THE ECONOMIC IMPACT OF SUBSIDIZED INDUSTRIAL R&D IN ISRAEL*

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✡ Ehud Zuscovitch passed away on 31 July 2000.

ABSTRACT

Israel offers contingent subsidies to selected industrial R&D projects, with the purpose of creating high-quality jobs, reducing the trade deficit, increasing productivity and promoting growth. In 1987-94, 1,200 firms received $1,400 million of subsidies in support of $3,500 million of R&D (in constant 1996 dollars). We estimate that this R&D generated more than $31,000 million of sales, increasing industrial employment by about 10% and contributing to the trade balance a sum slightly less than the entire private sector deficit in the current account. It added 0.3% to GDP in increased productivity, each dollar of supported R&D adding an additional $0.45 to GDP and earning the economy a direct annual return of 13.4%. Electronics, broadly defined, received roughly half the subsidies while accounting for nearly two thirds of the gains; small firms that received one sixth of the subsidies contributed over a quarter of the gains.

1. INTRODUCTION

Growing recognition of the importance of technology as a determining factor of economic performance is leading governments increasingly to seek policies that promote investment in innovation. Israel was a pioneer in this regard, having pursued an active policy of promoting industrial research and development (R&D) for the last thirty years. The main vehicle of this policy is the Law for the Promotion of R&D in Industry, administered by the Office of the Chief Scientist, Ministry of Industry and Trade (OCS). It provides contingent matching grants to selected industrial R&D projects, generally covering 50% of approved expenses, which successful projects repay in royalties on sales. Its explicit goals are creating high-quality jobs, promoting exports to reduce the trade deficit, and fostering productivity and growth. In this paper we estimate the impact of subsidized R&D on these goals, focusing on the period 1987-94 during which OCS paid out $1,400 million in subsidies to 1,200 firms in support of $3,500 million of R&D.[1]

Our analysis views the effect of supported R&D on economic performance as the result of a process in which investment in R&D builds technological capital that enables the development of innovative products. Sales of these products then create jobs, improve the trade balance and increase productivity and growth. Two new data sources serve us in our empirical analysis: the OCS project database, containing full administrative data on

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[1] Monetary data are denominated in fixed 1996 dollars; data from other years were converted to 1996 prices using the Israel CPI index, and then converted to dollars using the average exchange rate for that year. The program is very large in relation to the economic activity that it supports. In 1996, R&D expenditures in manufacturing totaled $906 million (CBS, 1999), while gross OCS payments through this program equaled $278 million, and the government's share, net of royalties received on past subsidies, equaled $186 million. OCS also funds industrial R&D through several newer support programs outside the scope of this study— primarily a technological infrastructure program for consortia, a technological incubators program, and special funds for international cooperation— totaling $92 million in 1996. The meteoric rise of Israel's high-tech sector in recent years has led to demand for subsidies outstripping budget growth, and effective subsidy rates have fallen in recent years, especially for larger firms.

all projects submitted for support in the period studied, which we classified by firm size and industrial sector; and specially designed questionnaires administered by the research team to a sample of firms randomly drawn from the OCS database. We estimate the economic impact of supported R&D by first regressing sales on (lagged) technological capital for our random sample of firms—in the aggregate and classified by sector and size—to estimate the marginal effect of R&D on sales. We then multiply total supported R&D by its marginal effect on sales to obtain an estimate of the total sales that derive from supported R&D; use industry data to derive "contribution coefficients" that gauge the marginal impact of sales on different performance indicators; and calculate the overall impact of supported R&D on performance by multiplying the sales estimates by these coefficients. This methodology departs from earlier efforts in one important regard: where previous efforts largely assumed a Cobb-Douglas production function with unitary elasticity of substitution between R&D services and other factor inputs, we assume a hierarchy of production in which R&D is an enabling factor for which firms cannot substitute "conventional" factors of production.[2]

