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Abstract

The goal of this paper is to provide an overview of R&D policy in Israel, and critically examine the policies currently in place as well as proposals to change them. We review in Part I the various programs of the Office of the Chief Scientist (OCS) of the Ministry of Industry and Trade in Israel, followed by a discussion of studies on the impact of OCS support, and an overview of the rise of the High-Tech sector in Israel with the aid patent data. Part II examines outstanding policy issues and suggestions for reform. It opens with a discussion of allocation schemes for the OCS Grants Program in view of a rigid budget constraint, and an assessment of possible departures from "neutrality". We then examine the payback system, the conditionality of production in Israel, the "Magnet" program for the support of generic R&D, and related issues. Next we review the difficulties in setting a policy target for R&D spending, and lastly we ask whether government policy should perhaps be aimed also at the supply side (of the market for R&D personnel), rather than just keep subsidizing the demand side. Clearly, these policy issues are of relevance not just for Israel but for any economy contemplating active government involvement in R&D.

Key words: R&D Policy, High-Tech, Innovation.

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Introduction

The High-Tech sector in Israel has turned in the course of the last decade into a striking economic success story, both by local and by international standards. In fact, Israel stands as one of the most prolific innovating economies, and as one of the few "Silicon Valley" types of technology centers in the world. There is no doubt that Government policy was key to the emergence and early success of the sector, a policy embedded for the most part in the programs and budgetary resources of the Office of the Chief Scientist (OCS) at the Ministry of Industry and Trade. However, the very success of the sector and its relentless dynamism call for the periodic revision and reexamination of those policies. Moreover, the policy impasse of the late 1990s (due to tight government funding at a time of growing demand for R&D grants) brought to the surface basic tensions that were built into the policies, and that could no longer be ignored.

Interest in R&D Policy as an area of research has experienced recently a marked upsurge within mainstream economics (see for example Klette, Moan and Griliches, 1999, David and Hall, 2000, Jones and Williams, 1998, etc.). This probably reflects the perception that technical advances in Information Technologies (IT) and related areas have had a noticeable and sustained impact on productivity growth in recent years (contrary to the previous uneasiness in that respect vividly articulated in "Solow's Paradox"). Since R&D is driving the relentless flow of innovations that fuel IT and the "New Economy", policies that affect R&D have thus become an attractive field of inquiry. Moreover, advanced economies other than the US, and in particular European countries, see it as a major goal to partake in the processes associated with the current wave of innovations, and therefore their interest in R&D Policy is immediate and pragmatic. So it is for Israel, where early recognition that its comparative advantage resides in its highly skilled labor and world-class academic resources (contrasted to its relatively poor endowment in natural resources) led the Government to actively promote commercial R&D for the past three decades.

The main goal of this paper is to provide the basic ingredients for the understanding of R&D policy in Israel, and to critically assess it in light of recent developments. It consists of a descriptive first part, whereby the various programs of the OCS are laid out in some detail, and a second chapter where we examine the outstanding policy issues. Following a brief account of the functioning and history of the OCS, we review in section I.2 the OCS main programs, including their mission, mode of operation, budget and composition. Section I.2.1 describes the standard R&D Grants Program, followed by the "Magnet" Program, and the Incubators Program; section I.2.4 touches on International Cooperation, including the BIRD Program. Section I.3 presents quantitative indicators of OCS activities over time, including budgets and projects by size of firms, followed in section I.4 by a review of econometric studies on the contribution of the OCS, and an overview of the rise of the High-Tech sector in Israel with the aid patent data.

Part II opens with a discussion of allocation schemes for the regular OCS Grants Program in view of a rigid budget constraint, followed by an examination of possible ways of departing from the principle of "neutrality". Section II.2 deals with a host of related issues, such as the payback system, the conditionality of production in Israel, and the need for ongoing economic assessment of the various programs. Section II.3 attempts to assess the "Magnet" program for the support of consortia engaged in generic R&D, and raises the question of the desirability of supporting it versus the regular commercial R&D projects. In section II.4 we review the difficulties in setting a policy target for R&D spending, and lastly we ask in section II.5 whether government policy should be aimed also at the supply side (of the market for R&D personnel), thus shifting away from the present exclusive focus on the demand side.

It should be emphasized once again that this paper is meant to be first and foremost a ***descriptive account*** of ongoing R&D government programs in Israel, with the goal of providing a suitable framework for a much needed discussion on outstanding policy issues. Hopefully, these issues are of relevance not just for Israel but also for any economy contemplating active government involvement in R&D.

Part I

Government Support for Industrial R&D in Israel: An Overview[1]

I. 1 Background

The beginning of government support for industrial (civilian) R&D in Israel dates back to 1968: a government commission, headed by Prof. Kachalsky, recommended the creation of the Office of the Chief Scientist (OCS) at the Ministry of Industry and Commerce, with the mandate to subsidize commercial R&D projects undertaken by private firms. Support was confined until then to National R&D Labs, and to academic R&D, in addition to the weighty resources that were devoted to defense-related R&D and to agricultural research. And indeed, industrial R&D rose rapidly following the establishment of the OCS. Between 1969 and 1987 industrial R&D expenditures grew at 14% per year, and High-Tech exports grew from a mere $422 million in 1969 (in 1987 dollars), to $3,316 million in 1987 (Toren, 1990).

The next key development was the passing of the "Law for the Encouragement of Industrial R&D" in 1985 (it has been revised several times since). This is the main piece of legislation that has defined the parameters of government policy towards industrial R&D ever since. The stated goals of the legislation, to be implemented by the OCS, are to develop science-based, export-oriented industries, which will promote employment and improve the balance of payments. In order to do this, the legislation was supposed to provide the means to expand and exploit the country's technological and scientific infrastructure, and leverage its high-skilled human resources. The 1985 Law may soon undergo a significant revision, in view of the changes undergone by the High-Tech sector in the course of the last decade, and the budgetary restraint of the late 1990s that has resulted in excess demand for R&D grants under the present system.

At the heart of the law is a program of financial incentives. Companies – whether big corporations or small startups – which meet certain eligibility criteria, are entitled to

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[1] As the title indicates, we confine ourselves to ***civilian, industrial*** R&D. Both defense R&D and academic R&D have played all along a pivotal role in Israel's overall research enterprise, and fueled to some extent the growth of High Tech via a variety of spillovers, but these are beyond the scope of this paper.

receive matching funds for the development of innovative, export-targeted products. The OCS funds up to 50 percent of R&D expenses in established companies, and up to 66 percent for start-ups. The OCS supports and administers a wide range of additional programs, the main ones being: (*i*) "Magnet", a program to encourage pre-competitive generic research conducted by consortia; (*ii*) a program of technological incubators; (*iii*) various programs involving bilateral and multilateral international R&D collaboration. We review these programs here in some detail. Other, relatively minor programs aimed at specific stages along the innovation cycle or at particular segments in the progression from an innovative idea to a full-fledged commercial enterprise are described in Appendix 1. In section I.3 we present quantitative indicators of the various programs.

I.2 A Review of OCS Programs[2]

I.2.1 Support for Standard R&D Programs

This is by far the largest program, and administering it constitutes the main activity of the OCS. The way it works is as follows. Qualifying firms submit grant applications for specific R&D projects, these are reviewed by a Research Committee, and if approved (about 70% are) the applicants receive a grant of up to 50% of the stated R&D budget for the project. Successful projects (i.e. those leading to sales) are required to repay the grant, by paying back to the OCS "royalties" of 3% of annual sales,[3] up to the dollar-linked amount of the grant. Recipients of the R&D grants have to abide by the following conditions: (1) the R&D project must be executed by the applicant firm itself; (2) the product(s) that emerge from the R&D project must be manufactured in Israel; (3) know-how acquired in the course of the R&D may not be transferred to third parties.[4]

[2] We draw for this section from a variety of material from the OCS (see Israel Ministry of Industry and Trade, 1994, 1999a, 1999b and 1999c), as well as from personal involvement with the OCS, in particular with the Magnet Program.

[3] Actually the original payback schedule was as follows: 3 % of revenues from sales of the products developed for the first 3 years; 4% in the next three years, and 5% from the seventh year onwards. This schedule has been revised a few times, and the Treasury has long been pressuring the OCS to increase these percentages, and even impose interest payments.

[4] The Research Committee may grant exemptions to requirements (2) and (3), but as far as I have been able to establish, this has rarely happened.

The Research Committee, chaired by the Chief Scientist, is responsible for defining the conditions for granting aid (within the confines of the 1985 Law), and for reviewing the applications and selecting the recipients. The committee is staffed both by qualified government officials and by public representatives, but it relies on (outside) professional referees and advisers to review the applications. Decisions of the Research Committee can be appealed before an Appeals Committee.

Grants of (up to) 50% of the total R&D costs are given to projects that "lead to know-how, processes or systems for manufacturing a new product/process or substantially improving existing ones."[5] Grants covering 30% of R&D costs are available for projects leading to ***improvements*** in existing civilian products, and 20% for improvements of military products. Start-up companies qualify for grants of up to 2/3 of R&D costs, with a ceiling of $250,000 a year for two years. Products aimed at the military (export) market qualify for grants of up to 30%.

Israel has a long-standing policy of encouraging the development of an industrial base in peripheral areas (away from the main urban centers), which is reflected also in the R&D support programs. Thus, R&D projects performed in the preferential peripheral areas ("Grade A Development Areas") are entitled to additional 10% grants: for civilian projects that means grants of up to 60% (rather then 50% for the others), and military projects are entitled to grants of up to 40% (rather than 30% for the others).

I.2.2 The "Magnet" Program

Notwithstanding the rapid growth of the High-Tech sector in Israel from the late 1960's onwards, it became clear by the early 1990s that the industrial landscape in Israel was too fragmented, and Israeli industrial companies were too small to be able to shoulder the escalating costs of developing new technologies in cutting edge fields. Moreover, Israel boosted world-class research universities, but they operated largely in isolation from surrounding industrial developments and needs, and hence the vast

[5] In the early 1990's the 1985 Law was amended so as to place the software industry on an equal footing with other industrial sectors, so that software development projects qualify for the same type of aid.

economic potential embedded both in the highly qualified academic manpower and in university research remained largely untapped.[6]

Against this background the OCS established in 1993 the "Magnet" Program[7], to support the formation of consortia made of industrial firms and academic institutions in order to develop ***generic, pre-competitive*** technologies.[8] These consortia are entitled to multi-year R&D support (usually 3 to 5 years), consisting of grants of 66% of the total approved R&D budget, with no recoupment requirement. The consortia must be comprised of the widest possible group of industrial members operating in the field,[9] together with Israeli academic institutions doing research in scientific areas relevant to the technological goals of the consortia.

Mindful of possible conflict with anti-trust provisions, consortia members must pledge to make the products or services resulting from the joint project available to any interested local party, at prices that do not reflect the exercise of monopoly power. Keeping with the mandate to encourage pre-competitive technologies, support to the consortia ceases once the equivalent of the "pilot plant stage" is reached. That is, the additional R&D required for the actual commercialization of the products is not supported by Magnet, but the member companies may then apply for regular grants from the OCS. Contrary to the regular OCS support to industrial R&D projects, the Magnet program operates on a competitive basis, that is, it is open to any number of proposals for the formation of new consortia, and it selects only those that merit support on the basis of a ranking system.

By the end of 1999 there were 18 consortia in operation, commanding a budget of about $60 million, and four additional consortia in various stages of gestation. These

[6] Israeli universities have proved also to be highly capable of generating innovations having economic potential (as manifested for example in the large number of US patents assigned to them – see Trajtenberg 1999), but once again weak links with industry have prevented the extensive exploitation of such potential.
[7] "Magnet" is the acronym (in Hebrew) for "Generic, Pre-Competitive Research".
[8] Magnet supports also the integration of advanced technologies into industry via users' associations, but that is a secondary activity.
[9] Participation is limited to Israeli-based companies, or Israeli subsidiaries of foreign companies.

Table 1
Active Magnet Consortia as of December 1999

1.	Ground Stations for Satellite Communications
2.	Digital Wireless Communications
3.	Broad-Wide Band Communication (BISDN)
4.	Multimedia On-Line Services
5.	Diode Pumped Lasers
6.	Multi Chip Module (MCM)
7.	Magnesium Technologies
8.	Hybrid Seeds and Blossom Control
9.	Algae Cultivation Biotechnology
10.	DNA Markers
11.	Drug and Kits Design and Development ("Daa't")
12.	MMIC/GaAs components
13.	0.25 micron/300 mm devices
14.	Ultra Concentrated Solar Energy ("Consular")
15.	Network Management Systems
16.	Digital Printing
17.	Image Guided Therapy ("Izmel")
18.	Computerized Industrial Processes
User Associations:	
1.	Users of Advanced Technologies in Electronics
2.	Users of Advanced Technologies in Metal

consortia span a wide range of technologies, primarily in communications, micro-electronics, biotechnology, and energy. Table 1 shows the complete list.

