is also the state's almost exclusive focus on promoting private firms to conduct R&D activities and follow business models based on new innovations. Because the development of management and business skills have lagged, many Israeli companies have difficulties in maintaining enduring success.

In Taiwan, the decision to utilize public research institutions-based S&T industrial policy led to the development of an industrial innovation system with strong division of labor between industry and public research institutions. This pattern limits the development of R&D capabilities of private firms by motivating these firms to concentrate more on the development part of the R&D. In this system, it is the public research institutions that decide which R&D projects should be pursued, conduct nearly all R&D, and only then diffuse the results to private industry; accordingly, core R&D capabilities' development is concentrated within the public sector. Thus, in Taiwan, specifically because its institutional system, the industry successfully developed advanced capabilities in second-generation, process, and manufacturing innovation, but not in new product development. While it has been this system that propelled Taiwan to unprecedented success in the IT hardware sector, it is an open question as to whether Taiwan can change this system to allow it to move to original, new product R&D activities in the future.

Financing and Resources – Going Local or Going Global?

A third critical variable in the diverse development paths of the IT industries in Israel, Ireland, and Taiwan has been the connections of industry with the global financial markets. In all three countries, key decisions by the state were taken as part of policy initiatives to create local VC industries. These were again decisions that are closely linked to questions about the ownership and the long-term embeddedness of the industry within the national context. On the one hand, a tight relationship with the global investing community and financial markets gives the industry an opening to an immensely rich supply of skills, resources, and capital. On the other hand, this same linking transfers a large portion of the ownership of local industry into foreign hands, and this same dependency on foreign financial markets weakens the industry's national linkages. Moreover, the more connected the industry is to the global financial markets, the more the fruits of the local IT industry's success are redistributed to foreign investors who are not as inclined as local investors, to reinvest their gains in the national economy. Lastly, national governments have more power to influence the behavior of local financiers. Hence, while from the point of view of overall industrial development, linking the IT industry with experienced foreign VCs might be preferred, governments might favor working with local institutions and individuals.

In each of our cases, the developmental agencies followed very different VC creation policies. A large percentage of these differences can indeed be explained by the different conceptualizations by policy makers of the VC industry itself. Chapters 2-4 showed the distinction between two VC creation policy styles: one that sees VC creation as a problem of a missing pool of capital, and a second that sees VC as a distinct industry with specific skills and capabilities (Avnimelech and Teubal 2003a). This explains much

of the outcome in terms of VC behavior. Nevertheless, this distinction obscures the intense political nature of these policies, specifically since, in the case of emerging economies, a decision to treat VC as a distinct industry, strongly suggests a need to tightly connect the local with the global VC industry and financial markets.

In Taiwan, the VC industry was, like many other initiatives, the brainchild of the leading technocrat-politician Dr. K.T. Li. Impressed by the US VC industry in the early 1980s, Dr. Li viewed the VC industry mainly as a supplier of a dedicated pool of capital. In the Taiwanese political context, Dr. Li considered it essential that the main investors in the industry would be Taiwanese. In 1983, under his influence, VCs were allowed to register as companies, and not as limited partnerships. The main vehicle to channel capital to these newly formed companies was tax credits of 20% to shareholders in VC firms. This tax incentive remained in place until 2000, and was the main reason behind the extensive amount of finance channeled specifically to VCs. It is not surprising that in this political context many of the early VCs were financial subsidiaries of different KMT investment vehicles. For the most part, the VC industry in Taiwan remains captive to various investors, both financial and industrial. The VCs themselves lack extensive industry experience and are mainly recruited from those with financial background. Taiwan's VC industry, operating under the regulations that force VCs to be registered as companies, also continued to be extremely local. As of the end of 2003, according to the Taiwanese VC association, foreign capital still amounted to less than seven percent.²³²

In Israel, the political and industrial contexts were almost the opposite. By the beginning of the 1990s, not only was the IT industry already relatively well embedded in the American financial markets, with a cumulative number of about a dozen companies

²³² Interview with Taiwan's VC Association secretary general, 11/3/2003.

already listed on NASDAQ, but also the first private VCs appeared and foreign financiers were their main investors. The OCS took the lead after a first failed attempt, Inbal, headed by the Ministry of Finance to spur a local VC industry with an organizational form very similar to Taiwan's – VCs as publicly listed holding companies on the Tel Aviv Stock Exchange. Unlike Taiwan or Ireland, the OCS linked VC policy and made it an integral part of its overall reconfiguration program for the high-technology industrial environment in the early 1990s. In this political context, we can understand why Yozma, as the VC creation initiative was known, was conceptualized in the way it was.

In the early 1990s, the OCS used the political window of opportunity created by the massive waves of immigration from the former Soviet Union to launch a series of policy initiatives. Each of these three initiatives was part of an overall program to fix what the OCS analyzed as areas of persistent weakness with Israel's RIB industries: extreme early seed investment, skills and finance in the more mature market penetration stage of firms' development, and advanced generic R&D capabilities. Thus, the creation of the VC industry was not conceptualized solely as a problem of financing, but as part of a systemic weakness of missing capabilities. It is in this context with the already deep embeddedness of the Israeli industry within the American financial markets, and only after the failure of the Inbal program to create a locally financed VC industry, that we can understand the advancement of the Yozma program. In particular, its conceptualization of VC as an industry with skills that were lacking in Israel, and as a deliberate political attempt to increase both the field of investors and their clients as well as to tie the Israel IT industry more fully with the global financial markets.

In Ireland, the one rarely talked about but quite striking political constraint, in the period when the IT-focused VC initiative materialized in the second half of the 1990s, was the recent reorganization of the developmental agencies and the sharp division of labor between their two domains and clientele. On one side of the divide was IDA-Ireland with MNCs and all FDI inflows into Ireland being its domain. On the other side was the newly structured, and out to prove itself, Enterprise Ireland with local industry and all local enterprise and investment being its domain. VC policy, under other political circumstances, a bridge with which to connect FDI inflows with local enterprise development, fell within the domain of EI and was led by the NSD.

Hence, even with the declared aim of the NSD VC initiative to embed the Irish IT industry more intimately with the global markets and to aid Irish companies in their pursuit of foreign success, and even with the acknowledged political goal of increasing the circle of financiers in Ireland, which was deemed too narrow, the political institutional constraints limited the NSD to seek established local financial institutions as partners for its VC program. Accordingly, the NSD, utilizing EU funds, opted on the one side to enforce the organizational form of limited partnerships, similar to Israel and in imitation of the US, but on the other side specifically chose only Irish institutions as its partners.²³³ The institutional division between the IDA and EI is also becoming an artificial obstacle with the growing interest of the MNCs in the Irish IT industry. Consequently, many managers of MNCs and their VC arms find that their “natural” political interlocutors are located within the IDA. However, the proper interlocutors for issues of Irish IT industrial development are all situated in EI.

²³³ Interview with EI VC program official 3/7/2002.

All the three very different VC creation policy initiatives of Ireland, Israel, and Taiwan have been exceptionally successful. However, all three had very different outcomes in terms of the VC industries created, and in terms of the tremendously different relationships between the local IT industry and foreign markets they nurtured.