Our principal findings indicate that the contribution of OCS-supported research to the economy was indeed substantial in both absolute and relative terms. The $3,500 million of supported R&D generated estimated sales of over $31,000 million, creating 260,000 job-years—roughly 10% of industrial employment—and contributing almost $22,000 million to the balance of merchandise trade, just slightly less than the private

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[2] See Griliches (1995) for a comprehensive exposition and numerous references on the standard approach. Two recent examples of its application to Israeli data are Bregman and Marom (1998) and Griliches and Regev (1999). Our distinction between routine production and innovative activities draws on Schumpeter's (1934) conceptual framework. For further elaboration of this approach in other contexts see, e.g., Nelson and Winter (1982) and Justman and Teubal (1991).

sector deficit in the current account in that period. Each dollar of R&D increased total factor productivity by an additional $0.45, annually contributing 0.3% of GDP on average, and earning a direct annual return of 13.4% for the economy. Electronics and communication and automation and control equipment received roughly half the subsidies while generating nearly two thirds of the gains. Small firms receiving one sixth of the subsidies contributed over a quarter of the gains. This reflects the important role of electronics and communication and automation and control equipment in Israel's high-tech revolution, and the large relative contribution of small firms.[3]

The structure of the paper is as follows. Section 2 presents the conceptual framework, Section 3 describes the population of firms, data sources and sampling procedures, Section 4 presents our main findings, and Section 5 concludes.

2. CONCEPTUAL FRAMEWORK

We describe the economic contribution of R&D as the result of a process in which investment in R&D builds technological capital, which leads to the development of innovative products. These products open new markets and generate sales, mostly in

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[3] We had intended originally also to gauge the amount of R&D that would not have been undertaken without OCS support (its "additionality") but were not able to construct a suitable control group. The few comparable firms that did not receive R&D support during the period in question were unwilling to cooperate with the study (firms that received support were strongly urged to cooperate by OCS). Project level data within firms that received support might have allowed us to use unsupported projects as a control group, but were generally unreliable and insufficient for our purposes: in addition to objective difficulties, firms had an interest in manipulating project definitions so as to minimize royalty obligations. (We elaborate on this in the next section.) Klette et all. (2000) survey the scant evidence on additionality and discuss the methodological difficulties involved in its measurement. As a partial substitute, we calculated relative *ex ante* measures of the impact of OCS assistance on the decision to implement R&D, based on the presence of market failures. The measures of market failure we derived for this purpose reflect levels of technological risk, commercial risk, liquidity constraints and positive externalities; they allow comparison between sectors and size groups, and provide benchmarks that can be used in future screening of R&D projects (for further details see Justman et al., 1999, available on request).

foreign markets, which increase domestic employment, improve the trade balance and raise total factor productivity. To calculate this contribution, we first estimate the quantitative relation between the stock of technological capital and sales, based on data from our sample of firms. We then multiply total supported R&D by its marginal effect on sales to obtain an estimate of the total sales that derive from supported R&D. Next, using industry data, we derive a set of "contribution coefficients" that gauge the marginal impact of sales on employment, the trade balance and productivity. Finally, to calculate the overall economic impact of supported R&D we multiply the total sales estimates by the contribution coefficients.

Our estimates of the effect of R&D on sales are based on three central premises. The first is that the relationship between R&D and sales can only be measured at the enterprise level and not at the project level. While the two often coincide in small firms, in larger multi-project firms the relationships among projects are too complex to separate their different costs and benefits: know-how gained in current projects draws on know-how gained from previous projects, spills over into parallel projects, and contributes to future projects.[4] Moreover, there is no standard system of project accounting, as project-level accounts are not externally required except for OCS purposes, and firms had strong incentives to manipulate project definitions so as to minimize royalty obligations to OCS.[5] Therefore we measure the marginal contribution of R&D to sales at the enterprise level and not at the project level.

