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Defense R&D and Economic Growth in Israel: A Research Agenda

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4 SCIENCE, TECHNOLOGY AND THE ECONOMY PROGRAM (STE)

WORKING PAPERS SERIES

Technion - Israel Institute of Technology

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March 2001

This paper was prepared for the "Science, Technology and the Economy", (STE), Program at the Samuel Neaman Institute for Advanced Research in Science and Technology, at the Technion-Israel Institute of Technology. It was updated in light of the discussions during the STE Workshop on this paper's topic, held on January 11, 2001. I want to thank Workshop participants, and in particular Joseph Bartov from the Ministry of Defense for his comments on an earlier draft which hopefully will be more fully reflected in future research on this topic.

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Abstract

When evaluating Israel's high-tech capabilities and impressive economic achievements since inception, it is difficult not to recognize the important role played by defense and military developments. In particular, defense-related R&D had significant impacts on, as much as it was aided by, Israel's industrial sector, higher educational system in science and engineering, research community, and the composition of its work force. However, a comprehensive empirical evaluation of the economic impacts of defense-related R&D in Israel is still missing. Such an evaluation could contribute to a better resource allocation and distribution of research activities among government agencies, academy and the thriving private high-tech sector. This documents reviews some salient results in the literature about the links between defense-R&D and economic performance, and lists some unique characteristics of the Israeli economy that might affect the validity of this results for Israel. Specific research questions regarding the economic impact of defense R&D in Israel, and the kind of data needed to analyze them, is provided.

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1. Introduction

When viewed in historical perspective, there can be little doubt that the defense sector in Israel had a fundamental impact on the development of this country's technological and industrial capabilities. For most of its first 50 years, Israel devoted a large share of its resources to defense purposes, putting a high priority on the development of modern armed forces with sophisticated military technologies and equipment, and on the ability to develop and supply these capabilities by its own means. Derived demand from this buildup for highly skilled workers, scientists and engineers affected public resources allocated to universities and research institutions, and accordingly the directions that these institutions emphasized as they expanded. Israel has today a concentration of scientists and engineers in its work force which is among the highest in the world, and a rate of high-tech startups which is high among industrialized countries even in absolute terms. The defense manufacturing industry in Israel accounts for a significant share of its industrial capacity, includes some of its largest corporations, and is considered a major worldwide player in some areas of the defense industry.

Adequate external security is of course necessary for any economic progress. However, since economic performance is not a factor in determining the size and the particular applications of defense budgets – the presumption ought to be that resources allocated to defense could have a larger contribution to economic growth had they been used differently. It is surprising, therefore, to see how *little* evidence was found in support of this view. Besides the difficulty in assessing such hypothetical questions, there may be countervailing forces at work, which offset some of the economic losses associated with military spending with indirect and serendipitous economic benefits. This paper reviews the economic literature, with emphasis on defense economics and R&D policy, in order to identify what these benefits and losses might be, and how they can be evaluated. It lists some unique characteristics of the Israeli economy which require special attention, and suggest some specific research questions which should be studied in light of them. The ultimate research goal, which hopefully will be aided by this paper, is to come up with quantitative and reliable answer to the question: *does defense-related R&D in Israel* *bring about positive growth externalities as a particularly effective catalyst of technological improvements, and a driving force for developing highly skilled technical workforce?*

In particular, we are interested to find out if there is a link between the national emphasis on employing and producing sophisticated military technology and Israel's exceptional growth in the high-tech sector and its recent impressive economic performance. We want to identify the channels through which defense-related R&D interacts with the development of technological capabilities in Israel. Understanding this interaction could provide a valuable input into resource allocation decisions at the national level regarding expenditure on defense-related R&D, and suggest avenues to maintain and strengthen Israel's high-tech capabilities, while satisfying its long-term defense needs.

The next section provides a brief overview of the size and trends in military spending and defense-related R&D in Israel and other industrial countries. The following section reviews some relevant issues and empirical findings in the literature about the effects of defense-related R&D, and more generally public funding of R&D, on economic performance and growth. Section 4 describes some unique features of Israel that warrant a reexamination of the results obtained in the literature concerning growth and defense-related R&D. Specific suggestions and topics that could be explored here if appropriate data is made available are contained in section 5.