In Taiwan, the creation and rapid growth of this VC industry has helped the Taiwanese IT industry, in particular the hardware industry, to evolve in the way that it did. Taiwanese VCs are both much more conservative than their US counterparts and also much less capable of giving added value in running a true R&D-based young venture. The VC industry in Taiwan prefers to invest in companies with the more established business models of second-generation innovation or OEM/ODM. Moreover, as virtually all of its financings are Taiwanese, and as the VCs are registered Taiwanese companies, the Taiwanese VCs are under no pressure to seek financial exits in foreign financial markets. Hence, not only does the Taiwanese VC industry strengthen the linkage of the Taiwanese IT industry within Taiwan, but it also diffuses some of the need it otherwise might have had to embed itself more tightly into the global financial markets. Thus, it seems as if the political goal of keeping the Taiwanese industry Taiwanese has been achieved; however, only at the price of a less sophisticated and much more conservative VC industry.

In Israel, on the other hand, the VC industry that rapidly grew in the late 1990s is better seen as an extension of the American financial markets and VC community than as a purely Israeli industry. Almost all of the financing of the industry is foreign, with the share of local investors actually diminishing after the dotcom crash on NASDAQ. Most of the biggest funds not only have offices in the US and Europe, but also have general

partners (i.e., VCs) who are experienced American and European VCs. Most of the VCs have industry experience and operate very similarly to Silicon Valley VCs. Even more importantly, with the finance and the organizational modes coming from the US, Israeli VCs are seeking foreign financial exits. Thus, the linkage of the IT industry with the rest of the Israeli economy is severely weakened, while its embeddedness in the global financial markets is growing. In addition, the need to seek foreign exits and the diffusion of the Silicon Valley VC model limit the Israeli IT industry to employ, almost exclusively, novel R&D-based models. Lastly, with the investors of the VC industry mostly being foreign institutions, most of their profits are transferred back to the investors, and hence, out of the Israeli economy, with, relative to Taiwan, only a small fraction of the capital staying within Israel. The existence of such a VC industry is thus both positive and negative. For example only with such intimate connections to foreign capital markets could Atrica, the spin-off of 3Com's Israeli R&D center, raise more than \$160USD million to support novel R&D activities, a sum that is alone larger than the combined capital managed by the biggest Irish VC companies. However, Atrica's CEO is no longer Israeli, the HQ is no longer in Israel, and the financial gains of Atrica's success, if and when they arrive, will be mostly enjoyed by foreigners.

In Ireland the VC industry seems to be stuck in the middle. On the one hand the industry tries to imitate the American model and employ a hands-on value-added investment and management policy. On the other hand, most of its finance, and hence, its connections are with Irish financial institutions and the VCs' background is mainly in the financial and management-consulting industry. Therefore, the Irish VCs' ability to add value and to link their companies to foreign financial markets is limited. Indeed, with the

Irish government being the single biggest source of funds, the VC industry is keener to be seen as helping the growth of the Irish IT industry. However, apart from a short period in the end of the 1990s, the VCs' apparent influence vis-à-vis the sums under the industry's management has actually declined. Nonetheless, the creation of a growing VC industry in Ireland has changed the rules of the game. Unlike in the past, a pure R&D business model is no longer seen as a taboo. Moreover, the strong connection of the VC industry to Ireland, in a very similar way to Taiwan, aids in diffusing some of the pressure of Irish IT firms to embed themselves more strongly in foreign markets at the expense of their "Irishness." With a VC industry flush with capital it is also plausible to expect that once the global IT industry shows signs of substantial improvement, Irish IT NTBFs can hope to raise significant amounts of finance for R&D. Nonetheless, as of 2005, not only did the rapid growth of the Irish VC industry not transform the shape and size of the Irish IT industry, but also the existence of the VC industry and the attention it gained from the state might actually have hurt the ability of NTBFs to commence operations in the short run.

In Conclusion: The Politics of RIB Industrial Growth in a World of Fragmented Production

The premise of this dissertation is that – with the extensive and rapid changes of industries, the international system, and the nature of industrial production itself – there is a need to establish a framework to analyze the role of the state in RIB industrial development. Since the early days of the late development theory, research on industrial production, innovation, and economic growth has diverged. Hence, we no longer have a coherent body of literature capable of answering the questions that motivate this

dissertation. Accordingly, the first chapter was devoted to analyzing, synthesizing, and building on three schools of thought – late development, systems of innovation, and globalization, particularly the globalization of production networks – to develop a theoretical framework. The rest of this dissertation used this framework to analyze the role of the state in the development of the IT industry in Israel, Ireland, and Taiwan. This inquiry was conducted in order to answer three questions: first, what are the roles of the state in RIB industrial development in emerging economies? Second, do states and societies have choices in their economic development strategies? And third how does globalization, especially the radical transformation of production, influence the development opportunities of peripheral economies?

Our analysis of the development of the IT industries in Israel, Ireland, and Taiwan yielded the following answers. First, there is a significant role for the state in creating and sustaining RIB industrial development. This role, however, is not fixed. Emerging economies have many different choices in their efforts to develop RIB industries. Each of these choices has major consequences on the developmental path of each industry. This is particularly true with regard to industrial and innovational capabilities, and the ways in which each of these national industries is embedded into the global product networks and financial markets. For this reason, while globalization might limit the scope of state capabilities to develop their national industries in the strong development state method used by South Korea or Japan, globalization, especially the growing fragmentation of production, opens numerous new entry points for RIB industries in emerging economies.

As a consequence, the role of the state in RIB industrial development has significantly changed. First, the state needs to actively engage in the fostering of

industrial R&D and innovation. In so doing, the state is devising different solutions to: i) the inherent industrial R&D market failure, which is heightened in the case of emerging economies; and, ii) the need to start a collective, i.e., a community, effort to foster innovation, which stems from the fact that innovation by its very nature is an iterative and social endeavor. However, precisely because of this, and the fact that long term strategic planning is less feasible in RIB industries where technology itself or its latest application are the products, the state cannot assume a position of central planning and command. Rather, the state role is more limited to that of creating capabilities, spurring specific activities, and motivating private enterprises for sustained efforts in RIB industries.

Another argument of our theory, that was found to be true in our analysis, is that the proper level of analysis of states' RIB industrial development efforts should be in the specific industrial sector level and at the level of particular state agencies, not solely in the national level. State can both fail and succeed in their RIB industrialization efforts in different sectors. Furthermore, many times sectoral, and not national, policies have more direct influence on industrial development. This is especially true as, in contrast with the traditional Weberian ideals, our view of the state bureaucracy is of a fragmented and flexible civil service deeply embedded in various industrial sectors. For this reason, we should no longer view the state as a monolithic whole. Thus, a crucial factor in understanding industrial success is to comprehend the political processes of state-industry co-evolution at both the national and sectoral level.

Another crucial role of the state is to link its local burgeoning RIB industry with global markets, both production networks and financial markets, both inside and outside its national borders. Our theory allowed us to develop hypotheses as to the specific

development paths of successful IT industrial sectors and apply them to analyses of Israel, Ireland, and Taiwan. As predicted, we found that in the case of Taiwan a hardware industry developed that excels in second generation innovation and high level design and manufacturing services, as well as in the supplying of components, where the state: i) located the R&D conducting agents mostly within its own structure; ii) is intimately involved in decisions about the technological development path of the industry; iii) has been aiming specifically at developing companies that excel as ODM/OEMs, as well as actively trying to foster OEM/ODMs relationships between local companies and MNCs; and, iv) has been striving to limit the relationship of Taiwanese NTBFs to Taiwanese financial institutions.