A second, related premise is that R&D enters the production function not as a

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[4] This is widely documented. Ron (1987), e.g., describes project spillovers in an Israeli chemical company.

[5] When projects are narrowly defined, as they were in the early years of the study, firms had an incentive to declare that supported projects on the brink of success had "failed", and then continue their development as "new" unsupported projects that do not carry an obligation to pay royalties.

flow but as a stock of technological capital (Griliches, 1979), implicit in our observation that present sales are influenced by past R&D, and current R&D will affect future sales. Two parameters determine our conversion of R&D investment flows into capital stocks: the initial time lag between investment in R&D activities and the realization of sales, and the (constant) rate of depreciation of know-how gained through R&D. We compared three different time lags: no lag, a one-year lag, and a two-year lag, and found they produced generally similar results. We preferred the one-year lag because of the simultaneity implied if no lag is taken, and because the two-year lag substantially reduced the number of observations and increased the variance of the estimates. We also tried different rates of depreciation and found the results to be robust to variation between 10% and 50%. The estimates reported in Section 4 are based on an annual rate of 30%, a relatively rapid rate that mirrors the short product cycles of the electronics and software technologies that dominate Israeli R&D; it generally yielded a good fit.[6]

Our third premise represents a departure from traditional econometric analyses of the contribution of R&D to industrial production. As we focus on innovation-intensive industries in which the role of technological capital in creating demand for a firm's output is predominant, we assume no significant substitution between R&D spending and "conventional" labor, capital and material inputs employed in production. Instead, we posit a hierarchy of functions in which R&D is an enabling factor for which firms cannot substitute conventional factors of production.[7] Formally, this is represented by a production function that assumes zero elasticity of substitution between the two types of

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[6] This implies a "half-life" of two years beyond the one-year lag. Griliches and Regv (1999) use a rate of 1/7 for their study of R&D in 1975-94, but remark that depreciation may have accelerated in the later years.
[7] The commonly used Cobb-Douglas function implies unitary elasticity of substitution.

production factors. It has the general form:

$$Y = \min \{ g(R), f(L, K, M) \}$$

where Y represents sales, R represents the stock of R&D capital, and L, K, and M represent conventional factors used in production (and not in R&D). The function g determines the marginal contribution of a dollar of R&D to the creation of a market for the output of the enterprise, while the function f is the production function that converts input factors into final goods, when there is a market for these goods. This leads us to estimate the marginal effect of R&D on sales by regressing sales on lagged technological capital alone. We allow for different effects in different industries and estimate a separate function for each sector, as well as separate functions for "large" and "small" firms where size is measured by technological capital. Then we break down total supported R&D by sector and size, and multiply total R&D and the various subtotals by their respective marginal effects on sales to obtain estimates of sales that derive from supported R&D—in total and for subgroups.

We use average industry data to estimate the "contribution coefficients", implicitly assuming that the marginal contributions of sales to employment, the balance of trade and productivity are constant, at least within sectors. The contribution of a dollar of sales to employment is measured by the labor-to-sales ratio—the inverse of sales per employed person. The contribution of a dollar of sales to the balance of payments is measured by the percentage of "local value added", i.e., the value of exports net of imported factor inputs. The contribution of a dollar of sales to total factor productivity is measured by the percentage of "net economic surplus"—the value of output net of standard payments to factors inputs (we elaborate on this below).

Finally, to calculate the *total* contribution to employment, the balance of trade and productivity of the R&D supported by OCS in the period 1987-94, we multiply our estimates of sales induced by supported R&D by their respective contribution coefficients. In addition, we calculate contribution per dollar of R&D and per subsidy dollar, overall and within sector and size groupings.

3. POPULATION OF THE STUDY AND DATA SOURCES

Two principal data sources are used in the study. The first is the OCS project database, containing full administrative data on all projects submitted for support in 1987-94,[8] including research budgets, subsidies received and royalties paid, summarized in Table 1.