2. Background

Defense industries in Israel amount to a significant part of the country's industrial capacity, and are big even in international terms. Dan & Bradstreet's 1997 listing of the largest industrial 150 corporations in Israel, (in sales), included 10 firms in the defense sector, as were 2 of the largest 5, (and 3 of the largest 30, if RAFEL, which is not incoporated , were included). Five Israeli companies appear in the list of the 100 biggest defense companies in the world, (Israeli Aircraft Industries, RAFAEL, Koor Industries, Tadiran, and Elbit Systems). The defense industry accounts for about 25%

of industrial output in Israel, and about 20% of total employment in the industrial sector.[1]

Furthermore, defense industries in Israel led its industrial sector in R&D and high-tech intensity through most of the first 4 decades of its existence. It was estimated that during the 80's, 65% of the national expenditure on R&D were defense related, while only 13% were oriented towards civilian industries. About half the scientists and engineers employed in the industrial sector worked in defense industries.[2] According to some measures, Israel stands out in its emphasis on defense-related R&D, which consumed 3.1% of GDP in the 80's, versus 0.84% of GDP in the US, 0.58% in Britain, and 0.43% in France.[3]

The relative technology sophistication of weapon system developed and used by Israel's armed forces had several reasons. Among them, the perceived need to maintain an independent supply of military hardware free from foreign political restraints and potential embargo, the desire for high "military power multipliers" for weapon systems capable of producing decisive results in a short time with few casualties, and the need to maintain a critical element of surprise which cannot be based upon imported systems. These reasons for maintaining Israel's own defense industry are still valid today, but the argument on the degree to which Israel should rely on imported "platforms" to be equipped by self-developed "systems", versus greater reliance on self-production of complete weapon systems is far from settled.[4]

The share of resources allocated to defense has been steadily reduced in Israel during the last three decades, from its peak of 32% of GDP in 1975, (including defense imports at 16% of GDP), to about 9% in 1999, (2.0% defense imports)[5]. Despite this dramatic decline in defense consumption, Israel's share of resources allocated to defense is still three times higher than that of the US or major European countries. In fact, Israel's military expenditures per capita was among the highest in the world in 1997, as was its share of resources allocated to military consumption, (see Appendix).

[1]See, Lifshitz 2000, p. 368.
[2]Lifshitz 2000, p. 369-370, citing Halperin 1987, (in Hebrew).
[3]Lifshitz 2000, p. 370, citing Halperin 1987, (in Hebrew).
[4]Lifshitz 2000, chapter 10.
[5]Source: Bank of Israel.

Military spending all over the industrial world experienced sharp declines since the end of the Cold War. For instance, the defense consumption share in the US declined from over 5% of GDP to less than 3% during the last two decades. In absolute terms, however, the entire defense budget in Israel today, of about $9 billion is miniscule in international terms, amounting to hardly 25% of the RDT&E, (R&D, Testing and Evaluation), budget of the Department of Defense in the US, (which is about 1/6 of the total expenditure on defense in the US).[6]

Such reductions in military spending, (which resulted from reduced global threats in the aftermath of the Cold War), have raised the concern of loosing a significant part of the driving force to technological development, as experienced in the industrial world during the middle part of the 20th century in diverse disciplines such as computing, aviation and communication.

However, these cuts in military spending were accompanied by deep and structural changes and by significant improvements in the R&D capabilities of the business sector, (in addition to reduced intensity and severity of global military threats). These changes, experienced both in Israel and other industrialized countries, included: (i) sizable consolidation of defense contractors, with those remaining possessing "vertical" capabilities heretofore unavailable to them; (ii) a much greater reliance on outsourcing and subcontracting of both production and R&D among defense contractors; (iii) an increased usage of commercial technologies in military applications, mostly using Information Technology, (IT), which now occupies a central strategic and tactical role in modern armed forces. Consequently, a much larger share of R&D and applications of advanced technologies are now *performed and funded* by the private sector.

Although it is possible that massive and innovative government R&D investments and procurement contracts for the design of weapon systems earlier on have contributed to

[6] It is worth noting, however, that the share of US defense budget allocated to RDT&E has increased from 9.3% in 1980, to about 16% in 1999. The importance attributed to defense-related R&D in the US is further reflected by the budget appropriations to RDT&E, and within it to R&D in Science and Technology, which have exceeded the requested budgets for these purposes by the Clinton Administration in the consecutive fiscal years 1999-2001. Comparable data for Israel is not publicly available.

the development of high-tech capabilities in the private sector, it is evident today that such government involvement is no longer necessary for creating and maintaining these capabilities. Still, the question which remains unanswered is:

> *To what extent publicly funded R&D efforts, (mostly defense related), can still bring about similar economic side-benefits of the kind they brought in the post-WWII era, and can push for further development of high-tech capabilities that seem necessary for sustained economic growth?*

This question is pertinent to R&D resource allocation processes and Science and Technology, (S&T), policy makers in most industrialized countries. It frequently appears in discussions of the OECD S&T Directorate, the European Commission Ministerial Forum, and various industrial and scientific associations[7]. It is important to keep in mind, however, that this question is completely distinct from the related issue of *who* is to perform the defense-related R&D, even if deemed desirable. Given the huge advances in the private sector and other civilian, (e.g. academic), high-tech and R&D capabilities, and the accompanying greater integration of commercial technologies in military applications, the conclusion might be that although defense-related R&D does bring about positive economic externalities, it can be performed in various forms of alliances and sub-contracting between the government and civilian entities.[8]

Comparison with technology development trends in other countries must be done carefully, recognizing country-specific needs, capabilities, and sheer economic size. The latter consideration is especially important given the high non-recurring engineering (NRE) component of the development of any kind of weapon system relying on new technologies, which affects its ultimate cost, (see more on that in Section 4).

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[7]For instance, see the report of the Center for Strategic & International Studies on defense restructuring and the future of US defense industrial base, (CSIS, March 1998), or the 1996 Technology Policy Symposium of the Institute of Electrical and Electronic Engineers on: “Is there a Role for the U.S. Government in Technology Devlopment?”, (ieee, June 1996).

[8]The US is leading the trend to merge military and commercial high-tech developments, and have successfully implemented several programs to that effect. For instance, see the statements by the Under Secretary of Defense for Acquisition and Technology, Jacque S. Gansler, before various committees of the Senate and the Congress, (e.g. Gansler (2000)).

This historical review and international comparison indicates the need for research on the following economic aspects of defense related R&D, incorporating Israel's advanced scientific and technological position, and the developed stage of its business sector and capital markets:

- The process by which investments in innovative military technology throughout Israel's history have contributed to its current high-tech capabilities and economic development;
- The extent and type of particular "spillovers" in technology, scientific know-how, and workforce development from defense oriented R&D projects;
- The potential of defense-related R&D to provide an economic and high-technology "driving force" to the Israeli economy, given its current advanced scientific capabilities and well developed private business sector.

3. The Economic Literature on the Impact of Defense Expenditures

The link between defense-related R&D and economic growth has been examined in various ways, at the national, industry, and individual firm levels. Among the issues examined were:

- Possible influence on total factor productivity, (TFP);
- Possible positive and negative impact on non-defense industrial sectors;
- Possible relationships between civilian and defense R&D;
- The potentially different productivity of R&D depending on the source of funding, (own-firm vs. external);
- Differences between impacts of government funded R&D for defense and non-defense purposes.
- The impact of military spending as a function of existing industrial base and general development conditions in the economy.
- The potential for developing scientific and engineering capabilities and infrastructures resulting from publicly funded "big" defense-related programs.

We review some of these findings while distinguishing between the aggregation levels of the studies: "macro" or aggregate level studies, and "micro" or firm-level ones.

a) Aggregate Models of Growth with Military Spending

Ram (1995) reviews the vast literature that investigated Benoit (1973) empirical finding that military expenditures have positive effects on economic growth in developing countries. Benoit's work has triggered a flood of works that challenged its findings on both theoretical and econometric grounds. Reviewing some 29 works, (mostly from the late 80's up to 1995), Ram (1995) concludes that there is little evidence for positive effect of defense outlays on economic growth in the "typical case". This conclusion is based on both cross section data across countries, as well as time series data for particular countries. However, the "typical" qualification indicates that for some countries the positive effects were present.

Most of the research covered by Ram (1995) uses a single equation regression model, where the growth rate is regressed against variables including the ratio of defense outlays to GDP, or the growth in defense spending. An obvious weakness of such "single equations" econometric procedures is the simultaneity problem. Resources allocated to defense purposes may be influenced by GDP, thus creating a bias in estimates of the link between defense expenditures and economic progress. A related weakness in simple-minded regression analysis of military expenditures and growth indicators is the absence of any causality inferences. In particular, such analysis cannot distinguish between the hypothesis that richer countries can afford to allocate higher share of their resources to military consumption, versus the hypothesis that military consumption is a contributing factor to economic prosperity. Looking at the data in Figures 1 and 2 in the Appendix, it is easy to see how one can be led to conclude that military consumption share, and in particular its R&D component, are promoting growth.