I.2.3 The Incubators Program[10]

Technological incubators are support organizations that give fledgling entrepreneurs an opportunity to develop their innovative technological ideas and set up new businesses in order to commercialize them. The program was introduced in the early 1990s, when immigration from the former Soviet Union had reached its peak. Many of these immigrants were scientists and skilled professionals that came to Israel with highly valuable human capital as well as with plenty of ideas for innovative products. However, they were lacking in virtually all other dimensions required for commercial success, from knowledge of the relevant languages (e.g. Hebrew and English) and of commercial practices in western economies, to managerial skills and access to capital. Even though it targeted new immigrants, the program is open to all.

The goal of the incubators is thus to support novice entrepreneurs at the ***earliest*** stage of technological entrepreneurship, and help them implement their ideas and form new business ventures. The premise is that the technological incubator would significantly enhance the entrepreneur's prospects of raising further capital, finding strategic partners, and emerging from the incubator with businesses that can stand on their own. Of course, this initial stage is the riskiest, and certainly in the early 1990s there were virtually no other sources of finance in Israel for such ventures. Since the mid-1990s there has been a growing influx of venture capital, and hence it may well be that the purely risk-sharing function undertaken by this program may be less critical at present than what it was at its inception.

Each incubator is structured so as to handle 10 – 15 projects simultaneously, and provides assistance in the following areas: determining the technological and marketing applicability of the idea, drawing up an R&D plan and organizing the R&D team, raising

[10] In addition to the sources already mentioned, we drew material for this section from the internet site of the program, www.incubators.org.il

capital and preparing for marketing, provision of secretarial and administrative services, maintenance, procurements, accounting, and legal advice.[11]

To qualify, projects must be aimed at developing an innovative idea with export potential. The R&D team is to be made of 3-6 workers, and the stay at the incubator is of up to two years. The expectation is that by the end of the period there would be a prototype and an orderly business plan, and the project should be ready for further commercial investment and/or the involvement of a strategic partner. The budget for each project is of about $150,000 per year, for two years at most.[12] As with the regular OCS program, the ensuing products have to be manufactured in Israel, and if successful the entrepreneur has to eventually repay the grant through "royalties" on sales.

Since its inception in 1991 and up to end of 1998, the incubators have managed close to 700 projects, of which about 200 were still running as of December 1998 in 27 incubators across the country. Current projects employ about 900 professionals, 70% of them recent immigrants, all with academic training and many with high degrees. Of the 500 "graduating" projects, the success rate was about 50%, i.e. half managed to continue on their own, the remaining half were discontinued. About 200 projects (out of the successful half) managed to attract additional investment, ranging from a mere $50K, to several $ million. There are no pre-determined technological areas for the submission of projects. The actual distribution of projects by fields has been as follows: Electronics 27%, Software 20%, Medical instrumentation 17%, Chemistry 27%, Miscellaneous 9%.

I.2.4 International Cooperation

The relative advantage of Israel's High-Tech sector manifests itself primarily in its technological prowess in the R&D stages. However, Israeli High-Tech companies

[11] Each incubator is an autonomous not-for-profit organization. Day to day operations are run by a professional (salaried) manager, and next to her operates a projects committee that selects and monitors the projects. These committees are composed of professionals from industry and academia, e.g. corporate executives, R&D managers, professors, etc. Committee members volunteer their time and expertise and do not receive any financial compensation.

[12] The budget for the incubator's administration is of $175,000 per year. This includes the incubator manager's salary, administrative expenses, outlays for sorting and studying of ideas, and organizational expenses for project commercialization and marketing.

suffer from serious difficulties in marketing abroad, primarily because of geographic distance from the target markets, and their relatively small size. Thus, cooperation with foreign companies active in the target markets is likely to increase the ability of Israeli technology and products to penetrate global markets. In that spirit, the Israeli government has signed in recent years a number of bilateral R&D cooperation agreements with foreign governments. These are meant to encourage contacts between Israeli and foreign companies leading to joint R&D, manufacturing and marketing. Foreign companies are expected to benefit by gaining access to advanced Israeli technology, and they are also likely to derive commercial advantages from Israel's simultaneous free trade agreements with the U.S. and the European Union (few countries enjoy both).

Joint ventures between Israeli and foreign companies, authorized by the relevant authorities in the respective countries, are entitled to aid from both governments according to the regulations prevailing in each. Bilateral agreements exist already with a number of countries, including the U.S., Canada, France, Holland and Spain; their implementation is the responsibility of the Chief Scientist, assisted by "MATIMOP" – The Israeli Industry Center for R&D.

The BIRD Program

The Israel-U.S. Binational Industrial Research and Development Foundation was founded in the early 1980s under a convention signed by both governments. Its objective was to "promote and support joint, non-defense, industrial research and development activities of mutual benefit to the (private sectors of the) two countries." The Foundation has an independent legal status and its main office is in Israel. Its Board of Governors is comprised of representatives of the U.S. and Israeli governments.

BIRD participates in the funding of joint R&D via "conditional grants" amounting to 50 percent of the project costs, up to a maximum of $1.5 million per project. If a project succeeds, BIRD receives royalties – a pre-tax expense to the payer – up to a maximum of 150 percent of the conditional grant. Only in cases where a project fails and there are no sales are the companies exempted from repaying the grants. BIRD also helps

Israeli or American companies identify partners in order to enable them to submit joint R&D programs for funding by the Foundation.

I.3 Quantitative Indicators of OCS Support Programs

Systematic data on the OCS are hard to obtain, and in fact there are virtually no "official" statistics on the activities and budgets of the OCS since its creation in 1969. The lack of data has been detrimental to the functioning of the OCS and has surely impaired the formulation of R&D policy at all levels. The OCS has long been aware of the problem, and efforts are being made to remedy it in a fundamental way. The data presented here are based on reports supplied to us by the OCS in January 2000,[13] but there still remain question marks regarding some of the figures, and hence these should be seen as tentative data, which require further scrutiny.

The dollar figures in tables 2 - 4 are all in current dollars; in order to transform them into *constant* dollars one would have to construct an appropriate R&D deflator, of which the main component would be of course the wages of R&D personnel (see section II.4.2 for a detailed discussion of such deflators in the Israeli context). Lacking at present a reliable deflator, and rather than using ready-made but potentially misleading price indices, we opt here to leave the figures in current dollars.[14] Thus, all statements henceforth implying comparisons of dollar figures across time need to be qualified, since these figures are not really in the same units.

Table 2 shows the OCS budget since 1988, as well as paybacks, and the amounts allocated to the Magnet and Incubators program. Total R&D grants administered by the OCS increased steeply since 1988 and up to the mid 1990s, then increased slightly until 1997, and have changed little since. Paybacks rose very fast throughout the whole period,[15] and in fact their weight in the OCS budget has increased dramatically from a mere 7% in 1988 to 32% by the late 1990s. What this means is that about 1/3 of the

[13] The data comes from the office of Lidia Lazens of the OCS, and was supplied by Shai Goldberg.
[14] A common practice is to deflate just by the rate of inflation in the US, but such deflator is in fact irrelevant for the case at hand.
[15] The projections for 2000 indicate that paybacks may have stabilized by now.

present OCS budget just constitutes ***"recycling" of funds within the High-Tech sector, and not Government subsidy to R&D.*** The net subsidy is given in column 4 under "Net Grants": these peaked in 1995, and have since declined slightly (certainly more so in real terms). Furthermore, if we subtract the funds allocated to the Magnet and the Incubators programs, we can see that the ***net*** subsidy to the ***regular*** OCS Grants program has declined very substantially since 1995 (by about 25% up to 1999, in nominal terms).

Table 3 shows the number of firms applying to the OCS for grants, total as well as first timers. Both peaked in 1994 and have declined substantially since. The decline includes, quite surprisingly, also start-ups that applied for the first time.[16] Given the rapid growth in the overall number of startups throughout the economy,[17] the decline in the number of first-time startup applicants may well reflect a change in their funding strategy, that is, more of them may prefer to rely on venture capital funds rather than on the OCS (without "strings attached" in terms of production in Israel or the eventual sale of the firm to foreign corporations).[18] It is worth noting that in the course of the 1990s a total of 2,380 firms applied for support from the OCS for the first time. This is a large number by any standard, and offers further indication of the prominent role that the OCS has played in fostering the High-Tech sector.

Tables 4 (a) – (c) show the distribution of projects and grants by size of firms.[19,20] The annual number of projects supported averaged 1,300 for the past 5 years, declining from a high of 1,500 in 1995 to 1,200 in 1999.[21] On the other hand the average $ amount per project increased from $227,000 in 1995 to $368,000 in 1999 (in nominal terms).

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[16] Start-ups are defined by the OCS as firms of up to 3 years of age.

[17] There are no official figures in that respect, but all indications are that startups have mushroomed in Israel since the mid 1990s. In fact, a recent newspaper report based on the number of startups that hired the services of accounting firms claimed that in 1999 alone 1,500 new startups were formed.

[18] This might also reflect a change in the technology mix of the newcomers, with more of them in Internet applications that represent novel business models rather than novel technology, and hence that may not qualify for support from the OCS.

[19] "Large firms" are defined by the OCS as those with over $100 million in sales; startups refer to firms of up to 3 years of age.

[20] In table 4 some dollar series are aggregated into 5-year totals: these sums obviously don't mean much since the figures are in *nominal* $, but may still be useful as ballparks to compare across firms of different sizes.

[21] This figure refers to projects ***approved***. In fact, the average number of projects applied for is about 1,800.

Table 2
The OCS Budget 1988 – 2000
(in current $ million)

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Year	**R&D Grants**	**Paybacks**	**Paybacks/ Grants**	**Net Grants***	**Magnet**	**Incubators**
1988	120	8	0.07	112	-	-
1989	125	10	0.08	115	-	-
1990	136	14	0.10	122	-	-
1991	179	20	0.11	159	0.3	3.6
1992	199	25	0.13	174	3.7	16
1993	231	33	0.14	198	4.6	23
1994	316	42	0.13	274	10	28
1995	346	56	0.16	290	15	31
1996	348	79	0.23	269	36	30
1997	397	102	0.26	295	53	30
1998	400	117	0.29	283	61	30
1999	428	139	0.32	289	*60*	*30*
2000**	*395*	*128*	*0.32*	*267*	*70*	*30*

* R&D Grants minus Paybacks.

** Estimates

Table 3
No. of Firms Applying for R&D Grants

Year	No. of Firms Applying	First-Time Applicants	
		Total	Start-Ups
1990	451	216	34
1991	576	264	109
1992	626	241	165
1993	661	245	179
1994	777	291	218
1995	715	236	146
1996	705	257	200
1997	643	200	170
1998	629	222	165
1999	598	208	138
total		***2380***	***1524***

Table 4 (a)
No. of Projects Approved
by size of firms

Year	Large	Small & Medium	*of which Startups**	Total
1995	219	1303	*357*	1522
1996	212	1170	*314*	1382
1997	207	1045	*270*	1252
1998	266	1009	*285*	1275
1999	202	960	*245*	1162
Total	1106	5487	*1471*	6593

Table 4 (b)
Grants (in current $M)
by size of firms

Year	Large	Small & Medium	*of which Startups**	Total
1995	144	202	*62*	346
1996	149	199	*66*	348
1997	161	236	*67*	397
1998	157	243	*60*	400
1999	99	329	*68*	428
total	710	1209	*323*	1919

Table 4 (c)
Average Grant/Project (in $thousands)
by size of firms

Year	Large	Small & Medium	*of which Startups**	Overall mean
1995	658	322	*174*	227
1996	703	366	*210*	252
1997	778	466	*248*	317
1998	590	463	*211*	314
1999	490	643	*278*	368
mean	642	440	*220*	291

*not including incubator projects

Notice though that the average size of projects for ***large*** firms declined quite steeply, whereas that of small and medium firms increased a great deal. Large firms commanded about 40% of grants (in $ terms) for most of the period, but their share of the budget declined steeply in 1999, to 23%.[22,23]

I.4 The OCS and the Rise of the High-Tech Sector

So far we have described the structure and programs of the OCS, and presented quantitative indicators of its activities over time. The natural questions that one would like to pose now are those related to the ***impact*** of the OCS, e.g. to what extent has the OCS fulfilled the goals envision by the 1985 Law? What effect have the various OCS programs had on the High-Tech sector and on the economy at large? And so forth. We review first existing econometric studies, we then discuss some economic indicators contrasting R&D-intensive sectors to traditional ones, and lastly we present an overview of the rise of the High-Tech sector in Israel with the aid patent data.

I.4.1 Review of Econometric Studies

The consensual view in Israel is that the OCS played indeed a key role in the emergence and development of the High-Tech sector, a role that went beyond the mere administration of grants. There have been various studies in Israel examining *inter alia* the impact of R&D expenditures on productivity at the firm level (Bregman, Fuss and Regev, 1991, Griliches and Regev, 1995, Bregman and Merom, 1998). They all find that the returns to R&D have been high, and in particular significantly higher than investments in physical capital. However, these studies do not address the effect of government support per se.

If one could assume that OCS grants brought about higher ***total*** R&D outlays (this is commonly referred to as "additionality"), then the findings of high returns to R&D would imply also positive returns to government support. Capital markets were extremely

[22] This was a conscious policy decision by the OCS, meant to cope with the excess demand for support in view of the budget cap imposed by the Treasury.

