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Innovation in Israel 1968–1997: a comparative analysis using patent data ☆

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Abstract

The Israeli high-tech sector is widely regarded as a hotbed of cutting-edge technologies, and as the growth engine of the Israeli economy in the 1990s and beyond. In this paper we present a close-up portrait of innovation in Israel for the past 30 years, with the aid of highly detailed patent data. We use for that purpose all Israeli patents taken in the US (over 7000), as well as US patents and patents from other countries for comparative purposes. The time path of Israeli patenting reveals big jumps in the mid 1980s and then again in the early 1990s, reflecting underlying "shocks" in policy and in the availability of relevant inputs. Israeli ranks high in terms of patents per capita, compared to the G7, the "Asian Tigers" and a group of countries with similar GDP per capita. Finland is strikingly similar, Taiwan's patenting has grown extremely fast and is now on par with Israel, South Korea is rapidly closing the gap. The technological composition of Israeli innovations reflects quite well worldwide technological trends, except that Computers and Communications, the fastest growing field in the US, has grown even faster in Israel. The weak side resides in the composition of Israeli assignees, the actual owners of the intellectual property rights: just 35% of Israeli patents were assigned to Israeli corporations, a much lower percentage than in most other countries. Relatively large shares went to foreign assignees, to Universities and the Government, and to private inventors. On the other hand, Israeli patents are of good "quality" in terms of citations received (and getting better over time): US patents command on average more citations, but not in Computers and Communications or in Biotechnology, and Israeli patents are significantly better than those of the reference group of countries.

JEL classification: 03; 034; 053; 057
Keywords: Patents; Citations; Israeli economy; High-tech

1. Introduction

In the aftermath of the 6-day war, Israel embarked in an ambitious course aimed at developing "high-tech" industries, as a means to exploit its perceived comparative advantage in world-class academic resources and highly skilled labor (contrasted to its relatively poor endowment in natural resources). The government undertook to actively support industrial

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R&D aimed primarily at export markets, in addition to harnessing the spillovers from a sophisticated defense R&D sector. And indeed, the last two decades have seen a surge of activity in high-tech fields in Israel, ranging from computer software to communications equipment to advanced medical devices to biotechnology. As a consequence, Israel is widely regarded as one of the few Silicon Valley type of technology centers outside the US, and has turned into an attractive location for R&D operations of leading multinationals.

We intend in this paper to provide a close-up portrait of the Israeli high-tech sector with the aid of highly detailed patent data, drawn from all patents granted in the US to Israeli inventors, and to US patents granted to other countries. We shall address questions such as: How does Israel fare vis-a-vis other countries in terms of patenting activity? What is the technological composition of its innovations? Who actually owns the intellectual property rights, and to what extent can the local economy expect to benefit from the innovations done by Israeli inventors? How do Israeli innovations compare to those of other countries in terms of their "importance" as reflected in patent citations? In addressing these questions we hope not only to shed light on the case of Israel, but also to demonstrate the power of this type of data for studying innovation in great detail and, in particular, for examining in a comparative fashion the innovative performance of countries and regions.

The reason for focusing on Israeli-held patents granted in the US is clear: if innovations are pursued primarily for export, it is the property rights in the *target* countries that have to be protected. True, Israel exports a great deal also to Europe, but it is usually the case that patents are sought first and foremost in the US (where the standards for patentability are more stringent than in most european countries).[1] Thus, one can hopefully learn a great deal about export-oriented technologies by analyzing the Israeli patents granted in the US. From the early 1960s through 1998 Israel-based inventors received about 7000 patents in the US. This is a large (absolute) number, and it placed Israel as the 14th largest foreign recipient of US patents, ahead of some OECD countries such as Norway and Spain.

Adam Jaffe and I have developed in recent years a methodological approach that allows one to study innovation in great detail with the aid of patent data, and not just to rely on patent counts.[2] In particular, building both on detailed information contained in patents and on patent citations, we can compute for each individual patent quantitative indicators of notions such as the "importance", "generality", and "originality" of patents (see Trajtenberg et al., 1997). We can also trace the "spillovers" stemming from each patent, and analyze their geographical and temporal patterns (e.g. are spillovers geographically localized? see Jaffe et al., 1993). Moreover, we have constructed a large data bank containing information on all US patents granted from 1963 to 1996[3] that allows us to compute this sort of measures for any subset of patents. This is a powerful capability that greatly enhances our ability to do empirical research in the area of the Economics of Technical Change.

The paper is organized as follows: beginning with a concise discussion of the data in Section 2, we then examine in Sections 3 and 4 the main trends in Israeli patenting, both in itself and in comparison to three groups of countries: the G7, a group of countries with GDP per capita similar to Israel (Finland, Spain, Ireland and New Zealand), and the "Asian Tigers" (Taiwan, South Korean, Hong Kong and Singapore). Section 5 deals with the technological composition of Israeli innovations, relative to that of the US. In Section 6 we look in detail at the distribution of Israeli assignees, in an attempt to elucidate the all important issue of who really controls the rights to the intellectual property embedded in these patents, and hence who can expect to benefit from it. Section 7 undertakes to examine the relative "importance" or "quality" of Israeli patents vis-a-vis other countries, in terms of citations received. Section 8 offers concluding remarks.

[1] In any case, casual evidence indicates that there is a strong correlation between patenting in the US and patenting in Europe.

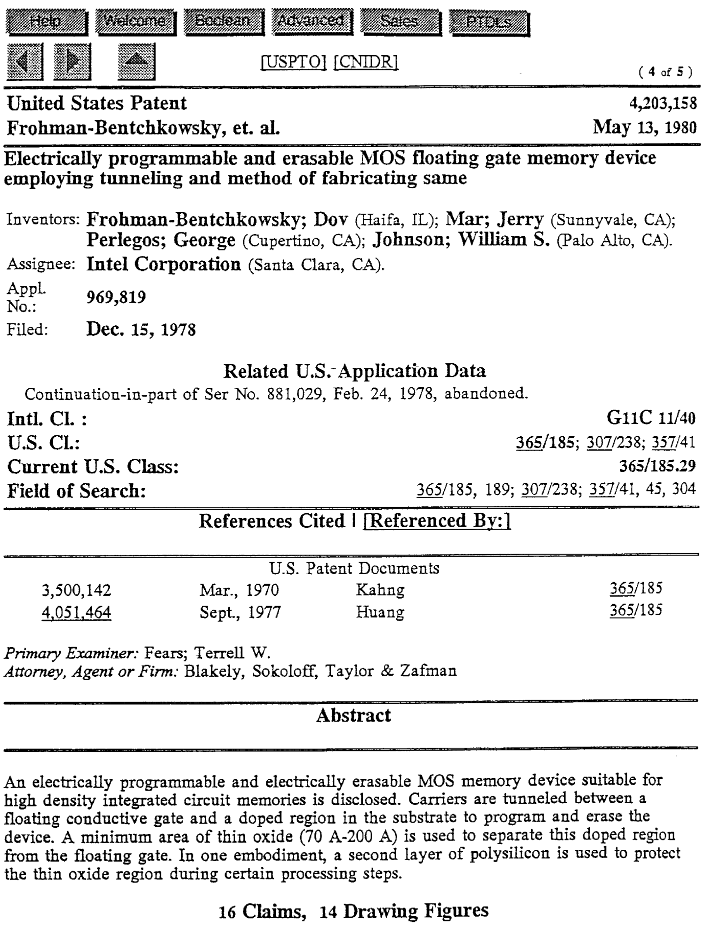
[2] Rebecca Henderson of MIT also participated in the initial stages of this endeavor, and Bronwyn Hall of Berkeley and Oxford has been involved in it for the past few years.

[3] With the assistance of Michael Fogarty and his team at Case Western University.

2. Data

A patent is a temporary monopoly awarded to inventors for the commercial use of a newly invented device. For a patent to be granted, the innovation must be non-trivial, meaning that it would not appear obvious to a skilled practitioner of the relevant technology, and it must be useful, meaning that it has potential commercial value. If a patent is granted, an extensive public document is created. The front page of a patent contains detailed information about the invention, the inventor, the assignee, and the technological antecedents of the invention, all of which can be accessed in computerized form (see Fig. 1).

These extremely detailed and rich data have, however, two important limitations: first, the range of *patentable* innovations constitutes just a sub-set of all research outcomes, and second, patenting is a *strategic* decision and hence not all *patentable* innovations are actually *patented.* As to the first limitation, consider an hypothetical distribution of research outcomes, ranging from the most applied on the left to the most basic on the right. Clearly, neither end of the continuum is patentable: Maxwell's equations could not be patented since they do not constitute a device (ideas cannot be patented). On the other hand, a marginally better mousetrap is not patentable either, because the innovation has to be non-trivial.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[USPTO] [CNIDR] (4 of 5)

United States Patent **4,203,158**
Frohman-Bentchkowsky, et. al. **May 13, 1980**

Electrically programmable and erasable MOS floating gate memory device employing tunneling and method of fabricating same

Inventors: **Frohman-Bentchkowsky; Dov** (Haifa, IL); **Mar; Jerry** (Sunnyvale, CA); **Perlegos; George** (Cupertino, CA); **Johnson; William S.** (Palo Alto, CA).
Assignee: **Intel Corporation** (Santa Clara, CA).
Appl. No.: **969,819**
Filed: **Dec. 15, 1978**

Related U.S. Application Data
Continuation-in-part of Ser No. 881,029, Feb. 24, 1978, abandoned.

Intl. Cl. :	G11C 11/40
U.S. Cl.:	365/185; 307/238; 357/41
Current U.S. Class:	365/185.29
Field of Search:	365/185, 189; 307/238; 357/41, 45, 304

References Cited | [Referenced By:]

U.S. Patent Documents

3,500,142	Mar., 1970	Kahng	365/185
4,051,464	Sept., 1977	Huang	365/185

Primary Examiner: Fears; Terrell W.
Attorney, Agent or Firm: Blakely, Sokoloff, Taylor & Zafman

Abstract

An electrically programmable and electrically erasable MOS memory device suitable for high density integrated circuit memories is disclosed. Carriers are tunneled between a floating conductive gate and a doped region in the substrate to program and erase the device. A minimum area of thin oxide (70 A-200 A) is used to separate this doped region from the floating gate. In one embodiment, a second layer of polysilicon is used to protect the thin oxide region during certain processing steps.

16 Claims, 14 Drawing Figures

Fig. 1. United States patent.

Thus, our measures would not capture purely scientific advances devoid of immediate applicability, as well as run-of-the-mill technological improvements that are too trite to pass for discrete, codifiable innovations.

The second limitation is rooted in the fact that it may be optimal for inventors *not* to apply for patents even though their innovations would satisfy the criteria for patentability. For example, until 1980 universities in the USA could not collect royalties for the use of patents derived from federally funded research. This limitation greatly reduced the incentive to patent results from such research, which constitutes about 90% of all university research in the USA. Firms, on the other hand, may elect not to patent and rely instead on secrecy to protect their property rights.[4] Thus, patentability requirements and incentives to refrain from patenting limit the scope of analysis based on patent data. It is widely believed that these limitations are not too severe, but that remains an open empirical issue.