In the case of Israel an IT industry developed that excels in novel product innovation and new technology creation, where the state: i) focused on motivating private firms to innovate and refrained from targeting specific technological development paths, instead focusing on fostering a specific set of activities, R&D; ii) has been actively helping in the creation of particular relationship between local companies and MNCs where Israeli firms focus on new product R&D, iii) has had an FDI-focused industrial policy whose sole goal was to motivate MNCs to open R&D subsidiaries in Israel; and, iv) has been vigorously trying to tie the local companies as closely as it can with foreign financial institutions. Nevertheless, the Israeli IT industry lacks several managerial skills, and is not highly tied to Israel and the rest of the Israeli economy.

In Ireland an IT industry developed that excels in developing software products of mid-sophistication, usually offering applications of novel technologies in new markets and industries, rarely developing the new technologies itself, where the state: i) focused

on job creation for many years, attempting to bring MNCs to open large-scale manufacturing facilities in Ireland and paying much less attention to the creation of the local IT industry; ii) was not actively trying to embed these MNCs with the local industry; iii) was for a long period of time not channeling many resources for industrial R&D activities, and since then has concentrating on the software industry, taking less notice of the hardware industry; and iv) while not specifically dissuading local industry from deeply interacting with the global financial institutional, was, nevertheless, growing an Irish-owned vastly state-dependent VC industry.

The most important conclusion of this dissertation is that states and societies still have real choices with regard to developing their own RIB industries. Moreover, each set of choices has particular consequences that can be foreseen, at least partly.

Therefore the final message of this dissertation is a positive one: less developed states and societies still have extensive opportunities to improve their economic well-being and spur RIB industrial development. Moreover, there is more than one model to follow in order to achieve success. Israel, Ireland, and Taiwan have demonstrated that there are at least three, and probably more, development paths that other countries can follow. Moreover, our theoretical framework has shown the feasibility of developing models that would help us to predict the industrial outcomes in both capabilities development and the social distribution of success of different choice sets. For that reason this dissertation constitutes one step in a research continuum that will grant us greater understanding of the politics and outcomes of RIB industrial development.

References

- Abouganem, M., & Feldman, M. (2002). Development of the High-Tech Industry in Israel, 1995-1999: Labour Force and Wages. Jerusalem: State of Israel Central Bureau of Statistics (In Hebrew).
- AFX (2001). "VIA sees P4 Chipset dispute impact fully reflected in Q4." *AFX News Limited - AFX Asia* 12/18/2001.
- Akamatsu, K. (1962). A Historical Pattern of Economic Growth in Developing Countries. *The Developing Economies*, 2, 3-25.
- Amit, I. (1988). The Defense Industry as a Political and Strategic Factor, *The State of Israel - The Ministry of Defense - Armament Development Authority - The Center for Military Research*. 88/02.
- Amsden, A. (1989). *Asia's Next Giant: South Korea and Late Industrialization*. Oxford: Oxford University Press.
- (2001). *The Rise of "The Rest" Challenges to the West from Late Industrializing Economies*. Oxford: Oxford University Press.
- Amsden, A., & Chu, W.-W. (2003). *Beyond Late Development: Taiwan's Upgrading Policies*. Cambridge, MA: MIT Press.
- Anchordoguy, M. (1989). *Computers Inc.: Japan's challenge to IBM*. Cambridge, MA: Harvard University Press.
- Ansell, C. K. (2000). The Networked Polity: Regional Development in Western Europe. *Governance*, 13, 279-291.
- Arendt, H. (1958). *The Human Condition*. Chicago: University of Chicago Press.
- Ariav, G., & Goodman, S. E. (1994). Israel: of Swords and Software Plowshares. *Communications of the ACM*, 37, 17-21.
- Arndt, S. W., & Kierzkowski, H. (2001a). Fragmentation: New Production Patterns in the World Economy. Oxford: Oxford University Press.
- (2001b). Introduction. In S. W. Arndt & H. Kierzkowski (Eds.), *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press.
- Arora, A., Gambardella, A., & Torrisi, S. (2001). In the Footsteps of Silicon Valley? Indian and Irish Software in the International Division of Labour, *SIEPR Discussion Paper*.
- Arrow, J. K. (1962). Economic Welfare and the Allocation of Resources for Invention. In R. R. Nelson (Ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors* (pp. 609-625). Princeton, NJ: Princeton University Press.
- Asis, Y. (2/20/2002). "Above the rest." *Ma'ariv (In Hebrew)*.
- Autler, G. H. (2000). *Global Networks in High Technology: The Silicon Valley-Israel Connection*. Unpublished Masters, University of California Berkeley.
- Avnimelech, G., & Teubal, M. (2002). Venture Capital - Start Up Co-Evolution and the Emergence and Development of Israel's New High Technology Cluster. *Economics of Innovation and New Technology*, Forthcoming.
- (2003a). Evolutionary Venture Capital Policies: Insights from a Product Life Cycle Analysis of Israel's Venture Capital Industry, *Science, Technology, and the Economy Program (STE) Working Paper Series - Samuel Neaman Institute for Advanced Studies in Science and Technology - Technion - Israel Institute of Technology*. Haifa.

- (2003b). Israel's Venture Capital Industry: Emergence, Operation and Impact. In D. Cetindamar (Ed.), *The Growth of Venture Capital: A cross cultural comparison*. Westport, Connecticut: Praeger.
- (2004). Venture Capital - Start Up Co-Evolution and the Emergence and Development of Israel's New High Technology Cluster. *Economics of Innovation and New Technology*, 3, 33-60.
- Bar, A. (1990). Industry and Industrial Policy in Israel - Landmarks. In D. Brodet, M. Justman & M. Teubal (Eds.), *Industrial-Technological Policy for Israel*. Jerusalem: The Jerusalem Institute for Israel Studies.
- Bathlet, H., Malmberg, A., & Maskell, P. (2002). Clusters and knowledge: Local Buzz, Global Pipeline and the Process of Knowledge Creation, *DRUID Working Paper 02-12*.
- Beaton, A., Martin, M., Mullis, I., Gonzalez, E., Smith, T., & Kelly, D. (1996). Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS). Chestnut Hill, MA: Boston College, TIMSS International Study Center.
- Ben-Bassat, A. (2002). The Israeli Economy, 1985–1998: From Government Intervention to Market Economics. Cambridge, Mass: MIT Press.
- Ben-Porath, Y. (1986). The Israeli Economy: Maturing through Crises. Cambridge, MA: Harvard University Press.
- Bentur, A. (2002). Investment in Civilian R&D in Israel: Data as a Basis for Discussion in the Purpose of Developing a National Policy, *STE Working Papers Series*. Technion - Samuel Neaman Institute.
- BIRD (2000). BIRD Foundation - Procedures Handbook. Tel Aviv: BIRD Foundation.
- (2004). BIRD Foundation's web site - www.birdf.com.
- (Various Years). Annual Reports. Tel Aviv: BIRD Foundation.
- Bizan, O. (2001). *Essays on the Economics of Research Alliances (Israel)*. Unpublished Ph.D., Northwestern University.
- BOI (2004). Table B-N-15 Total Factor Productivity by Sector 1961-2000, *Israel's Economy - Annual Tables*. Jerusalem: Bank of Israel.
- Bowsher, C. A. (1991). General Management Reviews: Building Government's Capacity to Manage. In A. Friedberg, B. Geist, I. Sharkansky & N. Mizrahi (Eds.), *Accountability and State Audit* (pp. 360-368). Jerusalem: State Comptroller's Office.
- Braczyk, H.-J., Cooke, P., & Heidenreich, M. (1998). Regional Innovation Systems: The Role of Governances in a Globalized World. London: UCL Press.
- Breathnach, P. (1998). Exploring the 'Celtic Tiger' phenomenon: Causes and Consequences of Ireland's Economic Miracle. *European Urban and Regional Studies*, 5, 305-316.
- Bregman, A., Fuss, M., & Regev, H. (1998). The Effects of Capital Subsidization on Israeli Industry, *NBER Working Paper Series*.
- Breschi, S., & Malerba, F. (1997). Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries. In C. Edquist (Ed.), *System of Innovation: Technologies, Institutions and Organizations*. London: Pinter.