Table 1: Summary of OCS Activity, 1987-94

year	new firms receiving support	new projects supported	total R&D approved for support*	total subsidies paid out*
1987	112	258	$305	$121
1988	138	290	$347	$133
1989	128	252	$322	$134
1990	128	266	$390	$156
1991	181	392	$414	$166
1992	158	377	$543	$211
1993	167	352	$581	$219
1994	171	399	$624	$250
total	1,183	2,586	$3,526	$1,390

*Constant 1996 dollars, millions.

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[8] The study was originally aimed at the period 1985-94 but data for 1985-86 were difficult to compare to later data because of the stabilization plan initiated in 1985 and a shift from fiscal to calendar years.

To these data we added a classification by firm size and industrial sector. Table 2 presents the distribution of subsidies by size category and year. The size-related variable universally available in the OCS database was the total R&D support received by the firm, which we divided into four categories: less than $250,000; $250,000-$1million; $1-$10million; and over $10 million. Where the distribution of funds is highly skewed towards the larger size categories, the distribution of the number of firms in each category is skewed in the opposite direction: the smallest size category accounts for 63% of the firms, the next largest 24%, the next largest 11%, and the largest size just 2%, or 28 firms. Thus 28 firms received over half of OCS support for R&D.

Table 2. Distribution of Subsidies, by Year and Total Subsidies Received

year	$1-250,000	$250-999,999	$1-10 million	$10 million +	total paid*
1987	4.3%	12.5%	27.9%	55.3%	$121
1988	5.5%	10.8%	29.8%	53.8%	$133
1989	5.2%	10.2%	29.2%	55.4%	$134
1990	4.7%	7.5%	26.9%	61.0%	$156
1991	6.5%	10.7%	27.4%	55.4%	$166
1992	5.7%	8.9%	21.7%	63.7%	$211
1993	6.7%	11.1%	27.6%	54.6%	$219
1994	8.9%	16.0%	27.3%	47.8%	$250
total	6.2%	11.2%	27.0%	55.7%	$1,390

* Constant 1996 dollars, millions.

The OCS database was also classified by industrial sectors, using a classification based on the Israel Central Bureau of Statistics (CBS) system, adapted to the distribution of firms receiving OCS support. Table 3 summarizes the distribution of subsidies by industrial sector and year. It highlights the structural change that Israel's high technology sector underwent in the period of the study: a sharp decline in the military industries and a sharper rise in electronic and communications equipment for the civilian market, and in programming and software. Compared with other countries, the share of the chemical industry in R&D activity in Israel is disproportionately small, and this is also reflected in the disbursement of subsidies.

Table 3. Distribution of Subsidies, by Year and Industrial Sector

	1987	1988	1989	1990	1991	1992	1993	1994
Automation and Control	25%	22%	22%	22%	22%	16%	17%	19%
Programming and Software	5%	7%	7%	7%	8%	7%	7%	9%
Medical Industries	16%	13%	15%	15%	16%	13%	13%	13%
Electronics and Communications	14%	15%	19%	22%	27%	40%	42%	39%
Chemicals and Materials	5%	8%	9%	7%	8%	6%	6%	6%
Military Equipment	25%	26%	16%	18%	14%	14%	11%	8%
"Other Industries"	8%	8%	11%	9%	5%	4%	4%	6%
total	100%	100%	100%	100%	100%	100%	100%	100%

Questionnaires administered by the research team to a sample of firms randomly drawn from the OCS database are a second source of data for the study. Here we use only annual firm-level data on sales and R&D spending from the questionnaires, which contain much additional information on different technological, commercial, managerial and financial aspects of the innovation process.[9] Our original sample design comprised

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[9] This information was used for descriptive purposes and to build market failure indices (further details are in Justman at al., 1999).