Our working hypothesis here is that, whereas these limitations may affect *level* comparisons across fields/industries and perhaps also across countries *at a point in time*, they do not affect the analysis of trends and changes over time. In other words, if we observe for example a big surge in the *share* of Israeli patents in the field of Computers and Communications and a concomitant decline in the share of Chemicals, it is hard to believe that these changes are due to underlying changes in the relative propensity to patent in these two sectors. Rather, the assumption is that these trends reflect true changes in the amount of innovation done in those fields.

The data that we use here were assembled from various sources. First, from our own massive data bank, which consists as said of all US patents and their citations, granted form 1965 through 1996, we extracted the following subsets: (1) all patents granted during that period to Israel, to the four countries in the Reference Group (Finland, Ireland, New Zealand and Spain), and a random sample of 1/72 of US patents; (2) for all those patents (over 30,000) we added all the patent citations that they received over the same period (about 110,000); (3) patent counts by application year for all the other comparison countries (the G7 and the Asian Tigers). Second, we extracted from the US Patent Office site in the Internet, all Israeli patents granted in 1997 and 1998 (up to December 15, 1998).[5] Third, we extracted from a related site data on "raw applications" for all these countries. We then added data on population for the comparison countries and Israel, data on R&D for the G7, and a variety of other data from the National Science Foundation (1996) and other sources.

3. Basic facts about Israeli patenting in the US

Fig. 2 shows the number of successful Israeli patent applications in the US over time, starting in 1968.[6] The growth in the annual number of patents has been very impressive, starting from about 50 in the late 1960s, to over 600 in the late 1990s (i.e. they grew by a factor of 12). However, as Table 1 reveals, 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 (in just 4 years!), and then they doubled again from 1991 to 1995. Notice that in between these two periods (i.e. 1987–1991) the annual flow of patents barely grew. We have to be careful with the timing though: patent applications reflect (successful) R&D conducted *prior* to the filing date, with lags varying greatly 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.[7]

[4] There is a large variance across industries in the reliance on patents versus secrecy: see Levin et al, 1987.

[5] The site is not geared towards massive data extractions, and hence we had to develop special software tools to extract the data. This turned out to be a rather complex and difficult endeavor.

[6] There were about 300 earlier patents, but we chose to conduct the analysis for the post 6-Day-War period, since concerted efforts to develop a innovative sector in Israel started only then.

[7] Notice for example the figures for the mid seventies: the number of patents grew substantially in 1973 and in 1974, but then declined in 1975 and barely grew in 1976. Moving back these figures 1–2 years would provide the right picture in terms of the impact of the Yom Kippur War.

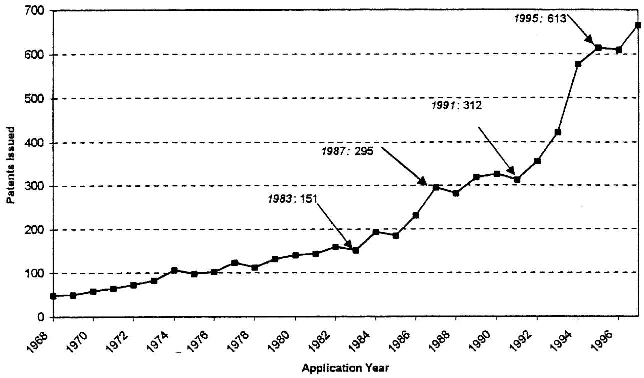

Fig. 2. Israeli patents in the US — 1968–1997.

What accounts for the observed path of Israeli patenting over time? I shall not attempt here to conduct a systematic analysis of the factors underlying such trajectory, but rather I'll content myself with, (i) enumerating key economic developments that coincided in their timing with turning points in patenting, suggesting that they may account at least in part for the observed pattern; and (ii) comparing the time series of patents to R&D expenditures. The first big jump in patenting (1983–1987) represents the very emergence of the high-tech sector in Israel, prompted inter alia by explicit policies designed to support industrial R&D, primarily through the establishment of the Office of the Chief Scientist of the Ministry of Industry and Trade. The in-between "flat" period of 1987–1991 (which represents R&D activity done circa 1985–1989) presumably reflects the big macro adjustment and micro restructuring that followed the stabilization program of 1985. That was also the period that saw the end of the "Lavi" program of the Israel Aircraft Industry (to develop a first-class jet fighter), and the beginning of the downsizing of defense-related industries. Both of these developments freed large numbers of qualified scientists, engineers and technicians, that were to play a key role in the subsequent second big jump of 1991–1995 (again, reflecting R&D activity circa 1989–1993). Notice that the single largest jump occurred in 1994, when the number of patents grew by a whooping 37%. It is likely that this dramatic increase incorporates, among other factors, the impact of the mass immigration from the former Soviet Union.

Fig. 3 shows industrial R&D expenditures (in constant 1990 US$) along with patents (see also Table 1).[8] There is clearly a (lagged) co-movement of the two series, as manifested for example in the following simple Pearson correlations:

	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 the 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. As said, this is the period that saw the emergence of the high-tech sector, and that is well reflected in both series. In 1986–1988 we see a decline in the level of R&D spending, and the concomitant flattening of patenting in 1987–1991, and then again a sustained

[8] 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 (see Section 6 below) 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.

Table 1
Israeli patents in the US — basic figures

Year	"Raw" applications	Patents issued, by appl. year	Rate of success	Patents issued, by grant year	Growth rate, %	Industrial R&D (1990 US$)
1960–1967		305		177		
1968	73	48	0.66	38	29.7	
1969	87	49	0.56	61	2.1	
1970	90	58	0.64	46	18.4	
1971	120	64	0.53	54	10.3	
1972	143	72	0.50	55	12.5	68.3
1973	155	82	0.53	84	13.9	74.5
1974	165	106	0.64	89	29.3	76.0[a]
1975	158	97	0.61	96	−8.5	77.5
1976	175	102	0.58	106	5.2	91.3
1977	206	122	0.59	92	19.6	150.7
1978	202	112	0.55	99	−8.2	153.8
1979	235	131	0.56	81	17.0	181.2
1980	253	140	0.55	113	6.9	205.8
1981	317	143	0.45	122	2.1	186.3
1982	316	159	0.50	114	11.2	242.9
1983	307	151	0.49	110	−5.0	275.5
1984	376	193	0.51	159	27.8	385.0[a]
1985	377	184	0.49	182	−4.7	495.4
1986	427	231	0.54	187	25.5	550.3
1987	503	295	0.59	244	27.7	423.2
1988	490	281	0.57	238	−4.7	396.6
1989	624	318	0.51	324	13.2	418.9
1990	608	325	0.53	298	2.2	468.6
1991	633	312	0.49	304	−4.0	510.7
1992	780	355	0.46	335	13.8	559.3
1993	803	421	0.52	314	18.6	574.7
1994	1,040	576	0.55	349	36.8	631.3
1995	1,072	613[b]	0.57	384	6.4	614.4
1996	1,042	609[b]	0.58	484	−0.7	668.6
1997	1,185	664[b]	0.56	529	9.0	
1998				741		
Total[c]	12,962	7013	0.54	6432	10.8	

[a] Estimates, interpolation.
[b] Estimates, based both on the average application-grant lag, and on the "success ratio".
[c] For 1968–98 (i.e. does not include 1960–67).

increase through the early-mid 1990s that anticipates the second big jump in patenting. It is clear then (and reassuring) that industrial R&D expenditures are closely linked (with a reasonable lag) to patents, but further research is needed to understand the joint dynamics, integrating at the same time the sort of qualitative factors mentioned before.

The above cursory description carries a warning sign (or at least a serious question mark) for the future. Given the high rates of obsolescence of "Knowledge Capital" (K) that characterize high-tech sectors, a steady stream of innovations (here in the form of the annual flow of patents, P_t) is needed just to maintain current levels of K_t. Faster obsolescence (as may be happening in some areas of computers and communications) thus requires a *growing* P_t, and the same applies if we want to see a steadily growing stock of K_t. As we have seen, the big jumps in P_t are likely to have occurred, to a significant extent, as a consequence of big "shocks" to the system (e.g. in policy, availability of relevant inputs, etc.), including of course the jumps in R&D expen-

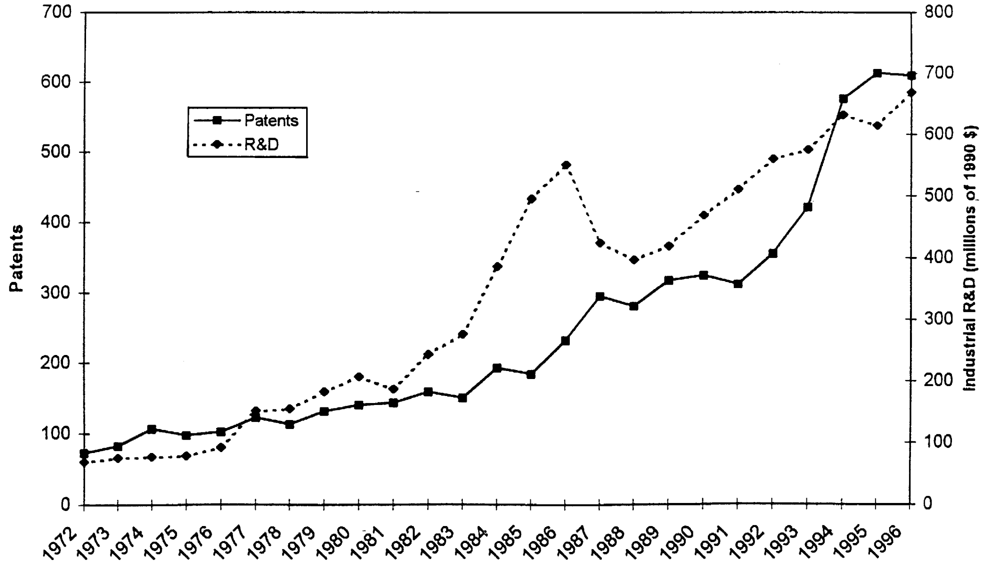

Fig. 3. Israeli patents and Industrial R&D.

ditures. The question is then how we expect to bring about/support a sustained increase in P_t in the future, absent further (positive) shocks of that sort. Perhaps the attainment of "critical masses" in several dimensions of the high-tech sector will generate by itself the required future growth, but that remains to be seen.

Table 1 shows also the number of "raw applications", that is, the overall number of patent applied for in the USA by Israeli inventors. Of these, only those under "patents issued, by application year" (which is the figure we shall use all along) were actually granted, the rest did not pass the rather stringent tests of the US Patent Office (novelty, usefulness, etc.). The average "success rate" over the whole period was 54%, with no clear trend over time (except for the fact that it was clearly higher in the first decade, 1968–1977). We shall return to this datum in the context of international comparisons, but it is worth pointing out now that a 54% success rate suggests that there are margins for improvements even within this (narrow) context. That is, close to half of the innovations that were good enough to merit a costly application to the US Patent Office[9] do not seem to bear fruit, in the sense that are not worthy of a US patent. Perhaps there is room for low-cost policies/actions that would target the R&D efforts underlying the unsuccessful 46% and channel them into more fruitful directions.