- Breznitz, D. (2004a). The Development of the Information Technology Industry in Israel: A Case of State-Induced Expansion of Academic R&D Capabilities Throughout the National Innovation System? *Research Policy*, Revised and Resubmitted.
- (2004b). An Iron Cage or the Final Stage? Intensive Product R&D and the Evolution of the Israeli Software Industry. *Research Policy*, Revised and Resubmitted.
- (2005a). Collaborative Public Space in a National Innovation System: A Case Study of the Israeli Military's Impact on the Software Industry. *Industry and Innovation*, 12, 31-64.
- (2005b). Development, Flexibility, and R&D Performance in the Taiwanese IT industry - Capability Creation and the Affects of State-Industry Co-Evolution. *Industrial and Corporate Change*, 14, 153-187.
- (2005c). Innovation and the Limits of State Power: IC Design and Software in Taiwan. In S. Berger & R. Lester (Eds.), *Global Taiwan*. New York: M.E. Sharpe.
- (2005d). Software Tooling: The Development of The Israeli Software Industry. In A. Arora & A. Gambardella (Eds.), *From Underdogs to Tigers: The Software Industry in Emerging Countries*. New York: Oxford University Press.
- Brodet, D., Justman, M., & Teubal, M. (1990). Industrial-Technological Policy for Israel. Jerusalem: The Jerusalem Institute for Israel Studies (in Hebrew).
- Bruno, M. (1989). Israel's Crisis and Economic Reform: A Historical Perspective, *NBER Working Paper Series*.
- Burt, S. R. (1992). *Structural Holes: The Social Structure of Competition*. Cambridge, Mass: Harvard University Press.
- Calder, E., Kent (1993). *Strategic Capitalism: Private Business and Public Purpose in Japanese Industrial Finance*. Princeton: Princeton University Press.
- Carlsson, B. (1995). Technological Systems and Economic Performance - the Case of Factory Automation. London: Kluwer Academic Publishers.
- Carlsson, B., & Eliason, G. (1994). The Nature and Importance of Economic Competence. *Industrial and Corporate Change*, 3, 687-711.
- Carlsson, B., Jacobsson, S., Holmen, M., & Rickne, A. (2002). Innovation system: analytical and methodological issues. *Research Policy*, 31, 233-245.
- CBS (1999a). National Expenditure of Civilian Research and Development 1989-1998. Jerusalem: State of Israel Central Bureau of Statistics.
- (1999b). National Expenditure on Education 1962-1997. Jerusalem: State of Israel Central Bureau of Statistics.
- (2000a). Education In Israel and International Comparison 1995. Jerusalem: State of Israel Central Bureau of Statistics.
- (2000b). National Expenditure of Civilian Research and Development 1989-1999. Jerusalem: State of Israel Central Bureau of Statistics.
- (2001). Development of Information Communication Technology in the Last Decade. Jerusalem: Central Bureau of Statistics - Israel.
- (2004). Israel's Statistical Abstract. Jerusalem: State of Israel Central Bureau of Statistics.
- Chang, P.-L., Hsu, C.-W., & Tsai, C.-T. (1999). A Stage Approach For Industrial Development and Implementation - The Case of Taiwan's Computer Industry. *Technovation*, 19, 233-241.

- Chang, P.-L., & Tsai, C.-T. (2002). Finding the Niche Position - Competition Strategy of Taiwan's IC Design Industry. *Technovation*, 22, 101-111.
- Cheng, T.-j. (1990). Political Regimes and Developmental Strategies: South Korea and Taiwan. In G. Gereffi & D. Wyman (Eds.), *Manufacturing Miracles*. Princeton, NJ: Princeton University Press.
- (1993). Guarding the Commanding Heights: The State as Banker in Taiwan. In S. Haggard, C. H. Lee & S. Maxfield (Eds.), *The Politics of Financing in Developing Countries*. Ithaca: Cornell University Press.
- Chibber, V. (2002). Bureaucratic Rationalist and the Developmental State. *American Journal of Sociology*, 107, 951-989.
- (2003). *Locked in Place: State-building and Late Industrialization in India*. Princeton, NJ: Princeton University Press.
- Chinworth, M. W. (1992). *Inside Japan's Defense*. Washington: Brassey's.
- Cohen, W. M., & Levinthal, D. A. (1989). Innovation and Learning: The Two Faces of R&D. *The Economic Journal*, 99, 569-596.
- (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, 35, 128-152.
- Cooke, P., & Morgan, K. (1998). *The Associational Economy*. New York: Oxford University Press.
- Cumings, B. (1984). The Origins and Development of Northeast Asian Political Economy: Industrial Sectors, Product Cycles, and Political Consequences. *International Organization*, 38, 1-40.
- Daly, G. (2002). "Iona Offspring Surprised by CapeClear Row." *Sunday Business Post* 05/05/2002.
- de Fontenay, C., & Carmel, E. (2001). Israel's Silicon Wadi: The Forces Behind Cluster Formation, *SIEPR Discussion Paper*.
- Dedrick, J., & Kraemer, L. K. (1998). *Asia's Computer Challenge: Threat or Opportunity for the United States and the World*. New York: Oxford University Press.
- Deri, D. (1993). *Political Appointments in Israel: Between Statism and Political Party-ism*. Tel Aviv: The United Kibutz Press (In Hebrew).
- DOIT (2003). TDP Annual Budget 1993-2003. Taipei: Ministry of Economic Affairs - Department of Industrial Technology.
- Dosi, G. (1982). Technological Paradigms and Technological Trajectories: A suggested Interpretation of the Determinants and Direction of Technical Change. *Research Policy*, 11, 147-163.
- Dror, Y. (2/6/2002). "Intel develops in Israel a cellular laptop." *Ha'aretz (In Hebrew)*.
- Dunning, J. H. (1994). Multinational Enterprises and the Globalization of Innovatory Capacity. *Research Policy*, 23, 67-88.
- Durkan, J., FitzGerlad, D., & Hramon, C. (1999). Education and Growth in the Irish Economy. In F. Barry (Ed.), *Understanding Ireland's Economic Growth*. London: Macmillan.
- Economics, E. G. P. A. (2001). The operational achievements of the Israeli Technology Incubators Program: Conducted for the Technology Incubators Administration, the Office of the Chief Scientist, in the Ministry of Trade and Industry, Israel.
- Edquist, C. (1997). *Systems of Innovation: Technologies, Institutions, and Organizations*. London: Pinter.