[23] A report prepared for the OCS in 1999 claimed that large firms commanded 56% of the OCS budget during the period 1985-94. If so there is a declining trend, beyond the one-time policy shift in 1999. However, the figures are not strictly comparable, and hence we cannot assert this with certainty.

limited in Israel during the early stages of development of the High Tech sector in Israel (i.e. in the 1970s and 1980s), and hence it is very unlikely that R&D grants supplied by the OCS would have crowded out private R&D funds back then. Later on though internal reform as well as international openness greatly increased the availability of funds to industry, bringing back to the forefront the additionality issue, certainly for the 1990s.

The basic conundrum posed by additionality is the obvious lack of counterfactuals (i.e. "what would the recipient firm have done had it not received an R&D subsidy?"), which effectively means the lack of appropriate controls (i.e. data on non-recipients that are otherwise similar to the recipients). Several recent papers have tried a variety of approaches to deal with it (see for example Busom, 2000, and Wallsten, 2000), but the jury is still out both on method and on "stylized facts."[24] Feldman and Kelley (2000) come closest to having an appropriate control group: they followed both winners of ATP grants, and applicants that failed to receive grants. Surveying both types of firms, they find *prima facie* evidence of additionality, e.g. non-awardees tend ***not*** to pursue the proposed projects by themselves, awardees are more successful in seeking additional funding for the projects, etc.

Lach (2000) carefully examines this issue for a sample of Israeli manufacturing firms that performed R&D during the period 1991-95, and finds that the R&D subsidies granted by the OCS in fact stimulated long-run company-financed R&D expenditures. According to his estimates, an extra dollar of R&D subsidies increases long run company-financed R&D by 41 cents (evaluating the effect at the mean of the data). Thus, total R&D outlays increase at the margin by 1.41 dollars: the full amount of the subsidy, plus the additional, induced effect of 41 cents. However, it is not clear to what extent those results are robust, both to the choice of specification and of instruments; in fact, in other specifications Lach finds little or no additionality. The problem resides mostly in the paucity of the data (i.e. there are not many firms with any given set of characteristics

[24] David, Hall and Tool (1999) survey a body of recent empirical studies, but do not find robust patterns that could be generalized. On the other hand, using a cross-country, macro economic model, Guellec and Van Pottelsberghe (2000) find evidence of significant additionality effects for 17 OECD countries.

at any point in time that can serve as controls for those receiving subsidies), and in the difficulty in finding appropriate instruments.

Taking a different track, Griliches and Regev (1999) examine whether the source of R&D funds per se (private vs. OCS grants) makes a difference on productivity (once again in a panel of firms), regardless of additionality. They find that it does: government-funded R&D appears to be significantly more productive than privately- financed R&D, by a surprisingly large margin. The reason may be rooted in the ability of the OCS to “pick winners”, and/or in the fact that the very process of applying for grants may compel firms to self-select projects, use more structured pre-assessment and planning techniques, etc. Finally, an unpublished study commissioned by the OCS itself examined the contribution of OCS grants to sales, exports, and the like, relying on detailed data from the OCS and on an extensive survey of firms (Michlol, 1999). The study finds very high “multipliers” per dollar of OCS support, higher for small firms than for large ones; however, the study is careful to point out to its limitations, particularly given the lack of a suitable control group.

The evidence thus far available from these studies provide then econometric support, albeit limited, to the presumption that OCS grants have had a positive and significant impact on productivity in R&D-intensive sectors, and through them on the economy as a whole. Still, there is a long way to go in that respect, if only because a major ingredient of the rationale for government support to R&D, namely spillovers, has not been investigated at all. Beyond the aforementioned studies, we present now some evidence on the development of the High-Tech sector itself, with the implicit understanding that the OCS was one of the main drivers behind the raise of this sector. We do that in two ways: first, we briefly recount reports from the Bank of Israel on the performance of technological advanced sectors vis a vis traditional ones; second, we present an overall view of innovation in Israel, relying on comprehensive and highly detailed information on Israeli patenting in the US.

I.4.2 Aggregate Sectorial Indicators[25]

Responding to the rapid changes in the composition of industry, and in particular the raise of the High-Tech sector, the Research Department of the Bank of Israel introduced in the mid 1990s a new classification of the manufacturing sector: it was divided into "advanced", "traditional" and "mixed" sectors, according to the quality and composition of the labor force (e.g. the percentage of scientists and engineers), the quality of the capital stock, and the relative size of the R&D stock.[26] Table 5 presents selected indicators according to this classification.

The advanced sectors outperformed the two other categories in virtually all dimensions during the reported period (1995 – 98). The differences between them increased substantially in 1997 and 1998, a period characterized by a rather severe recession. During those years the advanced sectors grew at a rate of 6% per year, whereas the others remained stagnant or declined. Similarly, exports from advanced sectors grew at a stunning 18.5% per year, whereas the mixed sectors exhibited an anemic 3% growth, and the traditional sectors ***declined*** 1.4%. Thus, it is clear that Israeli manufacturing is shifting away from traditional industries and into technological advanced, export oriented sectors.

[25] See also Israel CBS (1999a) for further detailed statistics on "advanced" versus traditional sectors.
[26] Thus the advanced sectors include for example electronics and electrical, the mixed sectors construction - related industries, and the traditional ones textiles and apparel.

Table 5
Performance Indicators by Type of Sector
Annualized rates of change, 1995 - 98

		Sector		
Indicator	**Period**	**Advanced**	**Mixed**	**Traditional**
Production	*1995-96*	8.0	6.3	5.9
	1997-98	6.0	0.3	-1.8
Labor Productivity	*1995-96*	3.5	2.4	4.2
	1997-98	4.5	0.6	2.2
Capital Stock	*1995-96*	10.7	6.4	9.7
	1997-98	10.0	6.1	6.8
Exports	*1995-96*	9.0	10.5	2.7
	1997-98	18.5	3.0	-1.4
Source: Bank of Israel, Annual Report for 1998, table B 10 (page 56).				

I.4.3 Innovation in Israel: Patent Indicators[27]

Patent-based statistics are often used as indicators of innovative activity. Indeed, their very wide coverage, long time series and richness of detail make them a unique and compelling data source for the study of technical change. There are also limitations: not all innovations are patented, both because of failure to meet patenting requirements, and because of strategic considerations. We present in this section an overview of innovation in Israel based on all patents awarded to Israeli inventors in the US, during the period 1968 - 97 (over 7,000 patents), as well as patents of comparison countries. Given that the High-Tech sector in Israel is overwhelmingly export-oriented, and that the US is a prime destination for those exports, there is reason to believe that Israeli patents issued in the US are representative of the main technological trends and patterns in Israel.

Figure 1 shows the number of successful Israeli patent applications in the US over time, starting in 1968. The growth in the annual number of patents has been very impressive, starting from about 50 in the late sixties, to over 600 in the late 1990's. However, the process was not smooth, but rather it was characterized by big swings in growth rates. Particularly striking are the two big jumps that occurred in the second half of the period: from 1983 to 1987 the number of patents doubled, and then they doubled again from 1991 to 1995.[28] Figure 2 shows industrial R&D expenditures (in constant 1990 $) along with patents.[29] There is clearly a (lagged) co-movement of the two series, as manifested for example in the following simple Pearson correlations:[30]

[27] This section consists of excerpts from Trajtenberg (1999).

[28] The in-between "flat" period of 1987-91 (which represents R&D activity done *circa* 1985-89) presumably reflects the big macro adjustment and micro restructuring that followed the stabilization program of 1985.

[29] The R&D figures are from Griliches and Regev (1999), table 1. Since these refer to *industrial* R&D, it may be more appropriate to relate them to Israeli ***corporate*** patents than to total patents. In practice the two patent series move pretty much in tandem, and hence the correlations with R&D of either series are virtually the same.

[30] Patent applications reflect (successful) R&D conducted ***prior*** to the filing date, with lags varying by sector. Thus, the number of patents in a particular year should be attributed to investments in R&D carried out in the previous 1-2 years at least, and in some sectors further back.

Figure 1
Israeli Patents in the US - 1968-97
by Application Year

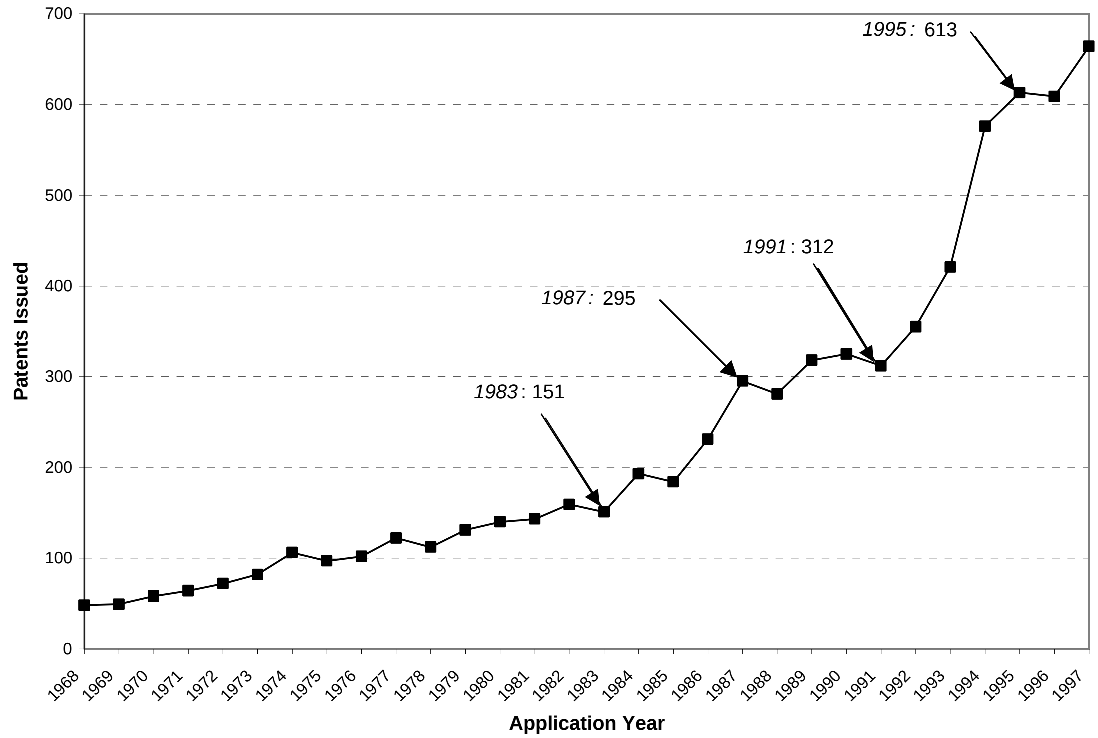
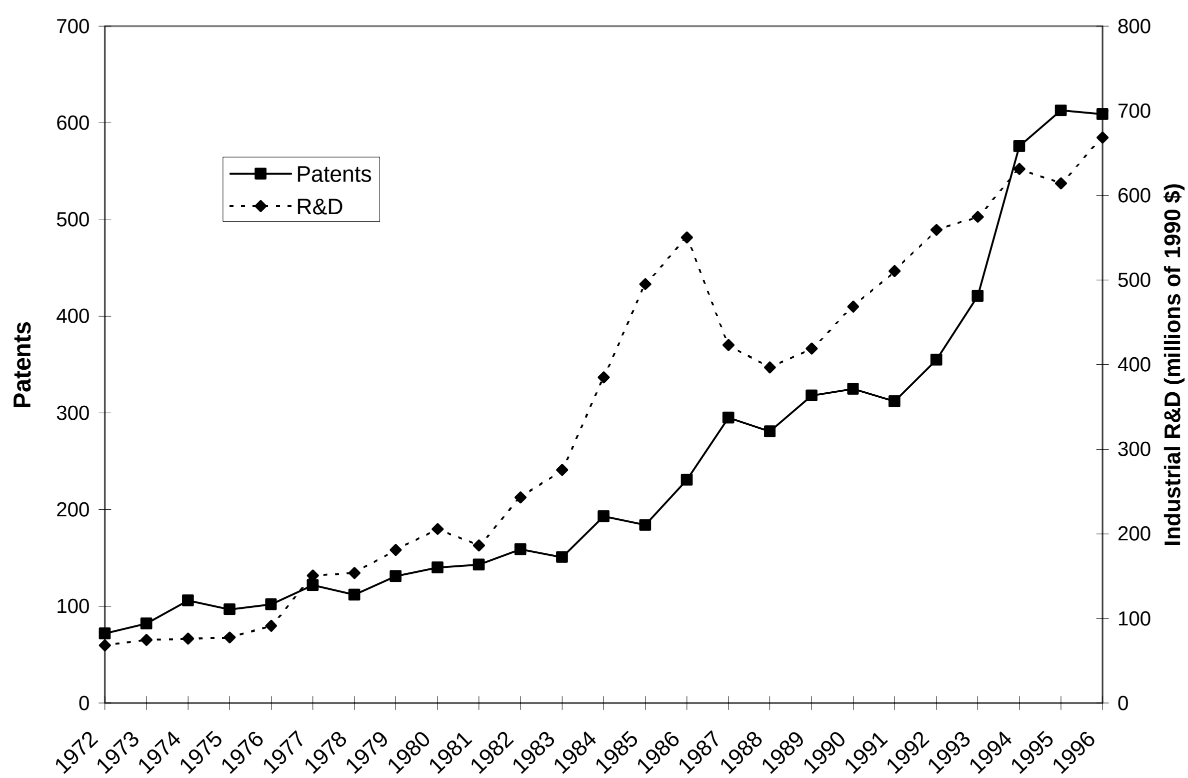


Figure 2
Israeli Patents and Industrial R&D



	R&D	R&D(-1)	R&D(-2)	R&D(-3)
Patents	0.850	0.877	0.884	0.883
Log(patents) with Log(R&D)	0.890	0.901	0.922	0.928

Thus, patents lead R&D by 2-3 years, and the correlation is stronger in rates (i.e. when using logs) than in levels. Looking in more detail, there is a striking run up in R&D from 1981 to 1986 (in particular, R&D expenditures more than doubled between 1980/81 and 1984/85), followed by the doubling of patents between 1983 and 1987. This is the period that saw the emergence of the High-Tech sector, and that is well reflected in both series. In 1986-88 we see a decline in the level of R&D spending, and the concomitant flattening of patenting in 1987-91, and then again a sustained increase through the early-mid nineties that anticipates the second big jump in patenting.