4. International comparisons

Whereas the detailed analysis of Israeli patenting is revealing in itself (as we shall see in subsequent sections), we resort to international comparisons in order to put in perspective the overall level and trend over time in Israeli patenting. We have chosen for that purpose 3 different groups of countries, as follows:

1. *The G7*: Canada, France, Germany, Italy, Japan, UK and USA.
2. A "Reference Group": Finland, Ireland, New Zealand and Spain.
3. The "Asian Tigers": Hong Kong, Singapore, South Korea and Taiwan.

The Reference Group was chosen according to their GDP per capita in the early 1990s, that is, we chose the four countries that had at that time a level of

[9] That already constitutes a high standard.

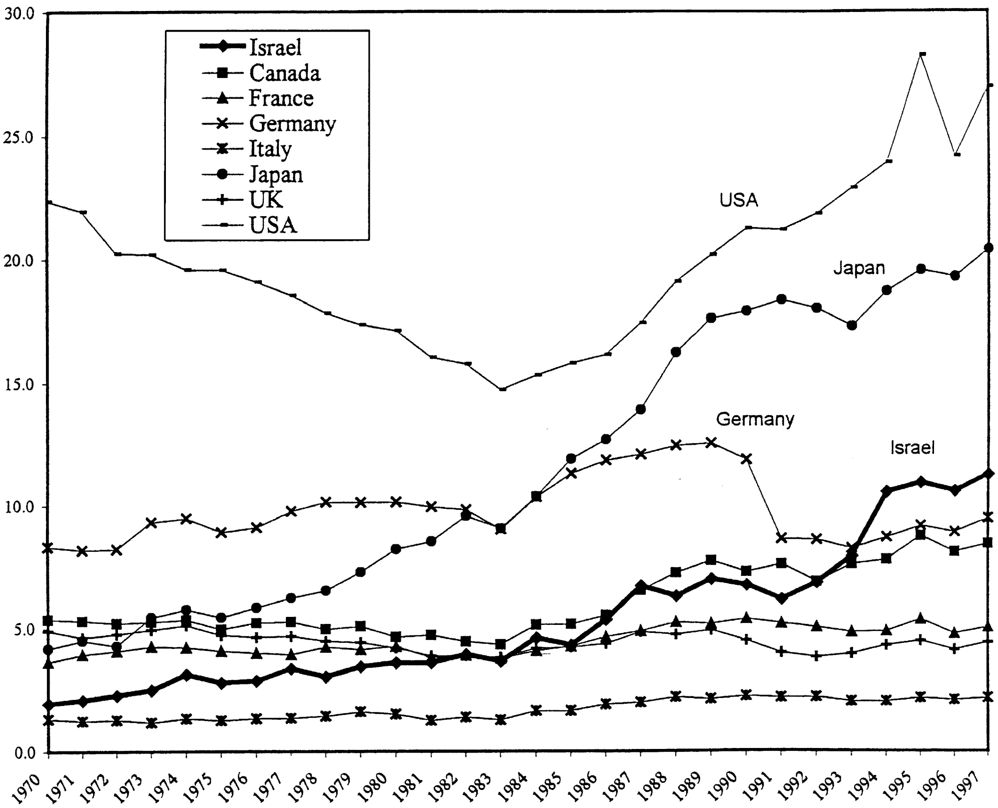

Fig. 4. Patents per capita: Israel vs. the G7.

GDP per capita closest to that of Israel (in ppp terms). Notice that, except for Spain, the other three countries in this group are very similar to Israel also in terms of population.

Appendix A contains detailed patent figures for each country, and Figs. 4–6 show the time patterns of patents per capita for Israel versus each of the above groups of countries. We chose to normalize the number of patents by population, simply because this is a widely available and accurate statistic that provides a consistent scale factor. Another normalization of interest would be R&D expenditures, but except for the G7, the figures for the other countries are far from satisfactory. Fig. 4 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 1990s it moved ahead of Canada and (the unified) Germany,[10] thus becoming 3rd after the USA and Japan. Using civilian R&D as deflator for these countries shows 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. It is interesting to note also that, other than Israel, the only country that grew all along since 1970 was Japan. The others were either stagnant or declined (as the USA did) until the early 1980s. The fact that 1983 proved to be a turning point for *all* of the largest countries at the same time (USA, Japan, Germany, and to a lesser

[10] Had Germany remained divided, Israel would probably reach parity with west Germany by 1998–1999.

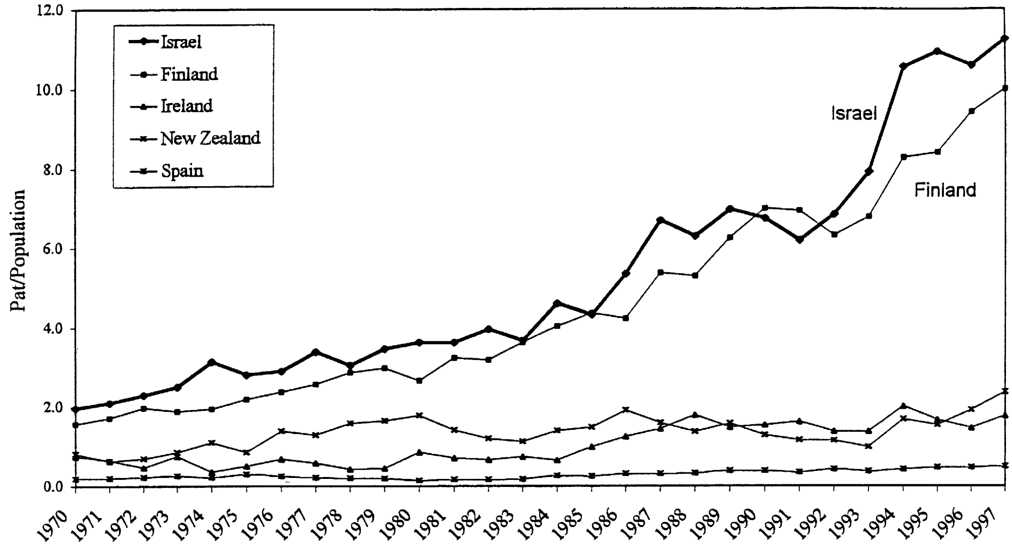

Fig. 5. Patents per capita: Israel vs. the reference group.

extent also for Canada) is interesting in itself, but remains to be explained.

The comparison with the Reference Group shows a very clear picture: the only country that is “game” is Finland, which has followed a pattern virtually identical to Israel, both in levels and in the timing of fluctuations (this striking resemblance deserves further scrutiny — see below). The other three coun-

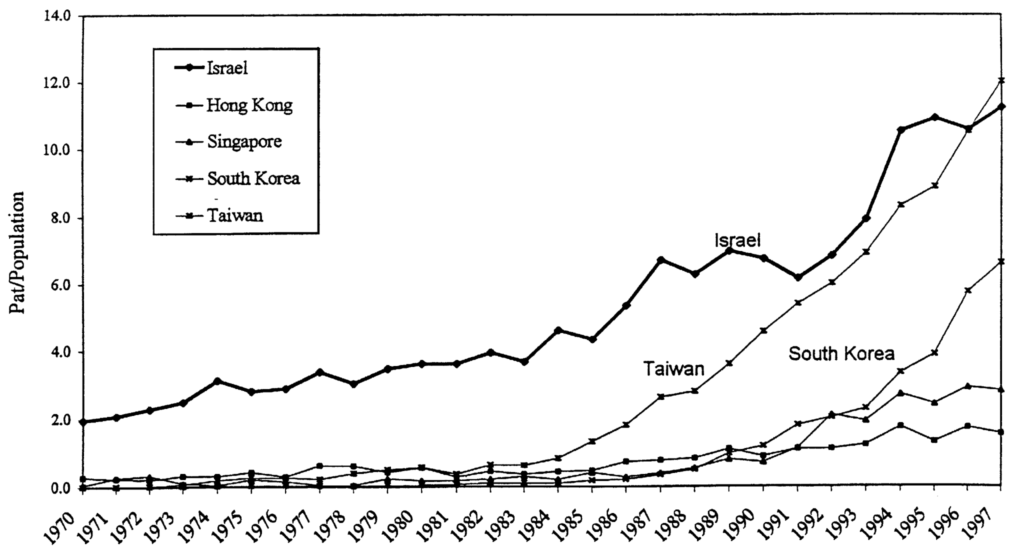

Fig. 6. Patents per capita: Israel vs. the NIC.

Table 2
Country statistics: averages by 5- and 30-year periods

Country	Patents per year		Patents per capita		Success rate		Annual growth rate	
	1968–1997	1992–1997	1968–1997	1992–1997	1968–1997	1992–1997	1968–1997	1992–1997
Israel	234	577	5.3	10.2	54%	56%	10.1%	13.3%
G7								
Canada	1525	2401	6.1	8.1	56%	55%	3.4%	5.5%
France	2423	2896	4.5	5.0	66%	63%	1.9%	0.5%
Germany	6338	7250	9.8	8.9	65%	63%	2.3%	2.4%
Italy	937	1197	1.7	2.1	59%	58%	2.8%	−0.4%
Japan	13,226	23,847	11.5	19.0	65%	61%	8.4%	2.8%
UK	2547	2494	4.4	4.3	55%	51%	−0.2%	3.1%
USA	46,913	66,325	19.8	25.2	62%	59%	1.6%	5.3%
Reference Group								
Finland	214	438	4.5	8.6	57%	58%	8.6%	10.0%
Ireland	35	60	1.0	1.7	49%	48%	6.8%	5.5%
New Zealand	42	61	1.3	1.7	42%	42%	4.9%	16.9%
Spain	105	173	0.3	0.4	49%	50%	4.2%	3.1%
Asian Tigers								
Hong Kong	39	95	0.7	1.5	49%	46%	12.5%	9.6%
Singapore	22	83	0.8	2.6	55%	52%	16.5%	10.3%
South Korea	443	1989	1.1	4.4	61%	62%	27.7%	27.9%
Taiwan	554	2006	2.8	9.3	44%	47%	33.8%	15.7%

tries are well behind, and have remained at the bottom without any significant changes over time. The one surprise there is Ireland, which has pursued for over a decade active policies to attract foreign investments in advanced technologies. As to the Asian Tigers, we can see immediately that Taiwan has grown extremely rapidly since the early 1980s, actually surpassing Israel as of 1997.[11] 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.

For all their limitations, these comparisons correspond quite well to what we know about these countries, only that this way we get a much more detailed and precise picture of the underlying trends. The observed patterns for Finland, Ireland and Taiwan are particularly revealing, and exemplify the power of patent statistics to uncover phenomena that otherwise are hard to detect.