180 firms that received OCS support, 10 that requested support but received none, and 10 that were eligible for support but did not request any. These proportions reflect the wide coverage of the OCS subsidy program: the vast majority of high-technology firms in Israel received some support from the program. The sampling of the 180 firms from the OCS database was designed to satisfy both size and sector criteria. We stratified our sample by total OCS support received, according to the four size categories described above, and chose sampling ratios that reflect the disproportionate share of funds received by larger firms: 1:20 in the first category, 1:6 in the second, 1:3 in the third and 1:1 in the fourth. Sampling by sector was proportional to actual representation within each size category. Thirty-one of the 180 firms in the sample were found to be inactive at the time of the study, and could not be contacted; one hundred and eighteen of the remaining 149 active firms agreed to cooperate in the study. Sampling twenty additional firms that did not receive support, as a control group, proved impossible to implement. Few high-technology firms eligible for support turned it down, and neither these nor firms that applied for support but never received any were willing to discuss their activities with us in any detail.[10]

4. ESTIMATION AND FINDINGS

4.1 The Impact of R&D on Sales

Our estimates of the relation between the stock of R&D capital and sales—the function *g*—was based on approximately 500 annual observations on 81 enterprises for which full,

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[10] More than one such firm informed us that not wanting to share this information with the government was the main reason it did not apply for subsidies.

consistent data were available. We assumed that firms for which the data were incomplete behaved similarly to firms in their category for which we had full information; and we assumed that the marginal productivity of R&D performed by inactive firms was zero (the correction made to take this into account is described below).

In estimating the quantitative relation between R&D and sales we tried both linear and logarithmic functional forms, and found that a double logarithmic specification provided the best fit. In this specification, the coefficient of the lagged R&D stock is an estimate of the elasticity of sales with respect to this stock.[11] Seven such estimates, with their standard deviations in parentheses, are presented in the first column of Table 4. The first row presents the results of a regression that pools all observations in the sample (with dummy variables controlling for fixed effects by sector, size and year); the next five rows present separate estimates for each of five industrial sectors; and the last row gives a separate estimate for small firms.[12] The standard deviations are small in relation to the estimates—all *t* values are greater than 6—implying a high level of statistical significance and narrow confidence intervals.

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[11] The percentage change in sales as a result of a one-percent change in the stock of R&D capital.

[12] We omit from the table separate estimates for the chemical industry, which were statistically significant but implied unreasonably large marginal effects; the bulk of activity in Israel's chemical industry is not innovation-based. As it accounts for only a small fraction, about 7%, of R&D support its impact on the aggregate estimates is limited. Separate coefficients for "other industries", comprising firms from widely different fields, are also not presented. The size classification is by size of R&D stock at the time of the observation, so that observations from different years on the same firm can be "small" in earlier years and "large" in later years. The "small firm" category comprises the bottom 50% of observations. The cutoff point was an R&D stock of approximately $5 million. "Large firms" behaved almost identically to the aggregate.

Table 4. Sales Elasticities and Multipliers
(standard deviations in parentheses)

	Elasticity (standard deviation)	Ratio of Sales to R&D Capital	Estimated Derivatives	% Support to Inactive Firms	Annual Sales Multiplier	Total Sales Multiplier
All firms	0.82 (0.06)	3.53	2.89	7.8%	2.66	8.87
Automation & Control	1.07 (0.08)	4.06	4.33	12.1%	3.81	12.69
Programming & Software	0.65 (0.1)	2.78	1.80	25.8%	1.36	4.45
Medical Industries	0.83 (0.1)	2.00	1.66	2.2%	1.63	5.42
Electronics & Communication	0.95 (0.04)	4.30	4.10	6.7%	3.83	12.75
Military Equipment	0.64 (0.08)	3.99	2.55	0.6%	2.60	8.46
"Small firms"	0.70 (0.09)	7.55	5.32	20%	4.25	14.18

An initial estimate of the marginal contribution of a dollar of R&D stock to sales at the mean—the derivative of the function *g* with respect to *R*—is obtained by multiplying the estimated elasticity by the ratio of sales to R&D stock at the mean.[13] The mean values of this ratio in the data are given in the second column of Table 4, and its product with the elasticity is given in column 3. These estimates are upwardly biased, as they are based only on the performance of enterprises that continued to be active at the time of the study, and an adjustment is needed to correct for the omission of inactive firms. We attribute to them a zero marginal contribution, and subtract from the estimated derivatives the proportion of OCS support in each category paid to such firms. The percentage of subsidies paid to inactive firms and the corrected derivative, to which we refer as the annual sales multiplier (ASM), are presented in the next two columns of Table 4.