Although we do not have "official" figures for R&D grants from the OCS prior to 1988, available figures indicate that the behavior of the time series for grants move very closely to that of total R&D industrial spending (see for example Griliches and Regev, 1999, table 6). In particular, from 1981 through 1986 OCS grants also doubled, they flattened during 1986-88, and they grew fast again up to the mid 1990s (see Table 2 for the latter). It is clear then that industrial R&D expenditures are closely linked (with a reasonable lag) to patents, and so are R&D grants awarded by the OCS. Further research is needed to unravel the joint dynamics.

International Comparisons

We resort to international comparisons in order to put in perspective the overall level and trend over time in Israeli patenting. We do that with respect to 3 different groups of countries: (1) The G7: Canada, France, Germany, Italy, Japan, UK and USA;

(2) a "Reference Group": Finland, Ireland, New Zealand and Spain;[31] and (3) the "Asian Tigers": Hong Kong, Singapore, South Korea and Taiwan.

Figures 3-5 show the time patterns of patents per capita for Israel versus each of the above groups of countries. We normalize the number of patents by population, simply because this is a widely available and accurate statistic that provides a consistent scale factor.[32] Figure 3 reveals that Israel started virtually at the bottom of the G7 (together with Italy), but by 1987 it had climbed ahead of Italy, UK, and France and was in par with Canada. In the early-mid nineties it moved ahead of Canada and (the unified) Germany, thus becoming 3d after the USA and Japan. Using civilian R&D as deflator for these countries show a similar result. Thus, there is no question that Israel had surged forward and placed itself in the forefront of technological advanced countries, at least in terms of (normalized) numbers of patents.

The comparison with the Reference Group reveals that the only country that is "game" is Finland, which has followed a pattern virtually identical to Israel. The other 3 countries are well behind, and have remained at the bottom without any significant changes over time. As to the Asian Tigers, we can see immediately that Taiwan has grown extremely rapidly since the early eighties, actually surpassing Israel as of 1997. And indeed, Taiwan is widely regarded today as a High-Tech powerhouse, after being associated with low-tech, imitative behavior for a long time. South Korea seems to be embarked on a similar path. By contrast, Hong Kong and Singapore remain well behind.

Comparisons based on ***normalized*** patent counts notwithstanding, many aspects of the innovation process require a "critical mass", and for those purposes it is the ***absolute*** size of the innovative sector that counts, as proxied here by the (absolute) number of patents. Israel has still a long way to go in those terms: it stands well below all

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[31] The Reference Group was chosen according to their GDP per capita in the early 1990's, that is, we chose the 4 countries that had at that time a level of GDP per capita closest to that of Israel (in ppp terms). Notice that, except for Spain, the other 3 countries in this group are very similar to Israel also in terms of population.

[32] Another normalization of interest would be R&D expenditures, but except for the G7, the figures for the other countries are far from satisfactory

Figure 3
Patents per Capita: Israel vs. the G7

(patents per 100,000 population)

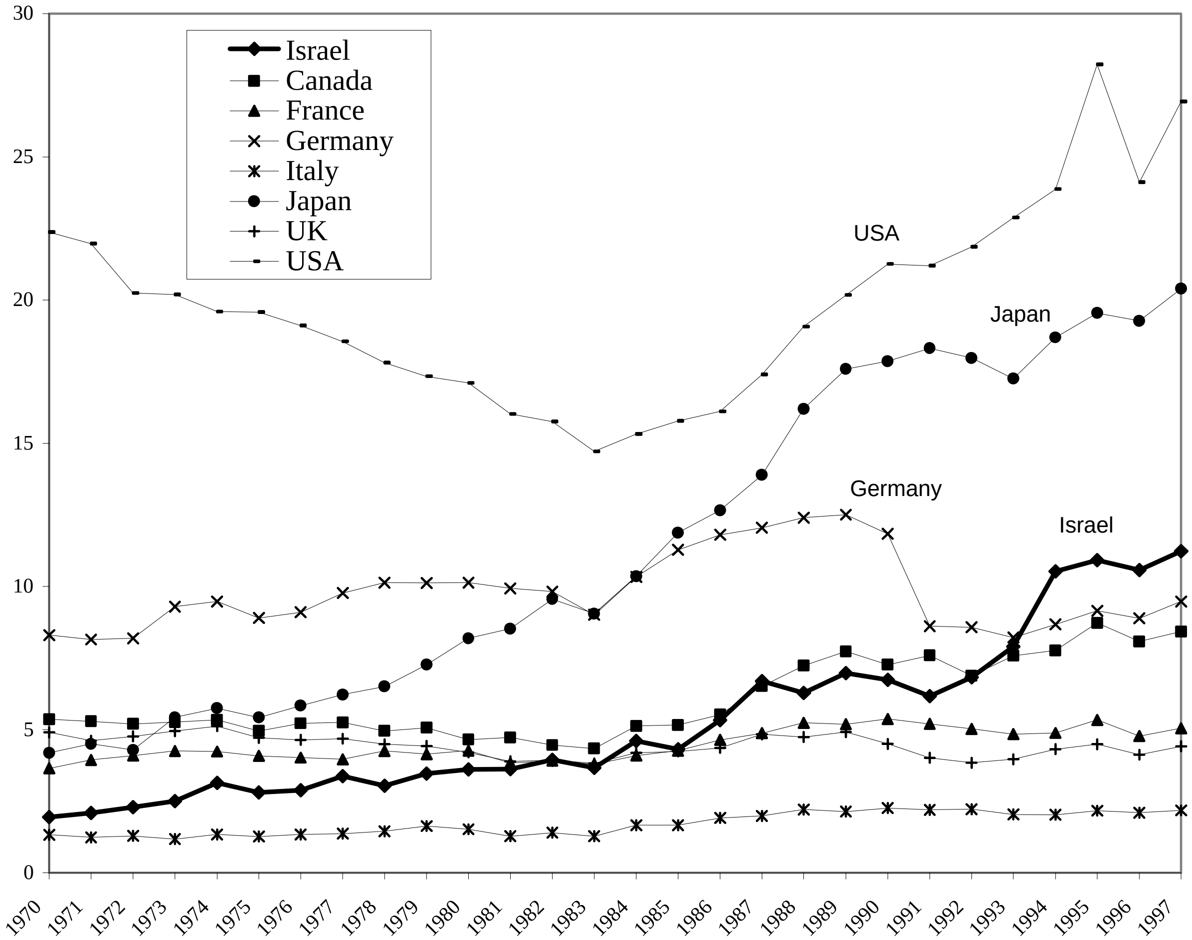


Figure 4
Patents Per Capita: Israel vs. the Reference Group

(patents per 100,000 population)

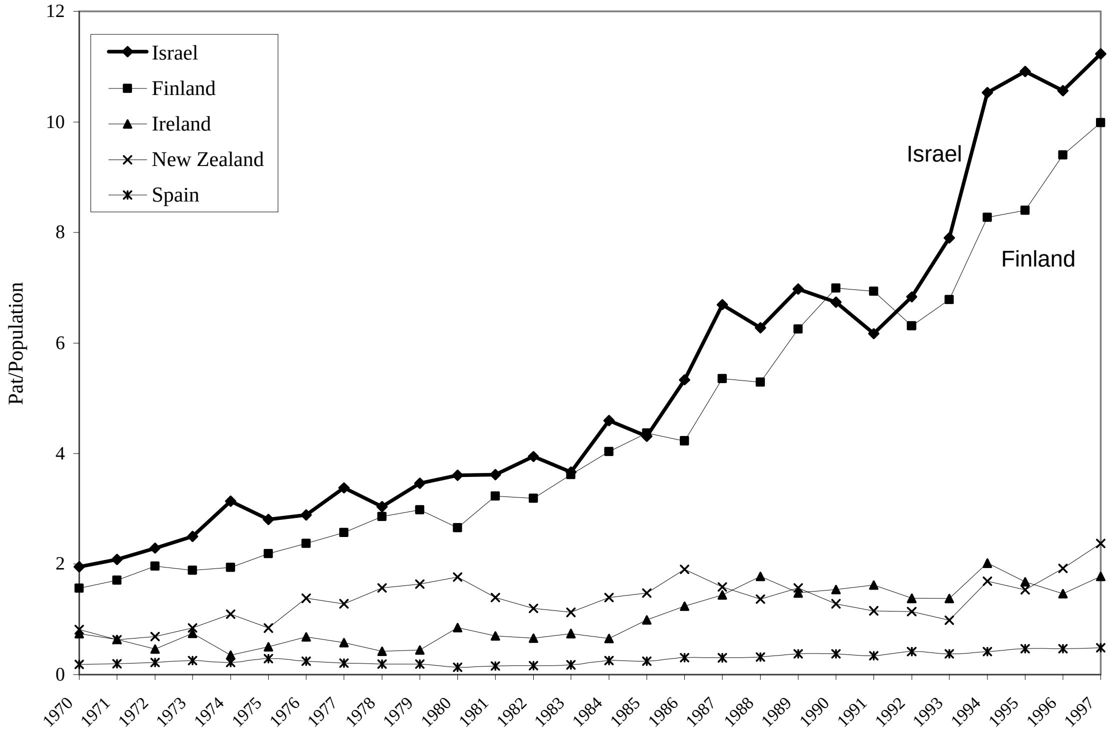
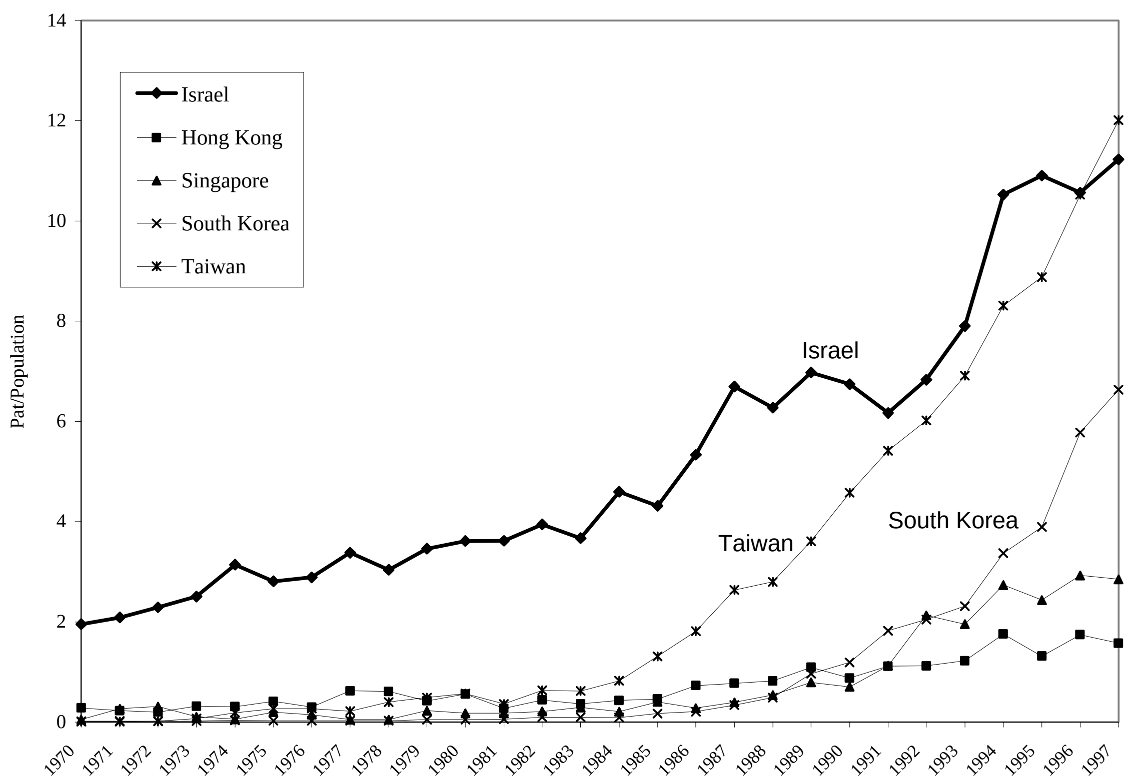