Table 2 summarizes the main statistics for all these countries, including their “success rates” and growth rates in patenting, over the whole period (1968–1997) and for the past 5 years. Notice that, in terms of recent patents per capita, Israel stands third after the USA and Japan, in comparison to *all* the 15 countries, and in terms of growth rates it also ranks third, after South Korea, Taiwan and New Zealand (the latter not yet an important player). This is no doubt a remarkable achievement. The picture is less flattering in terms of success rates: Israel ranks 8th, after most G7 countries, Finland and South Korea. The average for those countries ahead of Israel is 61%; if Israel were able to reach this mark from the present 56%, that would represent an increase of

[11] The number of patents *granted* to Taiwan inventors reached 4045 in 1998, almost doubling that of 1997 (this figure is not incorporated in our statistics) and hence it is clear that the trend is accelerating. See, however, Table 3 for the peculiar composition of assignees for Taiwan.

about 10% in the annual number of patents granted. This would be like an increase in the productivity of the R&D process, rather than an increase in the overall level of resources devoted to inventive activity. As to growth rates, Israel grew faster than both the G7 and the reference group over the whole period, with wide fluctuations in growth rates over time. The Asian Tigers display much higher rates, but we have to remember that they started from very low levels, and hence these rates should be seen primarily as "catch up".

Lastly, it is important to note that in the present context the *absolute* number of patents remains key (similarly to the absolute level of R&D expenditures, rather than its ratio to GDP). In order to establish a viable, self-sustaining high-tech sector, a country has to achieve a critical mass in terms of pertinent infrastructure, skills development, managerial experience, testing facilities, marketing and communication channels, financial institutions, etc. Similarly, it is clear by now that spillovers, and in particular *regional* spillovers, are extremely important in fueling the growth of this sector. Once again, the amount of spillovers generated, and the ability to capture external spillovers is a function of absolute, not relative size. If we take the number of patents as indicative of the absolute size of the innovative sector, then Israel has still a long way to go: it stands well below all the G7 countries, and is about 1/4 the size of Taiwan and South Korea. In order to get to the (absolute) level as of today of say the lower tier G7 countries (Canada, France, UK) and the leading Asian Tigers (Taiwan and South Korea), Israeli patenting would have to grow at a rate of about 30% per year over the next 5 years! At present growth rates (of 13.3% per year), it would take 10 years to get there. That's too long, by all accounts.

5. The technological composition of Israeli patented innovations

The US Patent Office has developed over the years a very elaborate classification system by which it assigns patents to technological categories. It consists of some 400 main patent classes, and over 150,000 patent subclasses. The 400 or so classes have been aggregated traditionally into four fields: chemical, mechanical, electrical and other. We have developed recently a new classification scheme, by which we assigned these 400 patent classes into 35 technological "sub-categories", and these in turn are aggregated into six categories: Computers and Communications, Electrical and Electronics, Drugs and Medicine, Chemical, Mechanical and Other.

Fig. 7a and b shows the breakdown of Israeli patents by these six technological categories (in percentages) over time. Fig. 8 does the same but for US patents,[12] thus providing us with a standard of comparison. Let us start from the latter, which is supposed to reflect the main world-wide trends in technology itself. The pattern is quite clear: from 1968 and up to about 1980 all series were pretty much flat, i.e. the relative shares of each of the six categories remained virtually constant. The shares of Mechanical and Other were highest (over a quarter each), then came Chemical (21–23%), and further down Electrical and Electronic (15%). Both Drugs and Medicine and Computers and Communications accounted to a tiny fraction back then, up to 5% each. Starting in the early 1980s this static picture starts to change, as follows: the three top fields decline (Mechanical decline the most), Electrical and Electronics does not change at all, and the two bottom ones surge forward, with Computers and Communications accounting in 1994 for over 15% of all patents.

As Fig. 9 reveals, the pattern for Israel is similar, except that the changes are much more abrupt (and the initial levels are also quite different). The most striking development is the surge of Computers and Communications from about 5% in the 1970s (as in the US), to a full 25% by 1994 and beyond. Likewise, Drugs and Medicine doubles its share from 10% to 20%. Electrical and Electronics oscillates around 15% (exactly as in the US), increasing recently 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%

[12] This distribution is based on the sample of 1/72 of US patents (over 20,000 in total).

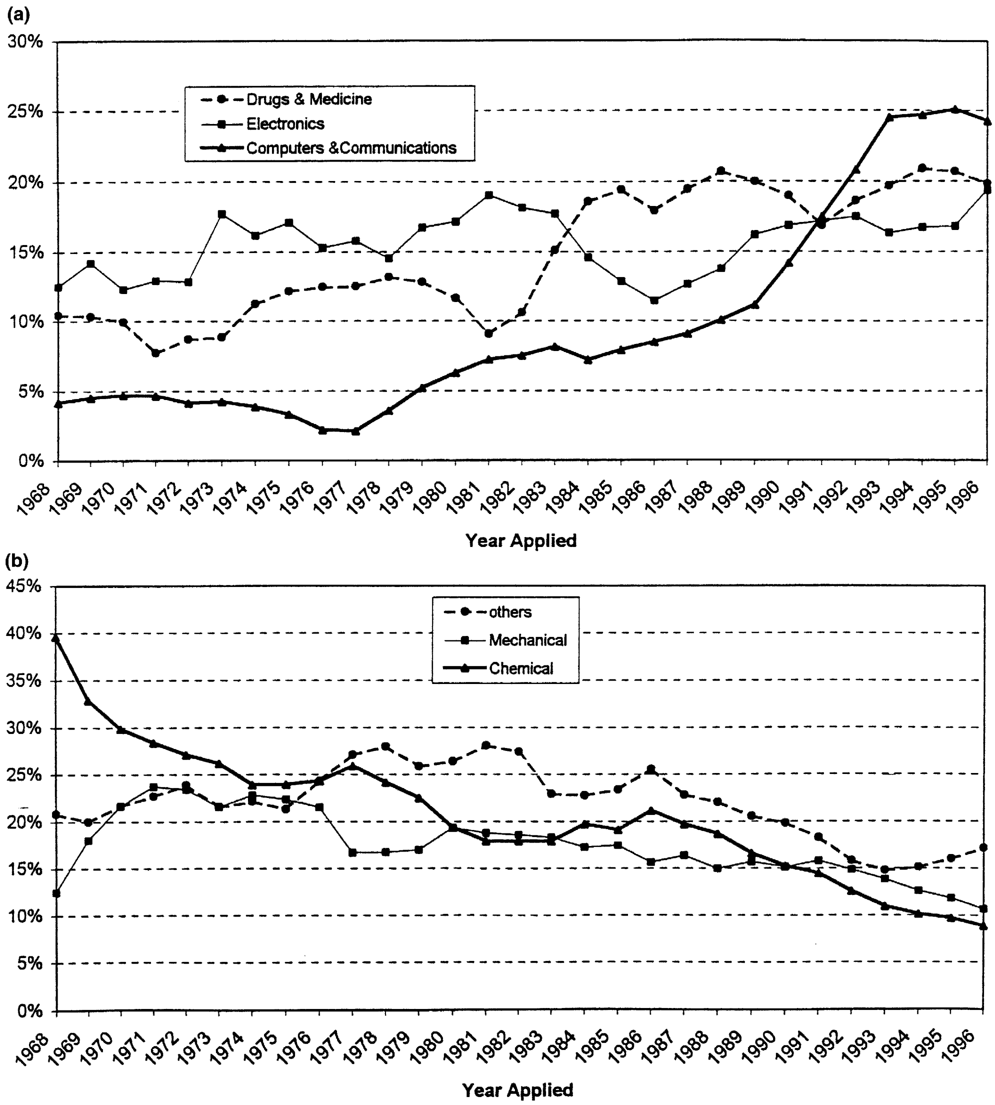

Fig. 7. (a) Israeli patents by Tech categories: rising fields. (b) Israeli patents by Tech categories: declining fields.

by 1996. Thus, the "big story" in Israeli patenting is the growth in Computers and Communications and Drugs and Medicine at a significantly faster pace than in the US, and the even faster decline in Chemicals. The composition of innovations has thus changed dramatically in Israel, and seemingly in a healthy way, in the sense that we are in tandem with world-wide changes in technology, but we experience them at an accelerated rate. Finally, Appendix B shows the actual number of patents in each sub-category, sorted by the cumulative number in the past 5 years.

6. Who owns what? A view at the distribution of Israeli patents assignees

By way of introduction, we need to describe the different "players" related to any given patent. First

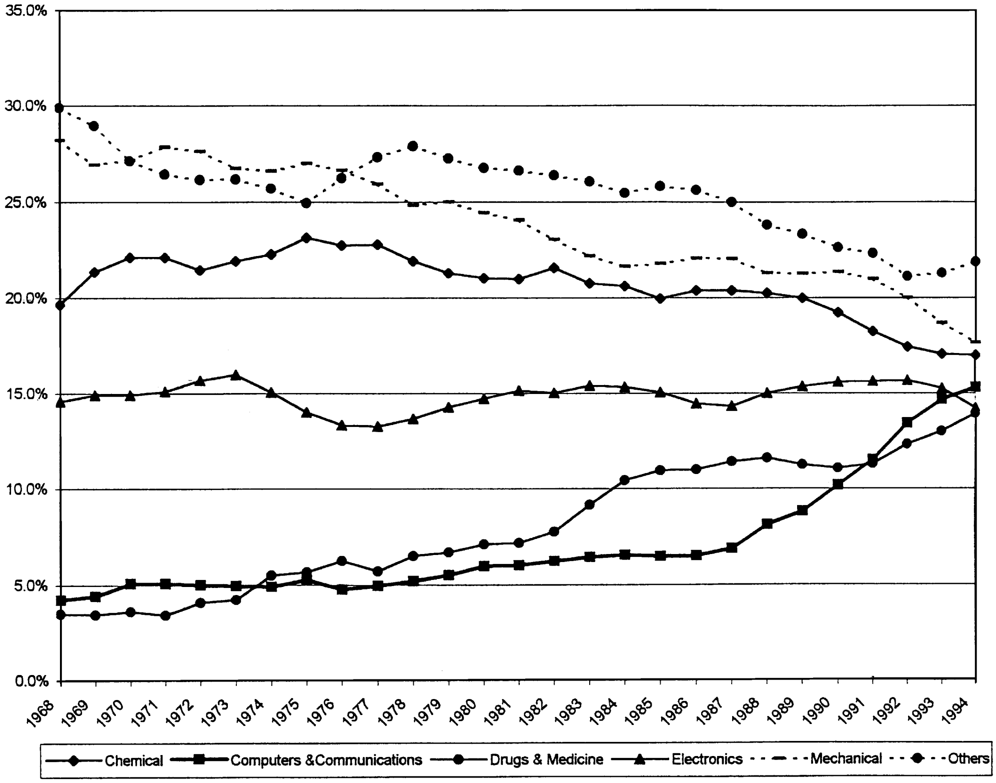

Fig. 8. Distribution of US patents by Tech categories.

there are the inventors, that is, those individuals directly responsible for carrying out the innovation embedded in the patent. Second there is the assignee, that is, the legal entity (corporation, government agency, university, etc.) that owns the patent rights, assigned to it by the inventor(s). However, there are individual inventors that work on their own and have not yet assigned the rights of the patent to a legal entity at the time of issue, in which case the patent is classified as "unassigned" (or "assigned to individuals").[13] For most patents, the inventors are typically employees of a firm, in which case the assignee is the firm itself.