This is the contribution to sales of a dollar invested in R&D in the first year after the lag. However each such dollar has a lasting, though diminishing, effect on sales. We refer to the total flow of additional sales over time from an additional dollar of R&D spending as the total sales multiplier (TSM). Given our assumption of a 30% annual depreciation of R&D, it is related to the ASM by the equation:

$$TSM = ASM * (1 + 0.7 + 0.7^2 + 0.7^3 + \ldots) = ASM / 0.3$$

The rightmost column of Table 4 presents the TSM values for each of the seven categories. They indicate that in firms that received R&D subsidies, a dollar of R&D generated \$8.87 of sales, on average. In electronics and communications and automation and control equipment a dollar of R&D generated between \$12 and \$13 of sales, a range of magnitude that accords with industry rules of thumb.

Total sales deriving from subsidized R&D were then calculated by summarizing subsidized R&D in 1987-94 by category,[14] and multiplying these sums by the Total Sales Multipliers from Table 4. The results are presented in Table 5. Electronics and communication and automation and control equipment together received less than half the subsidies paid out while accounting for almost two thirds of derivative sales. Small

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[13] Denoting the elasticity of sales with respect to R&D stock by η, $\eta = (dY/dR)/(Y/R)$ by definition, and so the marginal effect of R on S is $dY/dR = \eta\,(Y/R)$.

[14] Note that "all sectors" is not a summary of data for individual sectors, but is based on coefficients estimated for all sectors taken together. Since OCS records do not indicate size according to R&D capital stock, we used size classifications based on the sum of accumulated subsidies.

firms, receiving 17% of the subsidies, generated 28% of sales.

Table 5. Total Sales Deriving from Subsidized R&D
(financial data in millions of 1996 dollars)

Sector	Approved R&D		Subsidies Received		Estimated Sales	
All Sectors	$3,526	100%	$1,390	100%	$31,276	100%
Automation and Control	614	17%	269	19%	7,792	25%
Programming & Software	271	8%	104	7%	1,206	4%
Medical Industries	501	14%	201	14%	2,715	9%
Electronics & Communications	1,010	29%	426	31%	12,878	41%
Military Equipment	726	20%	223	16%	6,142	20%
Small firms	610	17%	239	17%	8,650	28%

4.2 Contribution Coefficients

In the next stage of the analysis we computed coefficients that convert R&D-induced sales into measures of economic impact on employment, the balance of payments and productivity deriving from these sales. Data from the questionnaires were inadequate in quality and coverage to estimate these parameters, and so we based the coefficients on industry data. Sectoral coefficients for employment and the balance of payments are presented in Table 6. Employment coefficients were computed as an average of Central Bureau of Statistics data on sales per employee for the period studied (Statistical Abstract of Israel, various years). Local value added, the value of exports net of the value of imported inputs, represents the contribution of sales to the balance of payments. We took as our coefficient values the total imports (CIF) coefficients from the 1992 input-output tables (CBS, 1999, Table 6.24), except for software for which we adopted Toren and Adelman's (1991) estimate of 80%.[15]

Table 6. Contribution Coefficients

Sector	Sales per Employee (1996 Dollars)	Percent of Local Value Added
All Sectors	120,000	70%
Automation and Control Equipment	120,000	71%
Programming & Software	120,000	80%
Medical Industries	130,000	64%
Electronics & Communications	120,000	71%
Military Equipment	110,000	70%