Figure 5
Patents Per Capita: Israel vs. the NIC



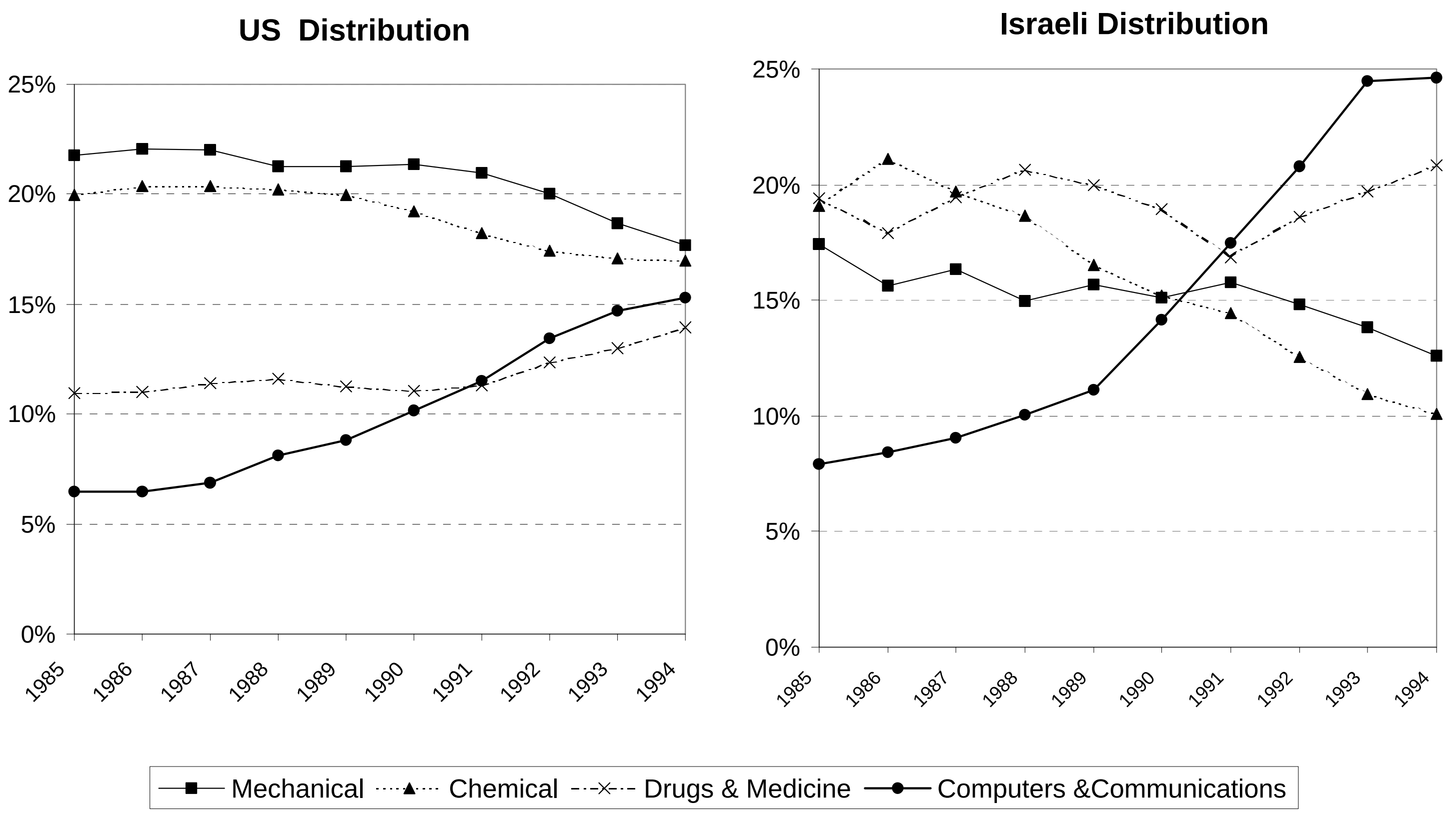
of the G7 countries, and is about ¼ the size of Taiwan and South Korea. The question is whether there are forces in the Israeli economy capable of keeping the momentum going for the High-Tech sector, bringing it up to the size required and ensuring its long-term viability. The stagnant budgets awarded in recent years to the OCS are not a good omen in that respect.

The Technological Composition of Israeli Patented Innovations

The US Patent Office has developed over the years an elaborate classification system by which it assigns patents to some 400 main patent classes, and over 150,000 patent subclasses. We have developed recently a new classification scheme, aggregating these 400 patent classes into 6 main categories: Computers and Communications, Electrical and Electronics, Drugs and Medicine, Chemical, Mechanical and Other. Figure 6 shows the shares of these categories over the decade 1985-94, for Israel and for the US. Up until the early 1980s the picture was quite stable in the US: the shares of Mechanical and Other were highest (over 25% each), whereas Drugs and Medicine and Computers and Communications accounted just for a tiny fraction, up to 5% each. Starting in the early 1980s this static picture starts to change: the 3 top fields decline, whereas the bottom two surge forward, with Computers and Communications accounting by 1994 for over 15% of all patents.

The pattern for Israel is similar, except that the changes are more abrupt. The most striking development is the surge of Computers and Communications from about 5% in the 1970's (as in the US), to a full 25% by 1994 and beyond. Likewise, Drugs and Medicine doubles its share from 10% to 20%. The flip side is the much more pronounced decline in the traditional categories, with Chemicals exhibiting by far the sharpest drop, from 40% at the beginning of the period, to less than 10% by 1996. The composition of innovations has thus changed dramatically in Israel, and seemingly in a healthy way, in the sense that they are in tandem with worldwide changes in technology, except that Israel is experiencing them at an accelerated rate.

Figure 6
US vs. Israel Tech Categories - 1985-94



Who owns, and who benefits from israeli patented innovations?

The patent-based indicators mentioned so far suggest that Israel's innovative performance has been quite impressive. However, the question arises as to whether the Israeli economy can take full advantage of the innovations generated by Israeli inventors, in view of the composition of the patent assignees, i.e. of the owners of the intellectual property rights to those innovations. In fact, just about half of all Israeli patents granted in the last 30 years are owned by Israeli assignees (corporations, universities or government): the rest belongs to private inventors ("unassigned" patents) or to foreign assignees. This percentage is lower than most of the comparison countries, certainly much lower than the corresponding figure for the G7 countries except Canada (local assignees made 74% of patents in the US, 96% in Japan). The presumption is that (local) economic gains from innovation are correlated with this figure, and furthermore, that they are correlated with the percentage of patents owned by local ***corporations*** (just 35% in Israel). The trend is encouraging though: the percentage of patents that belong to Israeli corporations has been raising steadily, and stands now at close to 50%.

The overall picture that emerges from these patent indicators is thus mixed: on the one hand Israel exhibits a rapidly growing and vibrant innovative sector, that has achieved an impressive international standing. On the other hand, the Israeli economy has still a way to go in order to achieve "critical mass" and to realize the economic benefits embedded in those innovations.

Part II
R&D Policy in Israel - A Reassessment[33]

After having described the programs and basic ingredients of R&D policy in Israel towards the industrial sector, we now undertake to examine the contents of such policy. Unfortunately, the lack of rigorous empirical research in this area hampers the formulation of sound, long term and well-grounded policies. Nevertheless, we shall scrutinize the policies currently in place and their implementation mechanisms, and evaluate proposals for changes in them that are called forth by recent developments. This should be seen just as an opening salvo, aimed primarily at fostering public debate in this area (see also Teubal, 1999, who lays out a detailed proposal for an R&D strategy for Israel).

First, we look at the system by which grants are allocated: with the recent imposition of a rigid budget constraint on the OCS, the present system is basically untenable, and hence we examine various alternatives that will incorporate this new reality. Second, we examine a series of policy issues that go beyond the allocation of funds: the payback system, the conditionality on production in Israel, etc. Third, we look in detail into the Magnet program, and the rationale for supporting it versus the regular OCS grants. Forth, we review the difficulties in setting a policy target for R&D spending, and lastly we ask whether government policy should be aimed also at the supply side (of the market for R&D personnel), rather than just keep subsidizing the demand side.

II.1 Rethinking the Rules of the Game in View of a Rigid Budget Constraint

II.1.1 Background

The R&D Law in Israel does not address the thorny issue of how to allocate a (rigid) budget for R&D support if the demand for such support exceeds the budget provision. That is, the OCS support program was not meant to be competitive, and in

[33] As mentioned in the Introduction, a great deal of research on R&D policy has been done recently. Aside from the references mentioned there, see also David et al (1999), Hunt and Tybout (1998), Klette and Moen 1998a and 1998b.

principle it should provide with R&D subsidies to ***all*** projects that pass the eligibility criteria. The latter are based on technological and commercial feasibility, and other procedural considerations. Projects are judged one by one, and there is no attempt to rank them or establish otherwise a funding priority. The paramount principle of "neutrality" that has been a cornerstone of R&D Policy in Israel since the late 1960s precludes also picking projects according to fields or any other such consideration.

In 1997 the projected demand for R&D support greatly exceeded the budget provision (by about 50%, i.e. some $200 million), and the Treasury refused to consider any substantial increase to the OCS budget to accommodate such demand.[34] An impasse ensued, bringing a great deal of uncertainty to the working of the OCS and to the High-Tech sector as a whole. A committee was formed to try to find a way out of the crisis. After months of deliberations the committee could not reconcile the conflicting forces at play: on the one hand the imperatives of the existing law, the expectations of the High-Tech sector based on it, and the perceived need to expand the R&D support budget in order to accommodate and foster the success of the High-Tech sector; and on the other hand the sudden imposition of a rigid budget constraint, that did not allow for any growth of demand.

The result has been ad hoc tinkering both with the OCS budget and its way of operation, in order to keep the system running without solving the underlying issues. More importantly, this protracted crisis made it clear that the R&D law as is, and the implementation mechanisms in place, are in need of extensive revision in view of the explosive growth of the High-Tech sector (as well as the rapid changes that took place within the sector), and the pressure that puts on the R&D support budget in an era of fiscal restraint.[35] Following is a discussion of the set of policy issues that lie at the core of this conundrum. The basic premise underlying the discussion is that, if current procedures

[34] Apparently this was the first time in the history of the OCS that demand exceeded the budget provision by a substantial amount.
[35] Indeed, in January 2000 the Government initiated a move aimed at revising the R&D Law, in view of this fundamental conflict, as well as of the dramatic changes that have taken place in the High-Tech sector.

are left unchanged, demand for R&D support will exceed present level budgets by wide margins,[36] and hence there is an urgent need to design a suitable allocation mechanism.

There are essentially two ways to go about allocating a fixed budget to projects that request support in excess of available resources. The first is to depart from the principle of neutrality in some dimension, the second to design an allocation mechanism that would do the job. Of course, the two are not mutually exclusive, and one could have a combination of both. We consider each in turn, starting from the latter.

II.1.2 Allocation schemes for the regular OCS program of R&D grants

Until now the system has been such whereby all eligible projects are supposed to be supported, and in principle the support should be equal across projects (in percentage terms). The eligibility criteria entail checks of technological and commercial feasibility (or "viability"), the good standing of the applicants, and other administrative criteria. There are three main options to move away from such system: (*i*) to adjust every time the support rates or the eligibility criteria so as to meet the budget constraint; (*ii*) to implement a competitive/ranking system; (*iii*) randomization.

The first option entails adjusting the support ***rates*** or the eligibility criteria with every new budget so as to meet the budget constraint. The major drawback is of course the uncertainty that such a policy shift will introduce, greatly impairing the ability of firms to plan ahead (certainly long term). In addition, this would make the whole support system vulnerable to political manipulation.

The second option simply means that projects would have to compete against each other for scarce support funds (as happens with the "Magnet" program). There will be a ranking system, and the funds will be allocated from the top down until the budget is exhausted. A serious issue that will almost certainly arise in such context is whether or not such system is compatible with neutrality, in view of the fact that any ranking system will be extremely hard to implement ***across*** fields, and the ranking would have to be done

[36] Some projections indicate that would be true even if the budget were increased substantially.

primarily ***within*** fields.[37] However, it may be that in any case the system will have to move away from neutrality (see below).

The last option is some sort of randomization, that is, to chose at random from the set of projects that pass some eligibility threshold (as in the present system), up to the point where the budget constraint is met. We shall not analyze this option in any detail, simply because it would seem that it is (at least at present) politically unfeasible.[38] Thus, it seems that the only viable alternative at this point is to implement some sort of ranking/competitive system, as suggested above, and tie it with a conscious departure from neutrality.