According to the conventions of the US Patent Office, the "nationality" of a patent is determined by the address (at the time of application) of the *first inventor*. That is, if a patent has many inventors and they are located in a variety of countries, the location of the first inventor listed on the patent determines to which country it is deemed to belong. Likewise, if the assignee is located in a country different from that of the first inventor, it is once again the location of the latter that determines the nationality of the patent. Thus, in the patent shown on Fig. 1, the first inventor has an Israeli address, whereas the other three inventors listed have addresses in the USA, and the patent was assigned to Intel of Santa Clara, CA; nevertheless, the patent is formally classified as Israeli.[14]

[13] That is, the inventor herself may appear as the legal entity that owns the patent rights.

[14] Clearly, this convention is completely inconsequential for anything but the compilation of statistics about international patenting activity.

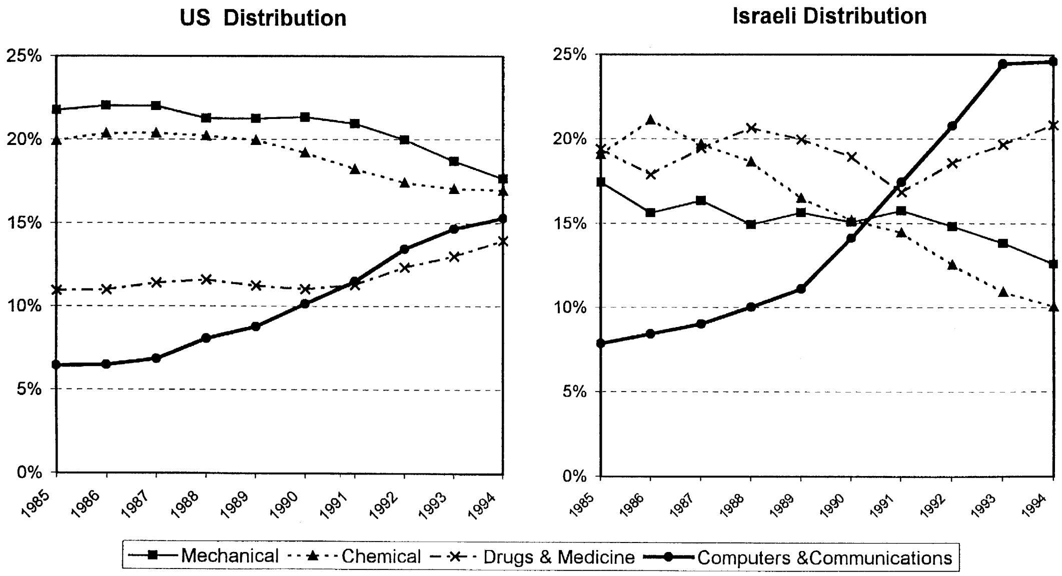

Fig. 9. US vs. Israel Tech categories — 1985–1994.

The data that we have presented so far (e.g. number of patents by countries) were compiled according to this convention: Israeli patents are those for which the address of the first inventor was in Israel, regardless of the identity and location of the assignees or of the other inventors, and similarly for the other countries. The important question now is, who actually owns the rights to these inventions? Keeping in mind that for patents labeled "Israeli" it was indeed Israeli scientists and engineers that were responsible for the "innovative act" that led to these patents (they certainly provided the "brain power"),[15,16] the question is: which entity, commercial or otherwise, is in a position to reap the economic benefits from these inventions?

At the upper level of aggregation there are three possibilities: (i) that there is no assignee (i.e. the inventor herself retains the rights to the patent), and hence it is not clear if and when the patent will be commercially exploited; (ii) that the assignee is also Israeli, that is, that the location of the entity owning the rights to the patent is in Israel; (iii) that the assignee is foreign. Even the seemingly sharp distinction between (ii) and (iii) is not quite as clear. There are on the one hand Israeli corporations that have established subsidiaries or otherwise related firms in other countries, and they may choose to assign the patents (done is Israel) to their "foreign" subsidiaries (but in fact we should regard them as Israeli). On the other hand, there are multinational corporations that have established subsidiaries in Israel, and some may choose to assign the locally produced patents to the Israeli subsidiary, even though the multinational retains effective control over the property rights. We have dealt as well as we could with the first difficulty, by examining the names of the assignees, and spotting those cases that were designated as foreign assignees but were clearly Israeli firms (e.g. Elscint US, Ormat, etc.). By contrast we have not addressed the second difficulty, but rather taken on face value the address of the as-

[15] We ignore for the moment the issue of the possible variety of nationalities of inventors, that is, we assume that for Israeli patents all inventors reside in Israel and not just the first, and the same for other countries.

[16] The reason we have to be careful with the wording here is as follows: suppose that an Israeli scientist goes to a sabbatical to MIT in Cambridge, MA, and carries out a project in a lab there that results in a patented invention (there are quite a few of these in the data). Such a patent would be labeled as Israeli, but the assignee would be MIT. Now, the invention was made possible not only by the ideas and efforts of the Israeli scientist, but also by the facilities, physical and otherwise, of the host institution. The end result is no doubt a function of both.

signee, e.g. Motorola Hertzlia will appear as an Israeli assignee, Motorola US as a foreign assignee.

The distinction between these three categories, unassigned, Israeli ("local") and foreign, is then telling of the extent to which the country can expect to benefit from "its" patents. The unassigned patents may of course find their way to successful commercial applications (and many do), but they typically face much higher uncertainty than corporate assignees that own from the start the patents issued to their employees. Moreover, corporations are in a better position to capture internally the spillovers generated by those innovations. Thus, the higher is the percentage of unassigned patents, the less would be the economic potential of a given stock of patents. The distinction between foreign and local assignees is presumably informative of the probability that the *local economy* would be the prime beneficiary of the new knowledge embedded in the patent. One can draw various scenarios whereby foreign ownership may be as good if not better in that respect than local ownership of the patent rights (e.g. the foreign multinational offers marketing channels for the innovation that would be inaccessible to local firms). Still, we are rapidly moving in many technological areas to an era where the prime asset is the effective control of intellectual property, and presumably that is correlated with the ownership of patent rights. However, we do not need to take a strong stand in this respect, only to agree that this distinction is informative and quite likely important for understanding the potential value for a country of its stock of patents.

A further distinction for assigned patents, whether Israeli or foreign, is according to the "type" of assignee, and in this context we consider three main categories (although we have made actually finer distinction in the data): corporate, government and universities (including hospitals and related research institutions). The working hypothesis is that the likelihood of down-the-line commercial application of a patent would be higher if owned by a corporation, and lower if owned by the Government or by Universities.

Fig. 10 shows the distribution of Israeli patents among different types of assignees for the whole period, at the two levels of aggregation. Just slightly

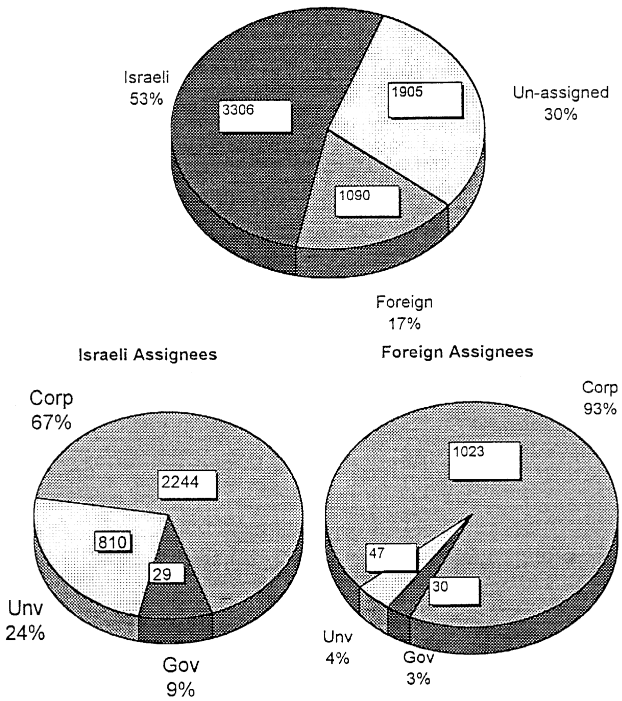

Fig. 10. Distribution of Israeli patents by type of assignees (totals).

over half of the total number of patents received during the past 30 years is owned by designated *Israeli assignees*. Almost a third are unassigned, and the remaining 17% belong to foreign assignees. Of the 53% owned by Israeli assignees, a full third went to Israeli Universities and to the Israeli Government, the latter mostly to Defense-related institutions (primarily to "Rafael" and to "Taas", the Military Industry). Thus, the percentage of all Israeli patents that belong to Israeli corporate assignees is just over a third: $0.53 \times 0.67 = 0.355$. This percentage is very low by any standard (see below): it implies that only a third of all patents generated by Israeli *inventors* have a relatively high chance to bring in economic benefits to the Israeli economy. To repeat, this is only a probabilistic statement: for sure many of the patents granted to Universities, to Rafael, or to private individuals eventually resulted (or will result in the future) in commercially successful innovations for Israeli firms. Still, unassigned patents, patents granted to foreign assignees, or to Universities and the Government presumably offer lower *expected local returns* than those assigned to Israeli corporations.

The following table puts these figures into perspective (see below for a more detailed comparison):

Distribution of assignee types[a]

	USA (1963–1993)	All other countries (1963–1993)	Israel (1968–1997)
Corporations	71%	84%[b]	43%
Unassigned	24%	15%	37%
Government	3%	1%	6%
Universities	2%	na	16%

[a] Percentages out of total number of patents issued to assignees or individuals of a given country, thus not including those assigned to foreign assignees.

[b] Including universities, but these account for a tiny percentage.

Source: National Science Foundation, Science and Engineering Indicators, 1996, appendix table 6–7, p. 275, in addition to our data.