- Efrati, N. (1999). In the Beginning 40 years of Computing in Israel. Tel Aviv: Meta Group Israel (in Hebrew).
- EI (2000). 2000 Report: Seed and Venture Capital Measure of the Operational Program 1994-1999. Dublin: Enterprise-Ireland.
- Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *Academy of Management Review*, 14, 532-550.
- Ernst, D. (2004a). Internationalisation of Innovation: Why is Chip Design Moving to Asia? *International Journal of Innovation Management*, Forthcoming.
- (2004b). Late Innovation Strategies in Asian Electronics Industries: A conceptual Framework and Illustrative Evidence. *Oxford Development Studies*, Forthcoming in a Special Issue in Honor of Linsu Kim.
- Evans, P. (1995). *Embedded Autonomy: States and Industrial Transformation*. Princeton: Princeton University Press.
- Evans, P., & Rauch, E. J. (1999). Bureaucracy and Growth: A Cross-National Analysis of the Effects of "Weberian" State Structure on Economic Growth. *American Sociological Review*, 64, 748-765.
- Evans, P., Rueschemeyer, D., & Skocpol, T. (1985). *Bringing the State Back In*. New York: Cambridge University Press.
- Feenstra, R. C. (1998). Integration of Trade and Disintegration of Production in the Global Economy. *Journal of Economic Perspectives*, 12, 31-50.
- Felsenstein, D. (1997). The Making of a High Technology Node: Foreign-owned Companies in Israeli High Technology. *Regional Studies*, 31, 367-380.
- Fields, K. (1995). *Enterprise and the State in Korea and Taiwan*. Ithaca: Cornell University Press.
- (1997). *Enterprise and the State in Korea and Taiwan*. Ithaca: Cornell University Press.
- Freeman, C. (1987). *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter Publishers.
- FT (2003a). "Mediatek to Challenge World's No. 4 Spot in IC Design." *Financial Times Global News Wire* 11/25/2003.
- (2003b). "Taiwanese Chip Designers Facing Lukewarm Season Earlier." *Financial Times Global News Wire* 12/09/2003.
- (2003c). "VIA, Intel Reach Patent Suit Settlement, to jointly face competitors." *Financial Times Global News Wire* 04/09/2003.
- Fuller, D. B. (2002). Globalization for Nation Building: Industrial Policy for High-Technology Products in Taiwan, *MIT IPC Working Paper*. Cambridge, MA.
- Fuller, D. B., Akinwande, A., & Sodini, C. G. (2003). Leading, Following or Cooked Goose: Successes and Failures in Taiwan's Electronics Industry. *Industry and Innovation*, 10, 179-196.
- Galvin, P., & Morkel, A. (2001). The Effects of Product Modularity on Industry Structure: The Case of the World Bicycle Industry. *Industry and Innovation*, 8, 31-47.
- Gassmann, O., & von Zedtwitz, M. (1999). New Concepts and Trends in International R&D Organization. *Research Policy*, 28, 231-250.
- Gereffi, G. (1994). The Organization of Buyer-Driven Global Commodity Chains: How the US Retailers Shape Overseas Production Network. In G. Gereffi & M.

- Korzeniewicz (Eds.), *Commodity Chains and Global Capitalism* (pp. 95-122). Westport, CT: Praeger Publishers.
- (1996). Commodity Chains and Regional Divisions of Labor in East Asia. *Journal of Asian Business*, 12, 75-112.
- (1999). International Trade and Industrial Upgrading in the Apparel Commodity Chain. *Journal of International Economics*, 48, 37-70.
- Gereffi, G., Humphrey, J., & Sturgeon, J. T. (2004). The Governance of Global Value Chains. *Review of International Political Economy*, Forthcoming.
- Gereffi, G., & Korzeniewicz, M. (1994). *Commodity Chains and Global Capitalism*. Westport, CT: Praeger Publishers.
- Gerschenkron, A. (1962). *Economic Backwardness in Historical Perspective, a Book of Essays*. Cambridge, MA: Belknap Press of Harvard University Press.
- Gerybadze, A., & Reger, G. (1999). Globalization of R&D: Recent Changes in Management of Innovation in Transnational Corporations. *Research Policy*, 28, 251-74.
- Giuliani, E. (2002). Cluster Absorptive Capability: An Evolutionary Approach for Industrial Clusters in Developing Countries, *DRUID Summer Conference: "Industrial Dynamics for the New and Old Economy - Who is Embracing Whom?"* Copenhagen.
- Glaser, B. G., & Strauss, A. L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago, IL: Aldine Pub. Co.
- Gold, T. B. (1986). *State and Society in the Taiwan Miracle*. New York: Armonk.
- Gourevitch, P. (2000). Globalization of Production: Insights from the Hard Drive Disk Industry. *World Development*, 28, 301-317.
- Granovetter, S. M. (1973). The Strength of Weak Ties. *American Sociological Review*, 25, 483-496.
- Grimes, S., & Collins, P. (2003). Building a Knowledge Economy in Ireland Through European Research Networks. *European Planning Studies*, 11, 395-413.
- Grinberg, L. L. (1991). *Split Corporatism in Israel*. New York: SUNY.
- Guiomard, C. (1995). *The Irish Disease and How to Cure It: Common-Sense Economics for a Competitive World*. Dublin: Oak Tree Press.
- Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2001). The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools, *NBER Working Papers*. Cambridge, MA.
- Halperin, A. (1987). The Building of the Military Power and Economic Growth. *Economic Quarterly (in Hebrew)*, 16, 990-1010.
- Halperin, A., & Berman, E. (1990). Skilled-Workforce, Security, and Growth. In D. Brodet, M. Justman & M. Teubal (Eds.), *Industrial-Technological Policy for Israel*. Jerusalem: The Jerusalem Institute for Israel Studies (in Hebrew).
- Halperin, A., & Tsiddon, D. (1992). The Conversion of the Israeli Defense Industry: The Labor Market, *The Israeli International Institute for Applied Economic Policy Review*. Tel Aviv.
- Hardiman, N. (2000). Social Partnership, Wage Bargaining, and Growth. In B. Nolan, P. J. O'Connell & C. T. Whelan (Eds.), *From Bust to Boom*. Dublin: Institute of Public Administration.

- (2002). From Conflict to Co-ordination: Economic Governance and Political Innovation in Ireland. *West European Politics*, 25, 1-24.
- Harmony, O. (2/14/2002). "Atrica, funded by 3Com, raised \$75 million." *Ha'aretz*.
- Haughton, J. (2000). The Historical Background. In J. W. O'Hagan (Ed.), *The Economy of Ireland: Policy & Performance of a European Region* (pp. 2-46). Dublin: Gill & Macmillan Ltd.
- HEA (2004). The PRTL I - program overview. Dublin: Higher Education Authority.
- Hecl o, H. (1977). *A Government of Strangers: Executive Politics in Washington*. Washington: Brookings Institution.
- Henderson, J., Dicken, P., Hess, M., Coe, N., & Yeung, W.-C. H. (2002). Global Production Networks and the Analysis of Economic Development. *Review of International Political Economy*, 9, 436-464.
- Herrigel, G., & Wittke, V. (2004). Varieties of Vertical Integration The Global Trend Toward Heterogeneous Supply Relations and the Reproduction of Difference in the US and German Manufacturing. In G. Morgan, R. Whitley & E. Moan (Eds.), *Changing Capitalism*. Oxford: Oxford University Press, Forthcoming.
- Hille, K. (2003). "Intel deal puts SiS under cloud." *Financial Times* 04/09/2003, pp. 31.
- Hong, S. G. (1997). *The Political Economy of Industrial Policy in East Asia: The Semiconductor Industry in Taiwan and South Korea*. Cambridge, UK: Edward Elgar.
- Hsu, C.-W., & Chiang, H.-C. (2001). The Government strategy for the Upgrading of Industrial Technology in Taiwan. *Technovation*, 21, 123-132.
- Hung, F. (2002). "Taiwan's Chipset Sales Plunge." *Financial Times Information* 07/10/2002.
- Hung, S.-C. (2000). Institutions and System of Innovation: An Empirical Analysis of Taiwan's Personal Computer Competitiveness. *Technology in Society*, 22, 175-187.
- Hwang, Y. D. (1991). *A Rise of a New World Economic Power: Postwar Taiwan*. New York: Greenwood Press.
- IAEI (2002). Israel Electronics Industries Profile (pp. <http://www.iaei.org.il/index-site.html>). Tel Aviv: Israel Association of Electronic and Information Industries.
- IASH (2002). Software Industry Statistical Information (pp. <http://www.ias h.org.il/content/SoftwareInds/StatisticalInformation.asp>). Tel Aviv: Israeli Association of Software Houses.
- (2003). Israel Software Industry Statistical Information: IASH.
- IDA (2000). Ireland - Vital Statistics. Dublin: IDA - Ireland.
- III (various years). *Zixun GongYe Nianjian (The Yearbook of Information Industry)*. Taipei: Institute for Information Industry, Market Intelligence Center.
- Insights, I. (2004). The McClean Report. Scottsdale, Arizona: IC Insights.
- ISA (2003). Irish Software Industry Outlook 2003. Dublin: Irish Software Association.
- (2004). Irish Software Industry Outlook 2004. Dublin: Irish Software Association.
- IT (2003a). "Intel opens €12m innovation center." *Irish Times* 06/28/2003.
- (2003b). "Policies of tech sector urgent - IBEC." *Irish Times* 01/23/2003.
- ITRI (2003). *Bandaoti Gongye Nianjian (The Yearbook of Semiconductor Industry)*. Hsinchu: ITRI - ISIS.
- (various years). Industrial Statistics. Hsinchu: Industrial Technology Research Institute - Industrial Economic & Knowledge Center.