II.1.3 Departures from Neutrality

As already mentioned, one of the hallmarks and basic premises of the OCS support programs has been all along ***neutrality***, that is, the OCS does not select projects according to preferred fields or any such criteria, but responds to demand that arises spontaneously from industry. It is fair to say that such policy has been eminently successful, since it basically reinforced existing competencies and emerging comparative advantage. Moreover, it avoided one of the main potential dangers of any industrial policy, namely, the "picking of winners" by government officials.

However, the fiscal constraint on the overall support budget implies that the OCS may have to depart from neutrality in any case, in which case it is certainly better to do it explicitly as a result of serious analysis, and not by default. There are at least two dimensions along which the OCS could opt for non-neutral allocation policies: according to fields, and according to type (or rather size) of firms.[39] As already suggested, such

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[37] It is quite likely that the present system in actuality is not neutral either, but the lack of neutrality is disguised. In a ranking system the issue rises to the surface and will have to be addressed head on.

[38] It is interesting to note that there is a great deal of interest in this policy both in the US and in Europe, and it would seem that at some point some version of randomization will be implemented. One of the great advantages (in the long run) of such a policy is that it allows for methodologically sound assessment studies of the efficacy of government support (since the "control sample" is built in).

[39] In fact, it would seem that, while formally neutral, actual support policies favored particular technological areas, primarily electronics, and until the mid 1990s large firms over smaller ones (see below).

departures could be made part of a revamped allocation scheme (e.g. adopting a ranking / competitive system).

Departing from neutrality in terms technological fields is always dangerous, since it implies outguessing future technological and/or market developments, and deciding "by committee" what is better left to the market. Thus, one should avoid it except if there are some glaring market failures that need to be remedied. There is room to believe that may be the case at present in Israel with the field of biotechnology. Israel has a very talented and plentiful scientific workforce in Life Sciences. Yet, this pool of human capital in one of the most dynamic technological areas at present, and potentially one of the most important *future* growth areas, has yet to make a mark on industry (i.e. in biotech). Thus, there is room to consider taking a more active and entrepreneurial attitude towards this sector (not necessarily by channeling more funds to it) but that requires further study. The second possible departure from neutrality is differential support to firms of different sizes. We discuss this option now in more detail.

II.1.4 Departing from neutrality: Large vs. small firms

In principle, the support policies of the OCS do not make any distinction among types of firms in terms of eligibility for the existing flat rate of support (50% of the approved R&D budget).[40] In practice though and as described in Part I, the support for large firms during the past two years has been reduced, reversing the previous trend whereby a handful of very large firms (large by Israeli standards) accounted for a large proportion of the total support dispensed. However, this ***de facto*** change has been essentially an ad hoc response to budgetary pressures (and hence is likely to be temporary), and not a well formulated policy reassessment. Thus, we still have to examine whether the principle of equal support to all firms regardless of size is a reasonable policy. In other words, the question is whether the rationale for R&D support (in terms of market failures etc.) holds equally for small and large firms. A brief review of the basic economic rationale for support to R&D reveals that indeed there is room to

[40] Except for the incubators program, as described in Part I.

(re)consider the prevailing policy, and reduce the rate of support to large firms versus smaller ones.

First, the larger is the firm, the more able it is to internalize the spillovers that it generates, and hence the smaller would be the divergence between the social and the private rate of return on the R&D that it performs. One of the main goals of government support to private R&D is precisely to bridge the gap between the two rates of return: absent that support firms will do too little R&D (relative to the ***socially*** desirable level), and hence the support is meant to encourage them to increase that amount, pass what is profitable according to the ***private*** rate of return on it. However, the more a firm manages to capture the spillovers that stem from its R&D projects, the less there is room to subsidize it on that basis. Size matters in that respect: small firms are hardly able to capture the externalities that they generate, but that ability increases as they grow larger.

A further rationale for government support of R&D has to do with risk and risk taking. First, the degree of risk of an R&D project from an economy-wide point of view may be lower than that perceived by private firms; or, closely related, the risk premium demanded by private investors may be higher than "warranted" because of asymmetric information. Second, the degree of risk aversion by private investors may be higher than the social rate. As a result, the market may provide for too little risk taking in R&D, and hence government support would encourage firms to move in the socially desirable direction.

The point in the present context is that there might be substantial differences in this respect between small and large firms. First, problems of asymmetric information are usually more acute for younger/smaller firms, and hence the risk premium that smaller firms are required to pay is often much higher. Second, R&D projects undertaken by small firms are, ceteris paribus, riskier than if done by larger firms, even if they are exactly the same in terms of technological goals. This is so because younger/smaller firms are disadvantaged relative to large firms in terms of a wide range of competencies and experience that are *complementary* to R&D, be it in marketing, pure management, access to complementary know how, etc. Thus, there is more room to subsidize risk taking by small firms than by larger ones.

Lastly, imperfections in capital markets usually affect small firms more than large firms. First, the availability of internal financing, which has been shown to be important in the context of R&D, is normally less constraining for older/larger firms than for smaller ones. Second, access to global capital markets is easier/cheaper for larger firms. Thus, government support to R&D meant to bridge over those imperfections ought to be channeled more towards small firms than to larger ones.

These considerations suggest that there is room to consider supporting small firms at higher rates than larger firms. One could envision the following support structure: Going start-ups (up to 5 M$ sales):[41] 66%; small to medium-sized firms (5 – 100 M $ sales): 50% (as at present); large firms (over 100 M $): 33%. This is of course just an example – a serious proposal would have to pay a great deal of thought to the cut-off levels, the implications for the budget, etc.

II.2 Further Policy Issues

II.2.1 The payback scheme ("Recoupment")

At present the policy is that successful projects (i.e. projects that eventually lead to sales) are required to pay back to the OCS the amount of support received, but the payback cannot account for more than a small percentage of annual sales.[42] The idea is that this way the OCS shares the risk of the R&D projects (effectively lowering the risk premium that private firms have to pay), and overcomes possible imperfections in capital markets by offering easily accessible finance. Moreover, it subsidizes R&D both in that it demands zero interest on the conditional loan, and in the sense already mentioned of lowering the risk premium. There are, however, serious drawbacks to such a system:

[41] By start-ups we mean young, small ongoing firms, not those that are still in the "incubator" phase.
[42] The percentage was set at 3%, but there have been several attempts by the Treasury to raise it further (to 4.5%), and even to charge interest on the principal. In fact, the Treasury has been promoting the idea that the grants should turn into a conditional loan, which will serve as a way of overcoming financial constraints by R&D firms, but not as a straight R&D subsidy.

- Since the payback obligation applies to sales that stem directly from the projects supported, this immediately creates moral hazard problems in terms of how projects are defined, and all sort of pernicious incentives as to how to relate products/sales to projects.
- The previous issue implies that the OCS and the firms supported find themselves engaged in an antagonistic/confrontational situation, that is detrimental to the efficient functioning of both.
- As we have seen in Part I, the weight of payback funds in the overall OCS budget is growing steeply over time, and there is a real danger of "political opportunism" in this respect, namely, that the commitment to R&D support may diminish but in the short run that could be disguised by the increased reliance on payback funds in order to support new projects.

Beyond those issues, the payback scheme may have had the unintended consequence of blurring the real intent of the R&D law, obscuring the true extent of the support budget, and hence the commitment of the government to R&D. As we have seen, such support is warranted for good economic reasons, that call indeed for a subsidy to R&D. Contrary to some widely held perceptions, the intent and rationale of the R&D law is not for the Government to assume just a financing role, in view of imperfections in existing financial markets in Israel. The main intent is to bridge the gap between the social and the private rate of return to R&D, and that calls for a straight subsidy. The recent availability of venture capital, and the opening of the Israeli economy to foreign capital markets may reduce the effective cost of capital and perhaps also the risk premiums to Israeli High-Tech firms. However, that has nothing to do with the fact that these same firms generate spillovers to the Israeli economy that they can only partially appropriate, a fact that calls for subsidizing R&D.

Thus, there is room to consider the phasing out of the payback scheme, or at least the offering of an alternative track consisting of a lower subsidy rate but without a payback proviso. If the payback scheme is eliminated, the R&D grants given by the OCS would become strictly and overtly what they were set out to be, namely, a straight subsidy, hence doing away with the hazards of political opportunism.

II.2.2 The conditionality of production in Israel

The R&D Law stipulates that if the OCS extends support to an R&D project, the innovation resulting from it should be produced in Israel. In fact, the Law states as one of its goals to increase employment in such a way. It should be clear that such conditionality might lead to serious allocational inefficiencies. Denote by c_I the costs of producing in Israel, by c_A the costs of producing abroad, and by S the R&D subsidy. It is trivial to show that, if $c_I - c_A < S$, the firm will choose to take the R&D subsidy, execute the project in Israel and produce there even though production in Israel is more costly than abroad. If the inequality is reversed then the project will be carried out abroad altogether (including the R&D). Denote the cost disadvantage by $S' = c_I - c_A$. In the case where $c_I - c_A < S$, we can see that the R&D subsidy is in fact composed of two parts: $S = S' + (S - S')$. The first part, S', is then a subsidy to *production*, not to R&D, and only the second part is a true R&D subsidy. The larger is the gap between production costs in Israel versus those abroad, the more the R&D grants are in fact subsidizing inefficient production, that quite likely would not be otherwise located in Israel.

Thus, there is room to consider the elimination of this provision of the law: there is no strict economic rationale for it, and it leads as said to production inefficiencies. Israel presumably has a comparative advantage in R&D, not in the assembly of “boxes” containing the sophisticated innovations produced there. It should be clear also that if this conditionality is repealed, then the *effective* R&D subsidy could be increased without increasing the actual amount of funds disbursed. Denote by S_N the new subsidy, then one could have $(S - S') < S_N < S$. Of course, the Government can legitimately try to encourage local employment, and see the R&D Law as one of the means to do so. In that case though it should be clear that part of the grants constitute in fact an ***employment subsidy***, and should not be counted as R&D support.

II.2.3 Policy changes and support to large firms

We suggested above that the rate of support to large firms could be set a lower level than that to smaller firms. However, we envision the implementation of these policy changes as a comprehensive package. In that case, while lowering the rate of "nominal" support to large firms, the effective rate may actually increase, both because of the phasing out of recoupment, and of the conditionality to produce in Israel. This latter provision is likely to affect larger firms more than smaller ones, since for larger firms the options and opportunities to produce abroad are much more extensive. As to the payback scheme, it is also likely that the percentage of successful R&D is higher for them, and hence that the payback burden is also disproportionally higher for larger firms. On both accounts then larger firms stand to gain from the repeal of these provisions, thus compensating for the lower support rate.

II.2.4 Ongoing economic assessment and policy making

The drawing of sound economic policies towards R&D, innovation and the High-Tech sector is of paramount importance for the Israeli economy. At present though there is no body in charge of setting such policies, and hence things happen in a rather haphazard way, in response to point-wise pressures and developments. What is needed is an economic policy unit, probably at the OCS, with the following mandate: *(1)* to collect and organize in a comprehensive and coherent way the data needed for policy making; *(2)* to set procedures for the ongoing evaluation of the effectiveness of the OCS policies; *(3)* to evaluate, research and discuss long term policies. It is interesting to note that the Advanced Technology Program in the US, which is the closest to the OCS in terms of intent, has such a unit as integral part of its mission and mandate.

II.3 The Magnet Program versus the Regular OCS Fund

As already mentioned, the Magnet program supports consortia of industrial firms and academia, aimed at developing "generic, pre-competitive technologies" common to the members of the consortia. Magnet finances 2/3 of the R&D budget of the consortia with straight grants, and there is no payback obligation. Contrary to the regular program of the OCS, Magnet selects consortia on a *competitive* basis, and allocates in this manner a budget of about 60 million $/year to the winning consortia.

One of the phenomena that underlies the need for the Magnet program is the fact that R&D efforts in the Israeli High-Tech sector have been rather fragmented. That is, this sector is characterized by the existence of a very large number of small to medium firms, a handful of large ones (but none with sales of over 1 billion $), and a great deal of turnover.[43] There is no question that the vitality, daring and some spectacular successes of the sector owes in no small measure to these features, that provide favorable conditions for an accelerated Darwinian process. On the other hand, these same features call into question the ability of the sector, and of the Israeli economy as a whole, to reap the long term economic benefits from its own success. The recent sales of a series of highly successful Israeli companies to foreign corporations is just one of the manifestations of this syndrome.

Fragmentation was perhaps unavoidable, certainly in the initial stages of development of the High-Tech sector, since the overwhelming majority of High-Tech firms grow out of start-ups established by single technological entrepreneurs. Moreover, most of them aim (at least initially) at narrowly defined market niches. As the sector moves on though size matters: in order to tackle larger markets and contemplate accordingly longer term projects, there is need for larger entities, and that in turn calls for various forms of cooperation, joint ventures, mergers and acquisitions. However, for reasons that we do not profess to understand, too little seems to be happening in that respect *internally* (i.e. within Israel). In fact, we witness time and again not only failures of cooperation, but even serious informational failures, in the sense that potential partners are unaware of the existence of each other, and/or of the potential for mutually beneficial cooperation.[44]

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[43] Consider that the OCS have dealt with R&D projects of about 3,000 firms in the past 15 years, and keep in mind that, as said before, the whole industrial R&D of Israel amounts to that done by the number 28th R&D spender in the US, 3M (see Table 6).