Table 3
Distribution of assignee types — international comparison 1976–1998

Country	Number of patents				Percentages		
	Unassigned	Foreign	Local	Total	Unassigned	Foreign	Local[a]
Israel	1815	1807	3443	7065	26%	26%	49% (52%)
G7							
Canada	15,756	8614	21,175	45,545	35%	19%	46% (50%)
France	6567	8883	49,500	64,950	10%	14%	76% (75%)
Germany	13,147	17,060	117,660	147,867	9%	12%	80% (77%)
Italy	3957	3904	19,293	27,154	15%	14%	71% (72%)
Japan	9003	6950	341,854	357,807	3%	2%	96% (95%)
UK	5812	15,698	37,693	59,203	10%	27%	64% na
USA	296,191	19,546	887,308	1,203,045	25%	2%	74% (76%)
Reference Group							
Finland	834	422	4739	5995	14%	7%	79% (81%)
Ireland	259	512	385	1156	22%	44%	33% (32%)
New Zealand	614	224	685	1523	40%	15%	45% (52%)
Spain	1048	784	1503	3335	31%	24%	45% (51%)
Asian Tigers							
Hong Kong	688	760	1824	3272	21%	23%	56% (55%)
Singapore	110	488	274	872	13%	56%	31% (43%)
South Korea	1154	531	10,666	12,351	9%	4%	86% (92%)
Taiwan	13,296	991	6362	20,649	64%	5%	31% (44%)

[a] Numbers in parenthesis: the percentages for 1998.

The differences between Israel and both the USA and all other countries are startling: Israel has much higher percentages of the three bottom types, Unassigned, Government and Universities, particularly so for Universities. As a consequence, the percentage of corporate patents, those that have the highest ex ante chance of finding commercial applications, is just 43%, almost half the corresponding percentage for all other countries except the USA, and 40% lower compared to the USA. These figures mimic the distribution of R&D by sector: in 1995 just 45% of civilian national R&D in Israel was conducted by the business sector, as opposed to 72% in the US, and a median of 62% for OECD countries (Central Bureau of Statistics, 1998, table 17).

Table 3 offers a more detailed (if slightly different) perspective. In it we show comparative figures for the upper "pie" of Fig. 10, that is, the distribution between unassigned, "local" and foreign assignees.[17] As we can see, the percentage of local assignees is much lower than that of all G7 countries except for Canada. As to the reference group, Finland has a much higher share of local assignees than Israel, the other three (with few patents each) have lower percentages. In the case of the Asian Tigers, the two large patent holders stand at opposite extremes: Taiwan has a very low percentage of local assignees (due to an extremely high share of unassigned, 64%), whereas South Korea has an extremely high share (topped only by Japan). These differences are clearly related to the industrial organization of these countries (e.g. Taiwan has a very large number of small enterprises, and an extremely high rate of turnover of firms, whereas South Korea is dominated by huge, stable *chaebol*), but it is a topic worth of further investigation. The contrast between the latest figures (for 1998) and those for the whole period 1976–1998 reveal that the G7 countries are quite stable, whereas most of the others increased the share of local assignees, some of them very significantly such as Taiwan, Singapore, New Zealand and Spain. Thus, the world-wide trend is towards an increase in the share of local assignees. What characterizes Israel vis-a-vis other countries is that *both* the shares of unassigned and of foreign are relatively high (the only other countries for which that is true are all minor players: New Zealand, Spain and Hong Kong).

6.1. Foreign assignees — a further look

We have referred extensively to the fact that Israel has a very high percentage of foreign ownership of patents received by Israeli inventors, compared to other countries. Who are these foreign assignees? The largest foreign patent holders of Israeli patents are: Motorola (112 patents), Intel (95), IBM (75) and National Semiconductors (57). Of course, these are the familiar names that have had a strong presence in Israel for quite a while now. The following table shows the annual number of Israeli patents taken by these corporations:

Israeli patents assigned to large foreign corporations

Time period	Average annual number of patients
1968–1986	2
1987–1989	6
1990–1991	18
1992–1993	36
1994–1995	70

Thus, the number of Israeli patents taken by these corporations grew extremely fast, from less than 10 prior to 1990 to about 70 in the mid 1990s, whereas in the course of the same period the overall number of Israeli patents barely doubled.

As already suggested, we have to be very careful in how to judge this phenomenon. On the one hand the fact that these multinationals have established a foothold in Israel is extremely important in terms of the (positive) externalities that they generate, as well as in opening foreign markets for Israeli technology. On the other hand they may be competing for the one key resource that Israel has, namely, innovative talent in cutting edge technologies (see below). It is this talent that they seek in opening R&D labs in Israel, and in so doing they acquire control over the

[17] These figures are not strictly comparable to those presented so far, for the following reasons: (1) The number of patents assigned to a country in table 3 include all patents in which ***any*** of the inventors resides in that country; (2) the period covered in table 3 is 1976–1998 for granted patents, as opposed to 1968–1997 for applied patents in all other tables. Both are due to limitations of the search capabilities in the Internet site of the US Patent Office.

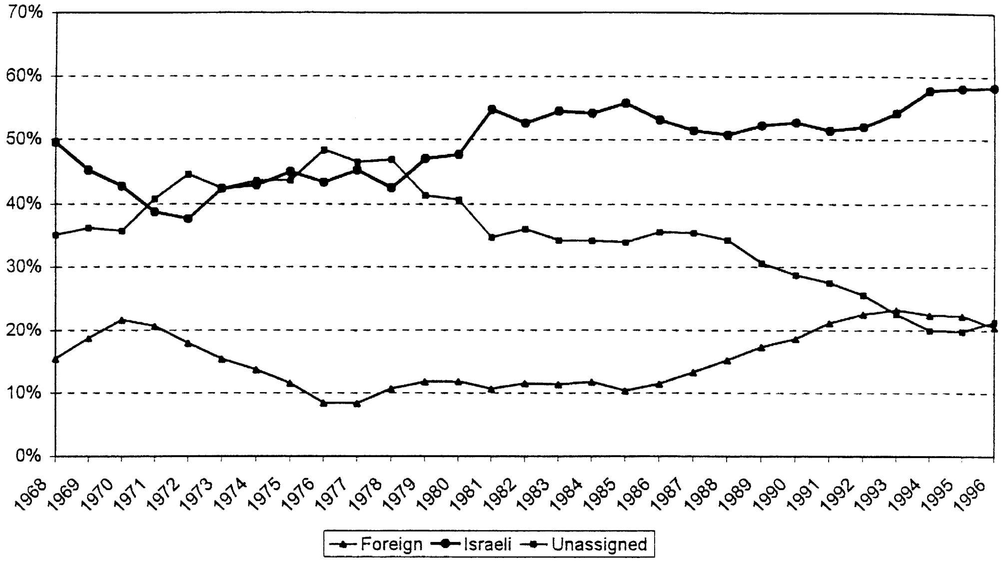

Fig. 11. Distribution of assignees — all Israeli patents.

intellectual property generated there. Whatever the normative stand that one takes on this issue, it is imperative to know well the facts, and this is what we have attempted here.[18]

6.2. Trends in the distribution of assignees

So far we have looked at the distribution of assignees for the whole stock of Israeli patents of the past 30 years, and the picture is rather bleak; however, the picture brightens significantly when we examine time trends. Fig. 11 shows the distribution over time of the unassigned-local–foreign percentages: there is a slow increase in the share of Israeli assignees, approaching now 60% (from about 45% in the 1970s), a marked decline in the share of unassigned (from about 40% in the 1970s to 20% in the mid 1990s), but also a significant increase in the share of foreign patents from about 10% in the 1980s to over 20% in the 1990s. The sharp and persistent decline in the share of unassigned patents (we are now in that respect at the level of the USA) is certainly very good news; the remaining (and still open) question is how to relate to the increase in the share of foreign assignees.

Fig. 12 displays the distribution of Israeli assignees among the various types: corporate, universities, and government. Here the main trends are very encouraging: the share of corporate-owned patents has risen steadily from a low of 30% at the beginning of the period, to a high of 83% in 1997. This rise came mostly from the corresponding dramatic drop in the share of universities: from a high of about half of all patents at first, to 12% if 1997. The share of government patents has fluctuated quite a bit around the 10% mark, but seems to be decreasing steadily as of the early 1990s (to 6% in 1997). Still, a total of 18% for Government and Universities combined is very high compared to all other countries, and we expect that this percentage will continue to shrink to internationally acceptable levels of less than 10%.

Fig. 13 summarizes these trends into one figure, the share of Israeli corporate patents out of the total number of Israeli patents. As already suggested, these are the patents with the highest expected payoff for the Israeli economy, and hence the focus on them. Once again, the overall trend here is certainly encouraging: Israeli corporate patents accounted for a dismal 15% at the beginning of the period, and now account for almost half (48%) of all Israeli

[18] The wider issue (not addressed here) is how to formulate R&D policies in the era of globalization, whereby brainpower and spillovers flow freely across national boundaries. The figures presented here offer partial evidence on these flows.

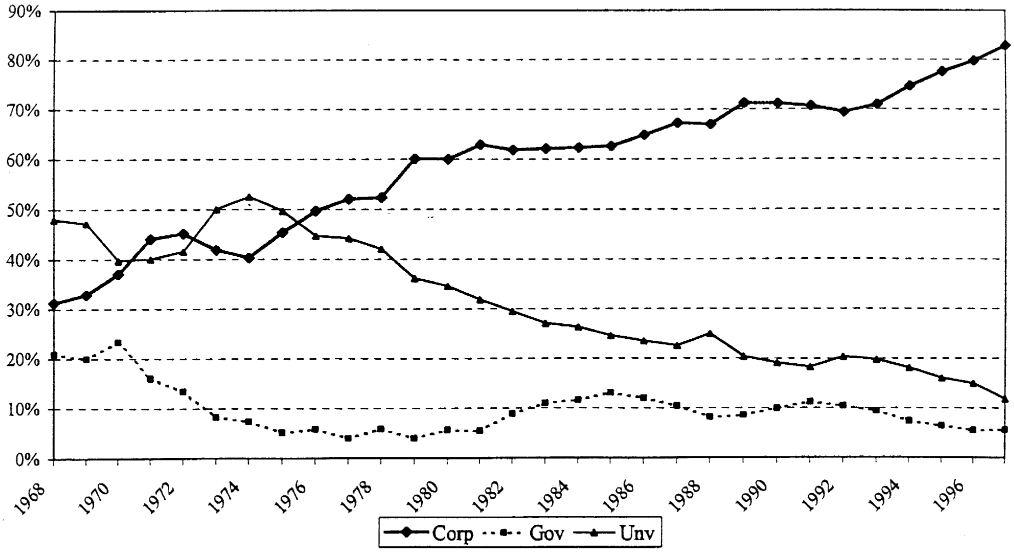

Fig. 12. Distribution of Israeli assignee types.