- IVA (1997-2003). Year Books - A Survey of the Israeli Venture Capital and Private Equity Industry. Tel Aviv: Israeli Venture Capital Association.
- JIM (1987). Export-led Growth Strategy for Israel. Jerusalem - Tel Aviv: Jerusalem Institute of Management and the Telesis Group.
- Johnson, C. A. (1982). *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975*. Stanford California: Stanford University Press.
- (1995). *Japan, Who Governs? : The Rise of the Developmental State*. New York: Norton.
- Justman, M., & Teubal, M. (1995). Technological Infrastructure Policy (TIP): Creating Capabilities and Building Markets. *Research Policy*, 24, 259-281.
- Justman, M., Zuscovitch, E., & Teubal, M. (1993). Technological Infrastructure Policy for Renewed Growth. Jerusalem: The Jerusalem Institute for Israel Studies (In Hebrew).
- Katchalski, E. (1968). The Report of the Committee to Inquire Into the Organization of Governmental Research and Its Management. Jerusalem: Office of the Prime Minister (in Hebrew).
- Kennedy, L. (1989). *The Modern Industrialisation of Ireland 1940-1988*. Dublin: The Economic and Social History Society of Ireland.
- Kenney, M., & Florida, R. L. (2004). *Locating Global Advantage: Industry Dynamics in the International Economy*. Stanford, Calif.: Stanford University Press.
- Kim, H.-K., Muramatsu, M., Pempel, T. J., & Yamamura, K. (1995). The Japanese Civil Service and Economic Development: Catalysts of Change (pp. xxi, 552 p.). New York; Oxford: Oxford University Press; Clarendon Press.
- Kim, L. (1997). *Imitation to Innovation: the Dynamics of Korea's Technological Learning*. Cambridge, Mass: Harvard Business School Press.
- King, G., Keohane, R. O., & Verba, S. (1994). *Designing Social Inquiry: Scientific Inference in Qualitative Research*. Princeton, N.J.: Princeton University Press.
- Klintworth, G. (1995). *New Taiwan, New China: Taiwan's Changing Role in the Asia-Pacific Region*. New York: St, Martin's Press.
- Kohli, A. (1994). Where do high growth political economies come from? The Japanese lineage of Korea's "developmental state. *World Development*, 22, 1269-1293.
- Lester, R. K., & Piore, M. J. (2004). *Innovation -- The Missing Dimension*. Cambridge, Mass: Harvard University Press.
- Levav, A. (1998). *The Birth of Israel's High-Tech*. Tel-Aviv: Zemora-Bitan.
- Levi-Faur, D. (1998). The Developmental State: Israel, South Korea, and Taiwan Compared. *Studies in Comparative International Development*, 33, 65-93.
- (2001). *The Visible Hand: State Directed Industrialization in Israel*. Jerusalem: Yad Ben-Zvi Press (in Hebrew).
- Lillington, K. (2003a). "IBM sets eye on Dublin for research agenda." *Irish Times* 09/12/2003.
- (2003b). "Indigenous software industry 'struggling'." *Irish Times* 12/11/2003.
- Lin, Y. (1987). *A Study of an Emerging Industry in a LDC - A Case Study of Taiwan's IC Industry (in Chinese)*. Unpublished Master, National Taiwan University.
- Locke, R. M. (1995). *Remaking the Italian Economy*. Ithaca: Cornell University Press.
- Lundvall, B.-Å. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.

- Lundvall, B.-Å., Johnson, B., Andersen, E. S., & Dalum, B. (2002). National Systems of Production, Innovation and Competence Building. *Research Policy*, 31, 213-231.
- M.O.P (2000). Report on Irish Venture Capital Industry. Dublin: Matheson Ormsby Prentice and the Irish Venture Capital Association.
- MacSharry, R., & White, P. (2001). *The Making of the Celtic Tiger: The Inside Story of Ireland's Boom Economy*. Dublin: Mercier Press.
- Mardor, M. M. (1981). *RAFAEL*. Tel Aviv: Ministry of Defense of Israel Press (in Hebrew).
- Martin, M., Mullis, I., Gonzalez, E., Gregory, K., Smith, T., Chrostowski, S., Garden, R., & O'connor, K. (2000). TIMSS 1999 International Science Report. Chestnut Hill, MA: Boston College: The International Study Center.
- Mathews, J. A. (2002). The Origins and Dynamics of Taiwan's R&D Consortia. *Research Policy*, 31, 633-651.
- Mathews, J. A., & Cho, D.-S. (2000). *Tiger Technologies: The Creation of a Semiconductor Industry in East Asia*. Cambridge, UK: Cambridge University Press.
- McKendrick, D., Doner, R. F., & Haggard, S. (2000). *From Silicon Valley to Singapore: Location and Competitive Advantage in the Hard Disk Drive Industry*. Stanford, Calif.: Stanford University Press.
- McManus, J. (2002). "All is not rosy in the venture capital garden." *Irish Times* 09/30/2002.
- Meany, C. S. (1994). State Policy and the Development of Taiwan's Semiconductors Industry. In J. D. Aberbach, D. Dollar & K. L. Sokoloff (Eds.), *The Role of the State in Taiwan's Development*. Armonk, N.Y.: M.E. Sharpe.
- MoEA (various years). Economic Statistics Annual, Taiwan Area, Republic of China. Taipei: Ministry of Economic Affairs.
- Morgan, K. (1997). The Learning Region: Institutions, Innovation and Regional Renewal. *Regional Studies*, 31, 491-503.
- MOTI (1998). Israel's Economic Overview. Jerusalem: Ministry of Industry and Trade.
- Mullis, I., Martin, M., Beaton, A., Gonzalez, E., Kelly, D., & Smith, T. (1997). Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS). Chestnut Hill, MA: Boston College, TIMSS International Study Center.
- Mullis, I., Martin, M., Gonzalez, E., Gregory, K., Garden, R., O'connor, K., Chrostowski, S., & Smith, T. (2000). TIMSS 1999 International Mathematics Report. Chestnut Hill, MA: Boston College: The International Study Center.
- Nelson, R. R. (1993). *National Innovation Systems: a Comparative Analysis*. New York: Oxford University Press.
- NID (2003). Software Industry Statistics for 1991-2000 (pp. <http://www.nsd.ie/htm/ssii/stat.htm>). Dublin: National Informatics Directorate.
- (2005). Software Industry Statistics for 1991-2003 (pp. <http://www.nsd.ie/htm/ssii/stat.htm>). Dublin: National Informatics Directorate.
- Noble, G. W. (1998). *Collective action in East Asia: how ruling parties shape industrial policy*. Ithaca: Cornell University Press.
- NSB (2000). Science and Engineering Indicators 2000: National Science Board.