[44] I am a member of the Board of Directors of Magnet, and in that capacity I have witnessed many times this sort of "failures", not only between firms but also between firms and academia. One of the most striking was the case of the digital printing consortium: the main players involved were unaware until the

Given this background, the importance of Magnet may lie not so much in its formally stated mission (i.e. supporting *generic* R&D), but in the fact that it fosters cooperation, it facilitates the creation of larger (sometimes "virtual") entities, it disseminates information about possibilities for joint ventures, and it encourages individual firms to seek such information. Contrary to deeply-rooted belief, one cannot just ***assume*** that if there are profitable opportunities for cooperation they will necessarily be realized - the institutional framework definitely has an impact in that sense.

It is therefore quite certain that the economic rationale for government support to R&D is stronger for a program such as Magnet, both because of the aforementioned reasons, and because of more traditional (but equally important) motives, namely, that it deals with "generic" projects and strongly emphasizes the sharing and dissemination of information. Thus, there is room to consider the expansion of Magnet as a policy instrument, perhaps increasing the share of the overall R&D support budget that it administers. There are a host of specific issues having to do with the way the Magnet Program is implemented, but that is beyond the scope of this paper.

II.4 How Much Support to R&D?

II.4.1 Is there a basis for setting a policy target?

As we have seen in section I.3, the budget of the OCS has stabilized since 1997 at a level of about $400 million per year, following a decade of rapid growth. The High Tech sector has been lobbying for further increases, claiming that OCS grants play a key role in lowering R&D costs and hence in fueling innovation, in making Israeli companies more attractive to foreign investors, and in compensating for geo-political disadvantages.[45] The government has refused, arguing that the massive influx of Venture Capital and other forms of financing in recent years (primarily IPO's in Nasdaq) prove

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formation of the consortium of crucial research on properties of ink that was being conducted at some academic institutions in Israel (virtually "next doors").

[45] The High Tech sector is actually split in this respect: on the one hand the traditional electronics sector demands bigger budgets for the OCS; on the other hand, Internet-related ventures and some of the new software developers lobby instead for favorable tax breaks, particularly with regard to capital gains.

that there is hardly a need for further R&D subsidies, and that in fact there may be room to reduce them. The result has been an impasse in policy making towards this sector, and the concomitant uncertainty has probably had a detrimental effect on it.

Stepping out from the political economy aspects of the issue, the question is, how should we think about setting a desirable level of R&D support? Is the current level of $400 million "appropriate", and if not what sort of policy gradient should the government pursue? As we shall see, these questions pose serious conceptual and empirical difficulties that are well beyond the scope of this paper. Thus, we shall content ourselves just with outlining these difficulties, in the hope that they will soberly inform the policy debate and prompt further, much needed research.

The basic premise underlying the sort of "neutral", across-the-board R&D subsidies that the OCS dispenses is that, left to its own, the market will undertake too little R&D. If so, the question of how much R&D subsidies should the government give out amounts to asking how much of its resources should a country (in this case Israel) allocate to R&D? If this "optimal" R&D allocation exceeds the actual one, the R&D support budget should then be set so as to close the gap between them. Thus, there are two distinct problems to tackle: assessing the presumed gap between actual and optimal R&D spending in the economy, and devising ways to bring the economy to the desired level (and perhaps mix) of R&D spending through a subsidy program such as that of the OCS. Notice that the latter necessitates first and foremost a reliable estimate of the "additionality" factor.

Unfortunately, existing literature provides little guidance regarding the assessment of the gap, be it in modeling or in empirical implementation. One notable exception is Jones and Williams, 1998: they take the social rates of return to R&D estimated in a series of studies by Griliches and others (e.g. Griliches 1994, Scherer, 1982), and use them (as well as their own estimate) in the context of a Romer (1990) growth model to derive the optimal R&D to GDP ratio. Jones and Williams find that the US devotes far too little resources to R&D, and that even taking a lower bound of 30% for the social rate of return to R&D, the optimal R&D/GDP ratio may be ***2 to 4 times higher*** than the present one of about 2.2%.

It is not clear though whether the results of Jones and Williams and the concomitant policy implications can be readily extended to other countries. First, the optimal R&D/GDP ratio depends critically on the ratio of the social rate of return to R&D, to the economy-wide real rate of return (e.g. the long term return on the stock market). On both accounts a country such as Israel may differ substantially from the US. Second, Jones and Williams consider R&D in the context of a close economy; in an open economy, whereby some of the benefits from own R&D spill over to other countries (see for example Coe and Helpman, 1995), the notion of a "social" rate of return is far less clear.

Eaton, Gutierrez and Kortum (1998) provide further support to the notion that countries may be underinvesting in R&D. They laid out a detailed model of the R&D process and of the transmission of research outcomes across countries (based on Eaton and Kortum, 1996), and proceed to calibrate it for the European Union countries, and to simulate its responsiveness to various policy levers. One of their conclusions is that increasing research activity in most European countries could make a substantial contribution to productivity levels not only in the EU but throughout the OECD. However, Eaton, Gutierrez and Kortum stop short of endorsing the channeling of additional resources into R&D, and they certainly do not attempt to compute an "optimal" R&D/GDP ratio that could serve as an actual target for policy in any specific country. Still, their conclusions are congruent with a policy gradient of increasing R&D/GDP ratios, at least for most European countries.

II.4.2 R&D Ratios as Yardsticks for Policy

Much of the discussion in the literature on R&D policy is cast in terms of various R&D ratios, particularly in terms of the ratio of total civilian expenditures on R&D to GDP (in short, R&D/GDP). Countries compare each other in terms of these ratios, and often set targets based on averages for various reference groups (e.g. the European Union, the OECD, etc.) This is so not only because the amount of resources devoted to R&D obviously cannot be divorced from total resources available, but also because there is indeed a great deal of uncertainty in this respect, and hence political feasibility and expedience often requires such linkages.[46] Israel is no exception, and indeed Israel's standing vis a vis other countries in terms of R&D/GDP ratios figures prominently in the current debate. While they surely may play a useful role in informing policy making, we would like to argue that these ratios should be considered with great caution as yardsticks for policy, both because of measurement problems, and because of the importance of "critical mass" in the R&D context.

The measurement of R&D expenditures poses serious challenges to statistical agencies, both because it is very difficult to delimit the scope of what counts as R&D, and because of difficulties in computing appropriate deflators. Ever since the publication and widespread adoption of the Frascati Manual in the 1980's, there has been remarkable progress in achieving international harmonization in terms of what constitutes R&D. However, the changing nature of innovative activities poses renewed problems at every turn, as is the case for example with many types of software development and Internet-related innovations.[47] Prompted by the sense that existing data collection procedures failed to account for substantial portions of R&D activities, the Israeli Central Bureau of Statistics (CBS) introduced in the late nineties a new and much more detailed survey of Business Sector R&D (BSRD), that resulted in drastic revisions of previously available estimates. Thus for example the newly computed BSRD for 1997 was 44% higher than the previous estimate, and as a consequence the R&D/GDP ratio jumped up by about half a percentage point to 3.1 for that year, reaching 3.5 in 1999.[48]

[46] Thus, advocating a move towards the mean R&D/GDP ratio of a "relevant" group of countries is politically easier to justify than persistent divergence from such reference ratios.
[47] Regarding the Internet, it is often hard to distinguish between developments that are purely the result of entrepreneurship as opposed to being the outcome of R&D as traditionally defined.
[48] These are the latest (and still preliminary) ratios computed by CBS for international comparisons. CBS (1999) reports a R&D/GDP ratio of 2.3 for 1996, the latest such official figure there. The revisions put the figure for that year at 2.8, so the increase in the ratio due to the new survey is at least of half a percentage point.

The revision that the CBS has undertaken exemplifies the difficulties of setting policy according to these ratios: until the publication of the revised figures, existing estimates indicated that Israel's R&D/GDP was about average relative to the OECD, and moreover, that Israel's BSRD constituted a significantly smaller proportion of total R&D than in other countries (about 50-55%, compared to a median of 62% for the OECD). Thus, if these ratios were used as yardsticks for policy, it would have been reasonable to advocate further support to BSRD so as to increase its share, a move that would have resulted also in a moderate increase in the R&D/GDP ratio.[49] The current figures put Israel at the upper end of OECD countries in terms of R&D/GDP ratios, and about average in terms of BSRD/R&D. Thus, international comparisons of this sort would render at present very different policy recommendations.

The second measurement problem is that of devising appropriate deflators for R&D expenditures. The practice at the CBS has been to compute for each R&D-performing sector an index based on the average wages in the sector on the one hand, and the costs of materials and capital outlays on the other hand (each component weighted by its appropriate share in R&D). However, a survey of wages conducted separately by the CBS (as part of its general survey of labor and wages), indicates that wages for ***R&D personnel*** in the business sector rose much faster than average wages in the sector. Thus, computing a deflator based on these wages renders a very different picture, as can be seen in the following comparison (see below for further discussion on the new index):

Annual Average Rate of Growth of BSRD: 1994 – 1999 *(using revised figures based on new CBS survey)*[50]	
In nominal Israeli Shekels	21%
Deflated by the CPI	12%
Deflated by the CBS R&D deflator (1994-98, prior to revision)	7%

[49] See for example an earlier version of this paper, Trajtenberg (2000).
[50] We inflated the old 1996 figure by a factor of 1.44 (recall that the new estimate for BSRD 1997 was 44% higher than the previous one) in order to compute the rate of change for 1996-97. From then on we used the new figures.

Deflated by new index based on wages of R&D personnel in business sector*	~ 3%
**Provisional computations, hence figure is approximate only*	

The impressive growth of BSRD in the past half-decade (12% per year, CPI-adjusted) is thus greatly attenuated when deflating it by the new and still provisional index, i.e. just about 3% per year. Of course, the R&D/GDP ratio would be significantly lower as well if we were to compute it on the basis of these “real” magnitudes. Once again, these disparities are just meant to illustrate the extent to which the figures that might serve us as guideposts for policy are sensitive to the way we treat these measurement issues.

The second problem with international comparisons of R&D ratios for policy is that of critical mass. Contrary to other areas where the ***relative*** amount of resources may constitute a good enough yardstick (such as in health or education), what determines the impact of R&D on the economic performance of the economy is in many cases the ***absolute*** and not the relative amount invested. That is so basically because there are substantial indivisibilities in R&D both at the micro and macro levels. At the level of individual projects and/or firms, a wide range of technological areas require the commitment of relatively large amounts of R&D in order to make these projects at all feasible (in other words, the minimum efficient scale of projects in such areas is large). Thus, the development of communication satellites requires R&D budgets of hundreds of millions of dollars, and so do new ethical drugs.

At the economy-wide level, the conduct of R&D requires a vast array of supporting infrastructure and services, the availability of adequate manpower (not only scientists and engineers but also supporting personnel of various sorts), and of financial institutions and markets. All of these would come into being only if “enough” R&D is being carried out to justify the emergence of the required infrastructure, venture capital institutions, etc. Moreover, the ability of firms conducting R&D to capture the spillovers generated by others in the same region/country depend as well on the existence of a sufficiently large nearby R&D sector. This latter factor can be critical for the chances of the high sector in the country to become a “Silicon Valley”. Thus, it is hard to compare R&D/GDP ratios for countries that vary a great deal in size, particularly when the differences are so extreme as between the US or Japan and Israel.[51]

Furthermore, the extent to which comparisons of R&D ratios are informative (and potentially telling from a normative point of view) depend *inter alia* on the growth strategy that the countries being compared have chosen. Israel has embarked long ago in a growth path that relies heavily upon the promotion of High-Tech, export-oriented sectors, reflecting its perceived comparative advantage in high-skilled labor. By contrast, countries such as Spain or New Zealand, while comparable to Israel in terms of current GPD per capita, have chosen a very different path (recall Part I, and Figure 4). Thus, while a R&D/GDP ratio of about 1% for Spain might be adequate given ***its*** growth strategy, Israel’s much higher ratio may still be below mark.

In order to gain further perspective on the issue of absolute versus relative size of expenditures in R&D, consider Table 6, where we list the leading industrial R&D performers in the US, and compare them to Israel as a whole. Thus, in 1997 the absolute amount of resources allocated to civilian R&D in Israel was $3,129 million, of which $2,006 million was business sector R&D.[52] That same year eight of the leading industrial R&D performers in the US spent ***over 2 billion $*** in R&D, ***each of them*** more than Israel’s industrial sector as a whole. To put it differently, ***all*** of Israel’s business sector R&D amounted to the R&D done by Pfizer, and was slightly less than the R&D done by Johnson and Johnson. If we took instead Israel’s total civilian R&D, that would place Israel as number 4, just in between IBM and Lucent. These gaps are well reflected also in patent statistics (see Trajtenberg, 1999): Israeli inventors were granted in 1997 a total of 653 patents, of which slightly less than half went to Israeli corporations, i.e. about 320 patents. By contrast, that same year IBM was granted 1,758 patents, Motorola 1,151, Intel 407, Hewlett-Packard 537, General Electric 667, and so forth.