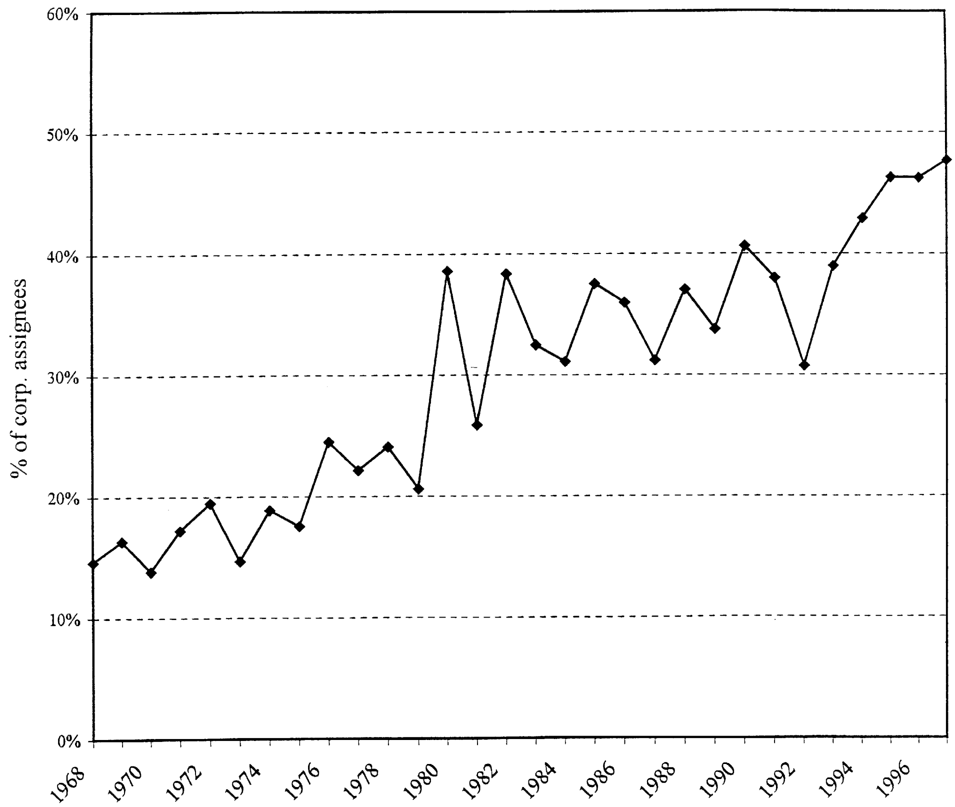

Fig. 13. Percentage of Israeli Corporate assignees.

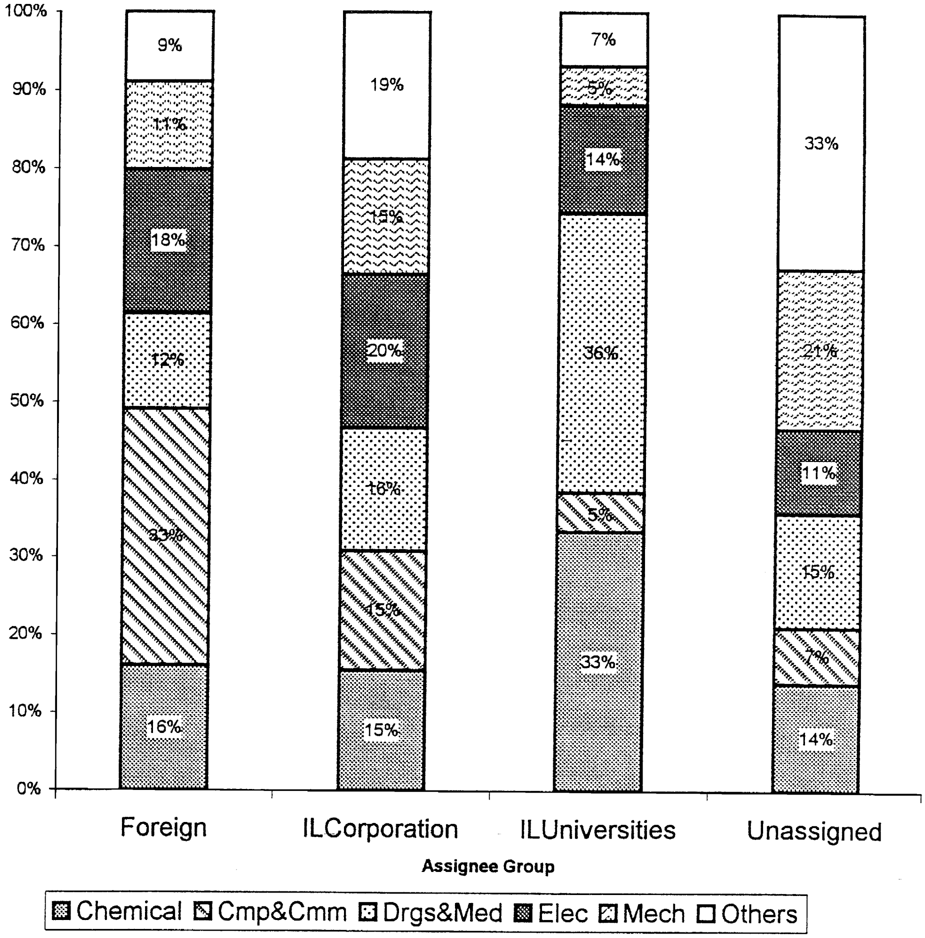

Fig. 14. Technological distribution by assignee types.

patents. As we can see, the rise was not smooth, and actually throughout the 1980s it hovered around the 35% mark. It is only since 1992 that it has climbed steadily up to today's level. Of course, there is still a very long way to go: in order to take full advantage of the potential embedded in Israeli inventions to the benefit of the Israeli economy, this percentage would have to increase steadily (to, say, the 70–80% mark). That would require a continuous reshuffling of inventive resources, away from all other competing players and towards the Israeli corporate sector.[19]

[19] We do ***not*** see so far such reshuffling in the distribution of R&D expenditures by sector — see Central Bureau of Statistics, 1998, table 1.

6.3. Competing for talent?

As already suggested, the identity of the assignees may be informative not only of who owns what, but of who competes for the limited pool of skills, scientific and technological talent and entrepreneurial drive that Israel has. One way to approach this issue is through the information displayed in Fig. 14, that is, the distribution of patents by technological categories, for each type of assignee. Thus, foreign and Israeli corporations look quite similar in that respect, except that foreign assignees are much more active than Israelis in Computers and Communications (the share of foreigners in that field is 33% versus 15% for Israeli assignees). By contrast, both Universities and individual inventors operate in rather different technological areas than corporations: Universities primarily in Chemistry and Drugs and Medicine, individual inventors in Mechanical and "Other". In short, foreign and local corporations do seem to compete for the same sort of human capital, universities and individual inventors do not.

7. The relative "importance" of Israeli patents

Simple patent counts are a very imperfect measure of innovative activity, simply because patents vary a great deal in their technological and economic "importance" or "value", and the distribution of such values is extremely skewed. Recent research has shown that patent citations can effectively play the role of proxies for the "importance" of patents, as well as providing a way of tracing spillovers (see Trajtenberg, 1990; Jaffe and Trajtenberg, 1996; Henderson et al., 1998). By citations we mean the references to previous patents that appear in the front page of each patent (see Fig. 1).

Patent citations serve an important legal function, since they delimit the scope of the property rights awarded by the patent. Thus, if patent 2 cites patent 1, it implies that patent 1 represents a piece of previously existing knowledge upon which patent 2 builds, and over which 2 cannot have a claim. The applicant has a legal duty to disclose any knowledge of the prior art, but the decision regarding which patents to cite ultimately rests with the patent examiner, who is supposed to be an expert in the area and hence to be able to identify relevant prior art that the applicant misses or conceals.[20]

We use data on patent citations here in order to examine the "quality" of Israeli patents vis-a-vis US patents, and patents of the reference group of countries. That is, we ask to what extent Israeli patents are more or less frequently cited than the patents of these other countries, controlling for various effects. Moreover, we analyze how these differences vary over technological categories, and over time. We regress the number of citations received by each patent (ncites), on control variables (dummies for five technological classes as well as for grant years), a dummy for the US and another for the group of reference countries. The sign and magnitude of the coefficients of these two latter dummies are telling of the extent to which Israeli patents receive more or less citations on average than these other countries, controlling for technological composition and age of patents. The results for the benchmark regression are as follows:

Number of obs = 37313
$F(7, 37272) = 196.21$
Prob $> F = 0.0000$
R-squared = 0.1330
Adj R-squared = 0.1321
Root MSE = 5.0211

ncites	Coef.	Std. Err.	t	P > $\|t\|$
usa	0.6954136	0.0793592	8.763	0.000
refer	−0.6985195	0.0855526	−8.165	0.000
chemical	0.335095	0.0773475	4.332	0.000
cmpcmm	2.372321	0.1090868	21.747	0.000
drgsmed	1.61299	0.107602	14.990	0.000
elec	0.3790388	0.0845855	4.481	0.000
mech	−0.2321834	0.0745865	−3.113	0.002
_cons	2.988059	0.0842784	35.455	0.000
gyear	$F(33, 37,272)$ (34 categories)	=	142.390	0.000

Thus, US patents are "better" than Israeli patents by about 25% (the coefficient of 0.695 for the US divided by the constant term of 2.98), but Israeli patents are of significantly better quality than the patents of the reference countries. Next we ask what happened to these differences over time, that is, are Israeli patents getting better or worse relative to other countries? Just interacting the coefficients of interest in the above regression with time won't do, because as time advances (i.e. as we get closer to the present, which necessarily truncates future citations) the number of citations received declines. One way to go about it is to define the dependent variable in logs, which in principle should be immune to trunca-

[20] Because of the role of the examiner and the legal significance of patent citations, there is reason to believe that patent citations are less likely to be contaminated by extraneous motives in the decision of what to cite than other bibliographic data such as citations in the scientific literature (Van Raan, 1988; Weingart et al., 1988). Moreover, bibliometric data are of limited value in tracing the *economic* impact of scientific results, since they are not linked to economic agents or decisions.

tion (since the coefficients on the dummies for countries are in percentage terms).[21] In the following regressions we compare in that fashion the relative standing of Israeli patents in the last 10 years versus the previous 20 years (dummies for tech categories are included in both but not shown):

grant year < 1986
Number of obs = 20287
$F(7, 20257) = 54.69$
Prob $> F = 0.0000$
R-squared = 0.0859
Adj R-squared = 0.0846

lncite01	Coef.	Std. Err.	t	$P > \|t\|$
usa	0.1928575	0.0384885	5.011	0.000
refer	−0.2633523	0.0427346	−6.163	0.000
_cons	0.5544518	0.0402906	13.761	0.000
gyear	$F(22, 20,257)$ (23 categories)	=	76.064	0.000

Grant year > 1986
Number of obs = 17026
$F(7, 17008) = 128.21$
Prob $> F = 0.0000$
R-squared = 0.3667
Adj R-squared = 0.3661

lncite01	Coef.	Std. Err.	t	$P > \|t\|$
usa	0.1751703	0.029623	5.913	0.000
refer	−0.266625	0.031084	−8.578	0.000
_cons	−0.4513321	0.032458	−13.905	0.000
gyear	$F(10, 17,008)$ (11 categories)	=	935.922	0.000

Thus, whereas in the pre-1986 period US patents were about 19% better than Israeli patents, in the post-1986 period that advantage seems to have decreased slightly (to 17%). The relative standing of Israeli patents vis-a-vis the reference group of countries did not change. We also run similar regressions for the whole period whereby time is interacted with the dummies for the US and reference countries, and the results are pretty much the same, except that their significance is rather fragile.[22] In any case, it is quite clear that the converse is not true, that is, one can easily reject the null hypothesis that the quality of Israeli patents has *declined* over time, in the wake of the rapid growth in their numbers.