- O'Brien, J. A. (1953). *The Vanishing Irish: the Enigma of the Modern World*. New York: McGraw-Hill.
- OCS (1974). *The Office of the Chief Scientist*. Jerusalem: Ministry of Commerce and Industry - Office of the Chief Scientist.
- (1975). *Industrial Research and Development Background and Policy*. Jerusalem: Ministry of Commerce and Industry - Office of the Chief Scientist.
- (1977). *Industrial Research and Development in Israel: Policy and Issues*. Jerusalem: Ministry of Commerce and Industry - Office of the Chief Scientist.
- (2000). *Database of Annual Activities*. Jerusalem: Ministry of Trade and Industry - Office of the Chief Scientist (In Hebrew).
- (2002). *Summary of 2001: Ministry of Trade and Industry - Office of the Chief Scientist (in Hebrew)*.
- (2003). *Summary of Operations - 2002*. Jerusalem: Ministry of Trade and Industry - Office of the Chief Scientist (In Hebrew).
- OECD (1965). *Investment in Education: Organization for Economic Co-operation and Development*.
- (1969). *Review of National Policies for Education: Ireland: Organization for Economic Co-operation and Development*.
- O'Gorman, C., O'Malley, E., & Mooney, J. (1997). *Clusters in Ireland: The Irish Indigenous Software Industry*. Dublin: National Economic and Social Council.
- O'Gr'ada, C. (1997). *A Rocky Road: The Irish Economy Since the 1920's*. Manchester: Manchester University Press.
- O'Halloran, B. (2003). "Business happy with Extension of BES and SCS." *Irish Times* 12/04/2003.
- O'Hearn, D. (1998). *Inside the Celtic Tiger: The Irish Economy and the Asian Model*. London: Pluto Press.
- O'Keefe, B. (2003). "Flinter leaves legacy of competitiveness." *Irish Times* 07/04/2003.
- Okimoto, D., I (1987). *Between MITI and the Market: Japanese Industrial Technology for High Technology*. Stanford: Stanford University Press.
- O'Riain, S. (1997). The Birth of a Celtic Tiger? *Communications of the ACM*, 40, 11-16.
- (1999). *Remaking the Developmental State: The Irish Software Industry in the Global Economy*. Unpublished Ph.D., University of California Berkeley, unpublished Ph.D. Thesis.
- (2000). The Flexible Development State: Globalization, Information Technology, and the "Celtic Tiger". *Politics and Society*, 28, 157-193.
- (2004). *The Politics of High Tech Growth: Developmental Network States in the Global Economy*. Cambridge, UK: Cambridge University Press.
- O'Sullivan, M. (2000a). Industrial Development: A new Beginning? In J. W. O'Hagan (Ed.), *The Economy of Ireland: Policy & Performance of a European Region* (pp. 260-282). Dublin: Gill & Macmillan Ltd.
- (2000b). The Sustainability of Industrial Development in Ireland. *Regional Studies*, 34, 277-290.
- Pack, H. (1993). *Exports and Externalities: The source of Taiwan's Growth in Taiwan*. Philadelphia, PA: University of Pennsylvania.
- Park, P. H. (2000). A Reflection on the East Asian Developmental Model: Comparison of the South Korea and Taiwanese Experiences. In E. Richter (Ed.), *The East Asian*

- Development Model: Economic Growth Institutional Failure and the Aftermath of the Crisis*. London: Macmillan Press.
- Pearce, R. D. (1999). Decentralised R&D and Strategic Competitiveness: Globalised Approaches to Generation and Use of Technology in Multinational Enterprises (MNEs). *Research Policy*, 28, 157-178.
- Pfiffner, J. P. (1992). Political Appointees and Career Executives: The Democracy - Bureaucracy Nexus. In P. W. Ingraham & D. F. Kettl (Eds.), *Agenda for Excellence: Public Service in America*. Chatham, N.J.: Chatham House Publishers.
- Piore, M., Lester, R., Kofman, F., & Malek, K. (1994). The Organization of Product Development. *Industrial and Corporate Change*, 3, 405-434.
- Piore, M. J., & Sabel, C. F. (1984). *The Second Industrial Divide: Possibilities for Prosperity*. New York: Basic Books.
- PriceWaterhouseCoopers (2000). Money for Growth: The European Technology Investment Report 2000: PriceWaterhouseCoopers.
- Ragin, C. C. (1987). *The Comparative Method: Moving Beyond Qualitative and Quantitative Strategies*. Berkeley: University of California Press.
- (1994). *Constructing Social Research: the Unity and Diversity of Method*. Thousand Oaks, Calif.: Pine Forge Press.
- Reddy, P. (2000). *Globalization of Corporate R&D: Implications for Innovation Systems in Host Countries*. Routledge: London.
- Rehav, U. (1998). Armament Development Institutes and their Economics - 3rd Edition, *State of Israel - Defense Ministry - Armaments Development Authority - The Center for Military Studies (In Hebrew)*. Haifa.
- Roberts, E. B. (1999). Global Benchmarking of the Strategic Management of Technology, *MIT IPC Working Paper 99-007*.
- Rose, R. (1981). *The Political Status of Higher Civil Servants in Britain*. Glasgow: Center for the Study of Public Policy, University of Strathclyde.
- (1986). *A House Divided: Political Administration in Britain Today*. Glasgow: Center for the Study of Public Policy, University of Strathclyde.
- Rostow, W. W. (1960). *The Stages of Economic Growth, a Non-Communist Manifesto*. Cambridge, UK: Cambridge University Press.
- Ruane, F., & Gorg, H. (2001). Globalization and Fragmentation: Evidence for the Electronics Industry in Ireland. In S. W. Arndt & H. Kierzkowski (Eds.), *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press.
- Samuels, R., J (1994). *Rich Nation Strong Army*. Ithaca: Cornell University Press.
- Samuels, R., J. (1988). *The Business of the Japanese State*. Ithaca: Cornell University Press.
- Sands, A. (2005). The Irish Software Industry. In A. Arora & A. Gambardella (Eds.), *From Underdogs to Tigers: The Rise and Growth of the Software Industry in Some Emerging Economies*. New York: Oxford University Press.
- Saxenian, A., & Hsu, J.-Y. (2001). The Silicon Valley-Hsinchu Connection: Technical Communities and Industrial Upgrading. *Industrial and Corporate Change*, 10, 893-920.