We calculate a productivity coefficient by deriving the "net economic surplus" from sales: the value of output net of standard payments to factor inputs excluding R&D expenditures. We base our calculation on Griliches and Regev's (1999, Table 4) summary accounts for all manufacturing firms receiving R&D subsidies, which indicate an average value of 5.0% for the gross margin net of charges to physical capital in 1988, 1991 and 1994. To this we add the ratio of annual R&D to sales (the inverse of the total sales multiplier), 11.3%, obtaining a "net surplus margin" (NSM) of 16.3%.[16] It implies that on average each dollar of R&D adds an additional $0.45 in productivity over an infinite horizon. Given the lag structure we have assumed, this represents an annual rate

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[15] The coefficient for automation and control is the average of electronics and precision instruments; that for medical industries is the average of electronics and pharmaceuticals; that for military industries is the average of electronics, metalwork, ships and aircraft and other transport. The "all sectors" coefficient is a weighted average of individual sectors, weighted by their share in OCS subsidies. These estimates differ very slightly from the coefficients used in the original report, which were based on earlier data.

[16] This value is lower than the coefficient used in the original report, prepared before Griliches and Regev's (1999) findings were available. An alternative calculation for electronics yields a similar estimate. Taking the gross margin coefficient for electronics equipment from the 1992 input-output tables, 15.1%, deducting from it Griliches and Regev's (1999, Table 4) charge to physical capital in 1991, 7.0%, and adding the R&D to sales ratio for electronics and communication, 7.8%, gives a net surplus margin of 15.9%.

of return (from direct benefits) of 13.4%.[17] This approach is conservative in that it takes into account only direct contributions. As an indication of the surplus created in supplier firms, note that the *total* gross margin coefficient for electronics equipment, 20.0% in 1992, is one third higher than the direct gross margin coefficient. Bregman and Marom's (1998) estimate a 30% for the social rate of return on investment in R&D capital in the industrial sector, from panel data on 17 "two–digit" industries between 1960–1996. Of course, external benefits run in both directions: Israel's high-tech sector has benefited substantially from public investments in education and especially defense-related R&D.

4.3 Total Contributions

The total impact of subsidized R&D on employment (in job-years) is calculated by dividing R&D-induced sales by sales-per-employee, for each of the seven categories in Table 4, and its contribution to the balance of payments is calculated by multiplying sales by the coefficients of domestic value-added. The total effects, presented in Table 7, are substantial in relation to Israel's industrial sector. Job gains amounted to over 10% of industrial employment, and the contribution to the balance of trade was only slightly smaller than the entire current account deficit of the private sector for the period, approximately $23,000 million (in 1996 dollars). Productivity gains contributed 0.3% to GDP, 0.45% to business sector product, and 1.8% to industrial product.[18] Helpman's

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[17] The rate of return is the value of r that solves: $-1 + (1 + r)^{-1} \cdot NSM \cdot ASM \cdot \Sigma_t [0.7/(1 + r)]^t = 0$. Of course, the private rate of return is higher than 13.4% because of the subsidy. The higher sales multiplier for electronics (3.81 *vs* 2.66), with its similar net surplus margin of 15.9%, implies an internal rate of return of 30%, and $1.07 of added output for each dollar of R&D.

[18] Total gross domestic product (GDP) was $515,000 million (in constant 1996 dollars) in 1987-94, total product of the business sector was $343,611 million, and total industrial product was $84,620 million.