In Fig. 15 we show graphically the results of the analysis for each technological class. The columns represent the value of the respective dummies, e.g. the coefficient of the USA dummy in a (separate) regression just for Drugs and Medicine was 1.01, whereas the coefficient of the reference group dummy in that same regression was –1.06, and so forth.[23] Thus, Israeli patents are particularly good in Computers and Communications (in that category we are on par with the US, and much better than the reference countries), whereas the biggest disadvantage vis-a-vis the US resides in Drugs and Medical.

In Fig. 16 we look into Drugs and Medical in more detail, and the picture that emerges is as follows. We stand at a large disadvantage vis-a-vis the US both in Surgery and Medical Instrumentation and in Drugs, but we are actually at a small advantage in Biotechnology and Molecular Biology. The reason for the disadvantage in Drugs is clear: the Israeli pharmaceutical industry has focused for the most part on generics, which by definition are not breakthroughs and therefore do not receive many citations, whereas the pharmaceutical industry in the US is by far the most advanced in the world. The disparity in Medical Instrumentation is more puzzling and requires further scrutiny, given the relatively high standards of that sector in Israel. The very good news resides in Biotechnology, whereas said Israeli patents are of comparable importance to those of the US.[24]

Thus, Israeli patents are on par with the US in terms of the "importance" or "quality" of its innova-

[21] The only remaining difficulty is what to do about observations with zero citations, which account for about 1/3 of all patents. A number of standard procedures are at hand, here we chose to assign the value of 0.1 to the observations with 0 citations, but the results are pretty much the same if one resorts to other means.

[22] The coefficient of (time × USA) is negative but borderline significant, and moreover its significance does depend on how we treat the observations with zero citations.

[23] We don't show there the s.e. (or t values): most coefficients are significant, not all, but the qualitative results are well represented in the figure.

[24] But we have to remember that there are still relatively few Israeli patents in Biotechnology (see Appendix B): just 196 for the whole period.

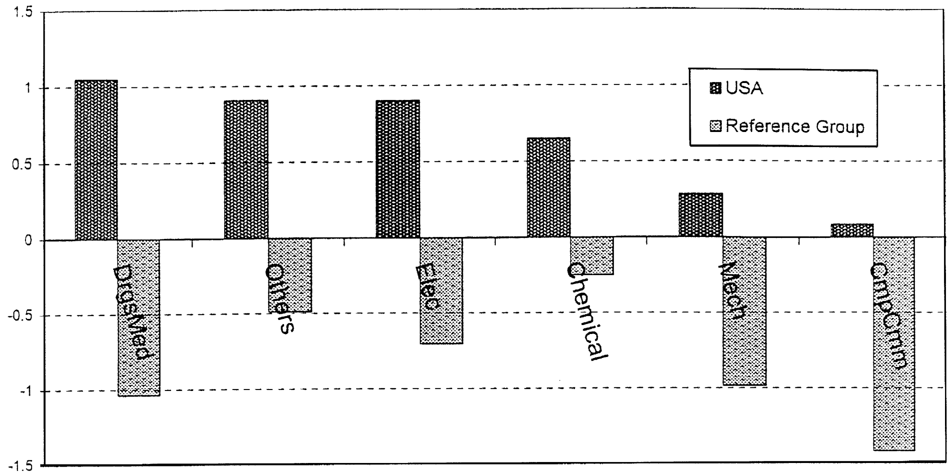

Fig. 15. Relative "importance" of Israeli patents by Tech category.

tions in two technological fields that stand at the forefront of technology worldwide, Computers and Communications and Biotechnology. The former is also Israel's fastest growing field, the latter is still very small but growing. This is a very reassuring finding, and speaks of the great potential that resides with the high-tech sector in Israel.

8. Concluding remarks

Before summing up, it is important to emphasize once again that the forgoing analysis was conducted entirely on the basis of data contained in Israeli and other patents issued by the US Patent Office. Clearly, not all Israeli innovations are reflected in those patents (the same is true for the comparison countries), and hence the results should be qualified accordingly. However, 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 indeed representative of the main technological trends and patterns in Israel.

Israeli patenting in the US has grown very rapidly for the past 3 decades (the growth rate averaging over 10% per year), placing Israel as the 14th largest

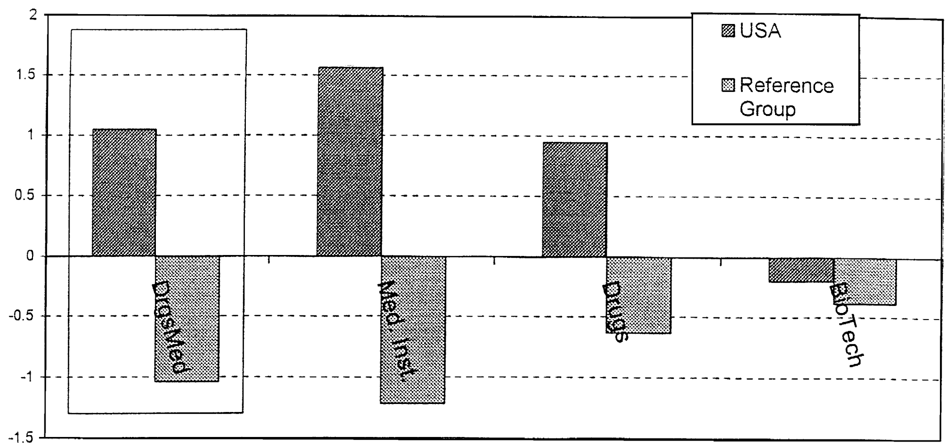

Fig. 16. Relative "importance" of Israeli patents in drugs and medical.

foreign recipient of US patents. There is a close statistical association between the annual flow of Israeli patents and Industrial R&D expenditures in Israel. Moreover, the time path of patents seems to have been strongly influenced by major "supply shocks" such as the termination of the project to build a jet fighter (which freed a large number of engineers and technicians), and the mass immigration from the former Soviet Union. This raises the question of whether such the rapid growth in innovative outputs is sustainable, given the recent stagnation (and even cuts) in Government support to R&D, and the lack of significant foreseeable additions to the pool of highly skilled workers.

Israel fares very well in international comparisons (vis-a-vis the G7, a Reference Group of countries with similar GDP per capita, and the "Asian Tigers"), both in terms of patents per capita, and in growth rates of patenting. Thus, in recent years it holds third place among these countries in patents per capita (after the US and Japan), and third again for growth rates (after Taiwan and South Korea). However, 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 of the G7 countries, and is about 1/4 the size of Taiwan and South Korea. Once again, 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 to ensure its long-term viability. This remains to be seen.

The technological composition of Israeli patents has changed dramatically over time: traditional fields such as Chemical and Mechanical have declined steeply (in relative terms), whereas Computers and Communications rose from a mere 5% of patents to 25% by the late 1990s. These changes are in tandem with worldwide trends in technology, except that Israel is experiencing them at an accelerated rate. Israeli patents are inferior to US patents in terms of "importance" as measured by citation rates, but better than patents issued to the Reference Group of countries. In terms of technologies, Israeli patents are particularly "good" (i.e. highly cited) in the key fields of Computers and Communications and Biotechnology.

The analysis so far indicates 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 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 fully realize the economic benefits embedded in those innovations.

A. Patents for selected countries, 1968–1997 by application year

Country	1968–1972	1973–1977	1978–1982	1983–1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Israel	58	102	137	211	281	318	325	312	355	421	576	613	609	664
G7														
Canada	1106	1180	1147	1345	1876	2029	1933	2049	1955	2180	2270	2583	2419	2555
France	1929	2164	2199	2397	2940	2925	3044	2968	2885	2795	2832	3107	2787	2957
Germany	4874	5745	6167	6,660	7621	7759	7487	6880	6909	6669	7063	7469	7278	7772
Italy	660	718	819	971	1267	1232	1282	1249	1260	1141	1159	1242	1204	1237
Japan	4062	6385	9359	13,979	19,866	21,650	22,072	22,701	22,342	21,515	23,357	24,474	24,252	25,637
UK	2764	2709	2357	2429	2704	2811	2584	2320	2227	2305	2517	2628	2421	2600
USA	45,150	41,894	38,222	37,990	46,968	50,190	53,130	53,451	55,741	58,990	62,216	74,249	64,026	72,144
Reference group														
Finland	70	103	143	212	262	310	349	349	318	344	421	429	482	513
Ireland	20	18	21	36	63	52	54	57	49	49	72	60	53	64
New Zealand	17	33	47	49	45	52	43	39	39	34	59	55	70	85
Spain	67	87	63	99	124	146	146	133	163	146	162	183	184	190
Asian Tigers														
Hong Kong	11	17	23	30	46	62	50	64	65	72	106	81	111	103
Singapore	4	2	4	8	14	21	19	31	60	56	80	81	99	98
South Korea	4	9	20	74	205	409	509	787	892	1019	1497	1747	2632	3049
Taiwan	1	33	87	279	557	725	931	1116	1256	1460	1778	1924	2262	2607

The figures for the four 5-year periods between 1968 and 1987 are yearly averages.

B. Distribution of patents by tech sub-categories[a]

Sub-category	5 years (1990–1994)	Total (1968–1997)
Communications	198	417
Computer Hardware and Software	197	409
Drugs	140	391
Surgery and Med Inst	135	424
Miscellaneous — chemical	104	389
Miscellaneous — Others	102	362
Power Systems	86	266
Biotechnology	77	196
Mat Proc and Handling	76	238
Measuring and Testing	63	230
Miscellaneous — Mechanical	56	187
Furniture, House Fixtures	55	168
Nuclear and X-rays	54	158
Organic Compounds	50	244
Optics	46	116
Electrical Devices	43	125
Miscellaneous — Elec	41	111
Fluid Sprinkling, Spraying, and Diffusing	41	175
Transportation	40	100
Liquid Purification or Separation	40	162
Agriculture, Husbandry, Food	37	150
Resins	32	125
Miscellaneous — Drgs and Med	26	90
Heating	26	109
Semiconductor Devices	23	58
Electrical Lighting	22	69
Refrigeration	20	76
Amusement Devices	20	101
Motors and Engines + Parts	20	110
Computer Peripherals	18	40
Receptacles	17	60
Fluid Handling	17	91
Information Storage	16	55
Apparel and Textile	15	57
Metal Working	10	50
Pipes and Joints	9	38
Agriculture, Food, Textiles	7	47
Earth Working and Wells	6	57
Coating	5	41
Gas	3	11
Total	1993	6304

[a] Sorted by last 5 years total.

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