[51] If one could compute an optimal R&D/GDP ratio for different countries, chances are that it would be a concave, decreasing function of size.
[52] These figures are based on the revised estimates produced by the CBS on the basis of their new survey. The previous estimates placed Israel much lower in that scale: 16th in terms of BSRD, and 7th in terms of total R&D.

Table 6

The 15 Leading Industrial R&D Companies in the USA, and Israel R&D Expenditures in 1997			
1997 Rank	**Company**	**R&D Expenditures**	
		Millions $	**R&D/Sales %**
1	General Motors	8,200	4.9
2	Ford Motor	6,327	4.1
3	IBM	4,307	5.5
Israel's Total Civilian R&D		***3,129***	
4	Lucent Technologies	3,100	11.8
5	Hewlett-Packard	3,078	7.2
6	Motorola	2,748	9.2
7	Intel	2,347	9.4
8	Johnson & Johnson	2,140	9.5
Israel's Business Sector R&D		***2,006***	
9	Pfizer	1,928	15.4
10	Microsoft	1,925	16.9
11	Boeing	1,924	4.2
12	Chrysler	1,700	2.9
13	Merck	1,684	7.1
14	American Home Products	1,558	11.0
15	General Electric	1,480	1.7

Source: NSF Science and Engineering Indicators - Top 500 Firms in R&D by Industry Category,1999. http://www.nsf.gov/sbe/srs/nsf00301

II.5 Prop up demand, or stimulate supply?

As mentioned in Section I, the basic premise underlying Israeli R&D Policy has been all along that Israel enjoys a comparative advantage in high-tech, science-based industries, because of the abundance of high-skilled labor and scientific personnel. This, coupled with the presumption that the market is likely to underinvest in R&D, provides the rationale for the direct subsidization of industrial R&D, as done through the OCS programs. Viewed from the vantage point of the market for scientists and engineers, such policy is one that stimulates demand, implicitly assuming that supply is sufficiently elastic so as to provide the additional personnel called forth by the government supported R&D.

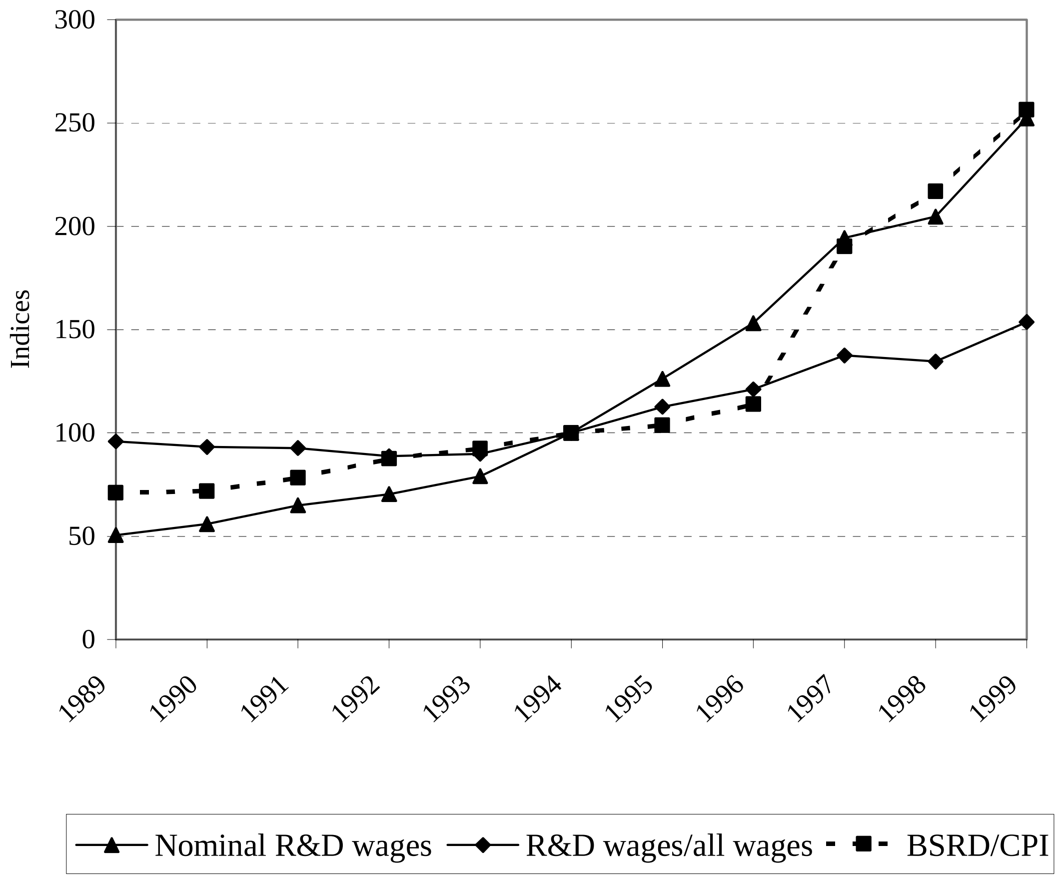
Figure 7 casts serious doubts on this set of premises: wages of R&D personnel in the business sector have risen extremely fast in the second half of the 1990's, much faster than economy-wide wages (by 1999 the index of wages in R&D had risen 54% more than all wages). Clearly, the dramatic increase in R&D outlays by the Business Sector during the same period fueled the inflation in wages of R&D workers.[53] Mirroring these developments, there is plenty circumstantial evidence of severe shortages in computer scientists and engineers, software developers, and related personnel.[54] The picture that emerges is thus of a very ***inelastic*** supply curve for qualified R&D workers in recent years, which implies that any additional financial resources channeled into BSRD would achieve little increase in real R&D in the short run, and instead would keep fueling wage inflation (see Goolsbee, 1998, for a similar argument regarding the effect of Government-supported R&D in the US).

Shortages of highly skilled personnel in cutting edge technologies seem to be a pervasive, worldwide phenomenon in recent years, certainly in the US as well as in

[53] The series for BSRD depicted in Figure 7 is not entirely consistent, in that the figures for 1997 onwards are those of the new survey of R&D in the Business Sector, which as said showed a large increase in the scope of R&D done by the sector. Thus, while the increase from say 1993-94 to 1997-98 is plausible, the path of the series in between is not necessarily accurate.

[54] As reflected for example in statistics of job openings, as well as the frequent reports of increasing difficulties of existing companies in retaining R&D personnel.

Figure 7
Indices of Wages in R&D and Business Sector R&D
(1994: 100)



leading European countries.[55] Romer (2000) suggests that existing institutional arrangements in the US higher education system limit the “supply response” to these market signals, and hence necessitate corrective policy changes. In essence, the incentive system within universities is not necessarily conducive to the timely supply of graduates in fields of high demand, both in terms of the number of students admitted to different fields, the mix of courses offered, the channeling of graduate students into lengthy, often dead-end post-doc positions, etc.[56] Thus, Romer advocates a shift of focus in government policy towards R&D, from the traditional subsidization of R&D itself that stimulates the ***demand*** for scientists and engineers, to programs that would directly encourage the ***supply*** of newly trained qualified manpower. In light of the trends depicted in Figure 7, it is clear that government policy towards R&D in Israel ought to address ***both*** sides of the market: the relative abundance of qualified manpower is no longer to be taken for granted, and there are plenty of institutional rigidities and frictions in the educational system to cast doubt on its ability to respond by itself in a timely fashion to market needs.

One specific problem in Israel in this respect, is that there are relatively large groups of the population that have acquired significant levels of “general” human capital, but not the skills that are required for the High Tech sector, and that essentially do not participate in the relevant labor markets. These are primarily ultra-orthodox Jews, Israeli Arabs, and residents in the “development towns” located in the geographically more distant areas. The impediments to their partaking in the job opportunities offered by the “New Economy” are numerous, ranging from cultural barriers to geographical isolation. It is clear that tapping their potential could alleviate the shortages alluded to, and at the same time improve the economic standing of these groups.[57] This would involve providing the appropriate training, setting up an institutional framework that would allow

[55] One of the related, hotly debated policy issues in many countries is the extent to which foreign high tech workers should be allowed in. This has become also a highly controversial issue in Israel.
[56] Romer’s view would seem to contradict Rosenberg’s (1999, 2000), who has persuasively argued that one of the key sources of strength underlying the technological and scientific prowess of the US has been the responsiveness of Universities to market needs and new technological developments. However, it could well be that what had characterized universities throughout most of the 20th century does not quite hold in recent years, and/or that the pace of change has accelerated, and hence the response of universities seems more sluggish now.
[57] These are mostly in the lowest income brackets, and account for a large fraction of the unemployed.

their employment in the High Tech sector without violating their cultural sensitivities, and investing in infrastructure to bring them closer to the centers of economic activity.

The case of Bangalore in India exemplifies the wide range of possibilities opened in terms of employing skilled labor in R&D-related activities from the distance, without the workers having to migrate and adapt to the environment of the employer. Indeed, as documented in Arora and Arunachalam (2000), a large part of the burgeoning software sector in India does subcontracting development work for US-based firms. It would seem that a similar model could be applied ***within*** Israel vis a vis the population groups mentioned above, that is, provide them with training *in situ*, and employ them in ***their*** communities via subcontracting employment relationships. There seem to be a host of coordination failures that prevent that from happening without intervention, and hence there is room for the government to undertake a facilitating role.

Developments in the labor markets associated with High Tech have of course wider implications. In fact, one of the most striking trends in the Israeli economy of the past two decades has been the rapid rise in pre-tax income inequality. Attempts by the government to keep a lid on after-tax inequality have necessitated a dramatic increase in the share of the budget (and of GDP) going to welfare, a trend that seems unsustainable. The rapid rise in the relative wages of workers in the High Tech sector has undoubtedly contributed to the growing income gap in recent years. Clearly, policies that shift up the demand for these workers would further increase inequality, at least in the short run, whereas policies that stimulate the supply response would presumably do the opposite. This is obviously a normative issue, and hence it lies well beyond the scope of this paper. However, what is becoming increasingly clear is that, as the sectors and activities associated with advanced technologies gain in importance throughout the economy, policies towards them would have to be guided by a wider set of considerations, including their distributive implications.

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Appendix 1
Additional Support Programs of the OCS

Beyond the main programs described above (the "regular" R&D Grants, Magnet, and the Incubator Centers), the OCS offers a variety of additional assistance programs, aimed at specific stages along the innovation cycle or at particular segments in the progression from a innovative idea to a full-fledged commercial enterprise. Although much smaller in terms of budget, these programs may play an important role in making sure that potentially viable projects don't fall in between the cracks along the hazardous way towards successful commercial implementation. Following is a concise description of some of these programs.

1. Bridging Aid

This program offers support for the transition between R&D and manufacturing and marketing. The intention is to enable companies that have completed the R&D stage to manufacture a number of prototypes for installation on the premises of potential clients, especially abroad. In the case of chemical innovations, the program supports the setting up of a pilot plant, enabling the manufacturer to obtain feedback on the performance of the new product or process.

Companies with sales of up to $6 million may receive a grant of 50% for these purposes, whereas larger ones (with annual sales of up to $30 million) are eligible for 30% grants. Total approved spending may not exceed $600,000 over a 30-month period. Recognized "transition period" expenses generally include:

- Construction of prototypes;
- Adaptation to standards in foreign countries;
- Registration of the product for marketing abroad;
- Operation of a pilot plant, not including construction costs;
- Patent registration fees.

2. Aid in Establishing Industrial Incubators

The goal of this program is to encourage ***established*** companies to develop cooperative start-ups in new technological areas, taking advantage of the companies' existing infrastructure, finance and management. The OCS grants 66% of the approved R&D outlay, up to a ceiling of $300,000 annually for a maximum of two years. Thereafter the projects would qualify for standard R&D grants. The program is aimed at scientific entrepreneurs (including new immigrants), who are required to create a cooperative framework with an established Israeli industrial company, having previous R&D experience and annual sales of at least $5 million.

3. Sub-contracting Industrial R&D

This program supports the carrying out of civilian R&D projects for foreign companies, by Israeli enterprises acting as subcontractors. The goal is to initiate joint ventures with foreign partners, so as to help Israeli companies market their technologically advanced products abroad. The OCS grants up to 20 percent of the approved R&D costs. The Israeli subcontractor must be an industrial company with annual sales of up to $100 million, and the R&D project must be in a new area for the Israeli company.

4. Exploratory Studies for Industrial R&D Projects

This program supports studies of the market potential for new technologies, prior to the investment of large sums in the R&D stage. It is intended primarily for start-up companies, or those with limited R&D experience. However, established companies interested in exploring new subjects not included in their current areas of activity are eligible as well. The program extends grants of 50% of approved costs, up to $30,000. The studies are to be carried out by experienced, external consulting companies, authorized by the OCS.