(1999) estimates for an earlier time frame, 1971-90, are comparable: he concludes that growth of Israel's R&D capital stock annually increased business sector product by 0.8% in that period.[19]

Table 7. Contribution of subsidized R&D to employment and the balance of trade
(financial data in millions of 1996 dollars)

Sector	Approved R&D	Subsidies paid	Sales	Job-years	Domestic value-added
All Sectors	$3,526	$1,390	$31,276	260,630	$21,893
Automation and Control	614	269	7,792	64,931	5,532
Programming & Software	271	104	1,206	10,050	965
Medical Industries	501	201	2,715	20,888	1,738
Electronics & Communications	1,010	426	12,878	107,313	9,143
Military Equipment	726	223	6,142	55,836	4,299
Small firms	610	239	8,650	72,082	6,055

We also calculated contributions to employment and the trade balance per million dollars of subsidized R&D and per million dollars of R&D subsidies (Table 8). The subsidy per job-year was $5,300, about 15% of the annual manufacturing wage. These calculations reinforce the important role of electronics and communication and automation and control equipment in Israel's high-technology sector, and highlight their large relative contribution, as well as the large relative contribution of small firms.

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[19] This is based on his earlier estimate of 0.078 for the elasticity of TFP growth in the business sector with respect to R&D capital, obtained from international panel data, and average annual growth of 10.4% in Israel's R&D capital stock. Griliches and Regev (1999, Table 3) report that R&D by firms that received OCS subsidies accounted for about 80% of all industrial R&D capital, and was more effective than R&D performed by unsubsidized firms. Helpman's R&D stock includes all civilian R&D.

Table 8. Contribution to employment and the trade balance per million dollars of subsidized R&D and per million dollars of R&D subsidies

(domestic value-added in millions of 1996 dollars)

Sector	per million dollars of subsidized R&D		per million dollars of R&D subsidies	
	Job-years	Domestic value-added	Job-years	Domestic value-added
All sectors	74	$6.21	188	$15.75
Automation and Control	106	9.01	241	20.57
Programming & Software	37	3.56	97	9.28
Medical Industries	42	3.47	104	8.65
Electronics & Communications	106	9.05	252	21.46
Military Equipment	77	5.92	250	19.28
Small firms	118	9.93	302	25.33

5. CONCLUDING REMARKS

Israel has always devoted a large share of its domestic product to research and development. Until the late 1980s its innovative efforts were mainly directed to defense and agriculture, and generated modest economic benefits. But the last decade has seen a surge of new success in fostering commercial entrepreneurship in high technology industry, mostly through a redirection of innovative effort to communications equipment and software products aimed at the civilian commercial market.

This dramatic transformation of Israeli industry can be attributed to a confluence of factors (Justman, 2000). The stabilization plan of 1985, ending a decade of hyperinflation, was followed by large cutbacks in defense-related R&D (especially the curtailing of the Lavie fighter-jet development program in 1987), which released large numbers of scientists and engineers into the labor market. The demise of the Soviet Union triggered a wave of mass immigration after 1989, which upgraded the country's human capital and fueled a building boom, and improved Israel's geopolitical position. US capital markets began a sustained boom, showing especially strong demand for new technology issues.

The OCS R&D fund played a key role in this window of opportunity for industrial transformation: serving as a primary source of venture capital for Israel's technological entrepreneurs, it filled an essential gap before extensive reform of the country's financial sector facilitated its integration in world capital markets and promoted the emergence of a domestic venture capital sector. It was (and remains) a large-scale program that enabled large gains to be realized in a short period of time. Other countries in similar circumstances, with a surplus of highly skilled labor and a shortage of specialized capital, might benefit from similarly structured and scaled programs, to provide publicly funded venture capital for industrial innovation until adequate private sources emerge.

However, with the integration of Israel's financial sector in world capital markets, and the new abundance of private venture capital the case for maintaining the OCS subsidy program, let alone expanding it, is substantially weakened. Essentially, an "infant industry" program for the development of a private venture capital sector, it is the "victim" of its success. Like other infant industry programs, it now faces the challenge of effecting an orderly exit—an eventuality that was not anticipated at the program's inception. The manner in which it meets this challenge in coming years—an issue of immediate public concern in Israel—will likely provide further useful insights on the design and implementation of industrial R&D subsidy programs.

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