- Schumpeter, J. A. (1961 (1934)). *The Theory of Economic Development: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle*. Cambridge, Mass.: Harvard University Press.
- SFI (2004). Science Foundation Ireland Website. Dublin: Science Foundation Ireland.
- Shalev, M. (1992). *Labour and the Political Economy in Israel*. Oxford: Oxford University Press.
- Sharkansky, I. (1989). Israeli Civil Service Positions Open to Political Appointments. *International Journal of Public Administration*, 12, 731-748.
- Sharon, E., & Naamen, Y. (October, 1961). Electronic Computers in Taxes and Administrative Services: A Report of a European Survey. Jerusalem: The State of Israel: the chamber of the state's revenues.
- Shefer, D., & Frenkel, A. (2002). An Evaluation of the Israeli Technological Incubator Program and Its Projects, *The Samuel Neaman Institute for Advanced Studies in Science and Technology - IFISE Report*.
- Smith, A. (1937). *The Wealth of Nations*. New York: Modern Library.
- Smyth, J. (2004a). "Fiscal incentive schemes delayed by EU review." *Irish Times* 07/08/2004.
- (2004b). "IBM invests €22 million in Dublin software laboratory." *Irish Times* 05/12/2004.
- SO (1958a). Economic Development. Dublin: Stationary Office.
- (1958b). Programme For Economic Expansion. Dublin: Stationery Office.
- Sterne, J. (2004). *Adventures in Code: The Story of the Irish Software Industry*. Dublin: The Liffey Press.
- Stigler, G. J. (1971). The Theory of Economic Regulation. *Bell Journal of Economics and Management Science*, 3-21.
- Sturgeon, J. T. (2000). Turnkey Production Networks: The Organizational Delinking of Production from Innovation. In U. Jurgens (Ed.), *New Product Development and Production Networks*. New York: Springer.
- (2001). How Do We Define Value Chains and Production Networks? *Institute of Development Studies Bulletin*, 32.
- (2003). What Really Goes on in Silicon Alley? Spatial Clustering and Dispersal in Modular Production Networks. *Journal of Economic Geography*, 3, 199-225.
- Sturgeon, J. T., & Lester, R. (2004). The New Global Supply-Base: New Challenges for Local Suppliers in East Asia. In S. Yusuf, A. Altaf & K. Nabeshima (Eds.), *Global Production Networking and Technological Change in East Asia*. Oxford: Oxford University Press.
- Sturgeon, T. J. (2002). Modular Production Networks: A New American Model of Industrial Organization. *Industrial and Corporate Change*, 11, 451-496.
- Sweeny, P. (1999). *The Celtic Tiger: Ireland's Continuing Economic Miracle*. Dublin: Oak Tree Press.
- TAF (2002). Calendar Year Patent Statistics (pp. <http://www.uspto.gov/go/taf/reports.htm>): U.S. Patent and Trademark Office: Information Products Division - Technology Assessment and Forecast Branch.
- Taylor, C. (2003). "Tech lobby calls for introduction of R&D tax credit in next Budget." *Irish Times* 11/1/2003.

- Teubal, M. (1983). Neutrality in Science Policy: The Case of Sophisticated Industrial Technology in Israel. *Minerva*, 21, 172-197.
- (1993). The Innovation System of Israel: Description, Performance, and Outstanding Issues. In R. R. Nelson (Ed.), *National Innovation Systems*. Oxford: Oxford University Press.
- (1996). R&D and Technology Policy in NICs as Learning Processes. *World Development*, 24, 449-460.
- (1997). A Catalytic and Evolutionary Approach to Horizontal Technology Policies (HTPs). *Research Policy*, 25, 1161-1188.
- (2002). What is the systems perspective to Innovation and Technology Policy (ITP) and how can we apply it to developing and newly industrialized economies? *Journal of Evolutionary Economics*, 12, 233-257.
- Teubal, M., Avnimelech, G., & Gayego, A. (2002). Company Growth, Acquisitions and Access to Complementary Assets in Israel's Data Security Sector. *European Planning Studies*, 10, 933-953.
- Teubal, M., Foray, D., Justman, M., & Zuscovitch, E. (1996). *Technological Infrastructure Policy: An International Perspective*. Boston: Kluwer Academic Publishers.
- Teubal, M., Naftali, A., & Trajtenberg, M. (1976). Performance in Innovation in the Israeli Electronics Industry: A Case Study of Biomedical Electronics Instrumentation. *Research Policy*, 5, 354-379.
- Teubal, M., & Spiller, P. T. (1977). Analysis of R&D Failure. *Research Policy*, 6, 254-275.
- Teubal, M., Yinnon, T., & Zuscovitch, E. (1991). Networks and Market Creation. *Research Policy*, 20, 381-392.
- Trajtenberg, M. (2000). R&D Policy in Israel: An Overview and Reassessment, *NBER Working Paper Series*.
- (2001). Innovation in Israel 1968-1997: A Comparative Analysis Using Patent Data. *Research Policy*, 30, 363-389.
- Tsuk, N. (2004). *Community, State, and Utopia: National Policy and Local Prosperity in the English Garden City and the Israeli Kibbutz*. Unpublished Ph.D., University of Cambridge.
- Van Evera, S. (1997). *Guide to Methods for Students of Political Science*. Ithaca: Cornell University Press.
- Vekstein, D. (1999). Defense Conversion, Technology Policy and R & D Networks in the Innovation System of Israel. *Technovation*, 19, 615-629.
- Vernon, R. (1966). International Investment and International Trade in the Product Cycle. *Quarterly Journal of Economics*, 80, 190-207.
- Wade, R. (1990). *Governing the Market: Economic Theory and the Role of the Government in the East Asian Industrialization*. Princeton: Princeton University Press.
- Wang, W.-C. V. (1995). Developing the Information Technology Industry in Taiwan: Entrepreneurial State, Guerilla Capitalists, and Accommodative Technologists. *Pacific Affairs*, 68, 551-576.
- WB (1993). *The East Asian Miracle - Economic Growth and Public Policy*. Oxford: Oxford University Press.

- Weber, M. (1952). *The Essential of Bureaucratic Organization*. In R. K. Merton (Ed.), *Reader in Bureaucracy*. New York: Free Press.
- (1958). *Essays in Sociology*. New York: Oxford University Press.
- (1999). *Essays in Economic Sociology* (edited by Richard Swedberg). Princeton, N.J.: Princeton University Press.
- White, T. (2001). *Investing in People: Higher Education in Ireland from 1960 to 2000*. Dublin: Institute of Public Administration.
- Woo-Cumings, M. (1991). *Race to the Swift: State and Finance in Korean Industrialization*. New York: Columbia University Press.
- (1999). *The Developmental State*. Ithaca, N.Y.: Cornell University Press.
- Wu, Y. (2001). *In Search of an Explanation of SME-Led Growth: State Survival, Bureaucratic Politics and Private Enterprise in the Making of the Taiwanese Economy (1950-1985)*. Unpublished Ph.D., Leiden University.
- Yaakov, I. (1974). *Industrial Research and Development and University Research in Israel*. Jerusalem: A report prepared by Ithak Yaakov Chief Scientist, Ministry of Trade and Industry and submitted to the President of the State of Israel.
- Yahalomi, L. (1991). *Promoting International Cooperation as a Strategy for Economic Development: A Case Analysis of Israeli and U.S. High-Technology Partnerships (United States)*. Unpublished Ph.D., University of Pennsylvania.
- Yeats, A. J. (2001). Just How Big is Global Production Sharing? In S. W. Arndt & H. Kierzkowski (Eds.), *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press.
- Yin, R. K. (1994). *Case Study Research: Design and Methods*. Thousand Oaks: Sage Publications.
- Zysman, J. (1983). *Governments, Markets, and Growth: Financial Systems and The Politics of Industrial Change*. Ithaca [N.Y.]: Cornell University Press.