Less ad-hoc models include variants of the Feder (1983) multi-sector neo-classical growth models, which allow for possible externalities from the military sector to the rest of the economy, and for potential efficiency differentials in using resources among the various sectors, (see Ram (1995) pp. 258-261, and Deger and Sen (1995) pp. 284-289).

Deger and Sen (1995) report that there are only few definitive empirical results from most of these studies, and suggest a list of conceptual and methodological reasons for this outcome. In particular, they, (as well as Ram (1995)), discuss simultaneity, causality, non-orthogonality of shocks, and other host of difficulties contaminating the empirical work. For instance, the single regression equation in which the rate of output growth is regressed against the military spending share of GDP, may suffer from a misspecification due to reverse causality from output growth to military spending. Among the remedies proposed is a mixed time-series cross-section approach, adopted by Macnair, Murdoch, Pi and Sandler (1995), who get strongly positive findings for a small cohort of nations within NATO.

Both static *cross-section* studies over different countries, as well as *time-series* studies of a single country used variants of the above model. The results are mixed, and Ram (1995) discusses the arguments for and against these two research approaches, (section 2.1.3, pp. 264-266).

One major problem with the above formulation is attributed to the fact that there is no market price for military output, and that its factor payments must be financed by taxes on civilian income and profits. Deger and Sen (1995) develop a version of that model which recognizes the *public good* nature of military security, and the implied need to finance it by taxes, (section 3.1.3, pp. 285-289).

Looking at military spending as providing a *public good* allowed researchers to consider a wide range of interactions between economic performance and military spending. In particular, several channels through which military expenditures affect the economy have been considered: (1) enhanced security, which increases social welfare; (2) defense allocations can increase total factor productivity through: training of high skilled workforce, creating infrastructure, increasing technical progress via R&D, and encouraging spin-offs; (3) government budget constraint and crowding-out of private investments; (4) a trade-off between different kinds of public goods to be provided by the government, (e.g. education versus military security); (5) the demand for high skilled workers “crowds out” skilled workers from civilian sectors, and accordingly may decrease the marginal product of capital in those sectors.

b) Microeconomic Effects of Military R&D

Lichtenberg (1995) reviews many studies performed on the private and social efficiency of defense related contracts in the US over the last several decades. The reviewed evidence includes research work by himself and other academic researchers, as well as Department of Defense (DoD) comprehensive studies of defense contractors profitability.

His main conclusions are:

1. Direct R&D contracting is not the only way to induce private firms to invest in defense related R&D. Design competition and R&D subsidies are some alternative modes of achieving similar results. Competitive defense procurement is responsible for considerable private R&D. The latter may be less relevant for Israel, where the “size of the market”, and resale restrictions may reduce the effectiveness of such competitive approaches to private funding of defense-related R&D.
2. The effective rate of subsidies to independent R&D (mostly defense related) by private firms exceeds 40%, and is much higher than the general subsidy to R&D provided by general R&D Tax Credit, (part of the 1981 Economic Recovery Tax Act). The profitability of government contractors is 68-82% higher than that of other producers. This stems in part from the ability to shift costs from commercial projects to the government.
3. Government funded R&D, (mostly defense related) – has an *insignificant* social rate of return, (and less so than privately funded R&D), in contrast to the spillover effects presumed to characterize defense-related R&D. There is no evidence

supporting the hypothesis that defense R&D stimulates civilian R&D, thereby having a positive indirect effect on productivity growth.

4. The conduct of defense R&D and procurement appears to be efficient in that demand for weapon development seems to be price sensitive, and independent R&D projects appear to be "dynamically optimal".
5. A $1 increase in sales to the government increased private R&D expenditures, (PR&D), by 9.3 cents, whereas a $1 increase in non-government sales increased it by only 1.7 cents.

The last finding above, (no. 5), is based on an earlier work by Lichtenberg (1988), which might be particularly relevant to Israel, where defense needs may have encouraged and shaped research directions unlikely to occur spontaneously. In that study, Lichtenberg estimated, using longitudinal firm-level data for 169 industrial firms over the period 1979-1984, regressions of PR&D expenditures on three variables: the value of firm's competitive and non-competitive government contracts, and the value of firm's non-government contracts. The period studied was characterized by a heavy defense buildup in the US, when government contracts were doubled while total sales by the involved firms rose by only 35%. In Israel, private R&D is encouraged by several alternative government programs, and it might be interesting to compare the inducement impact on PR&D of defense-related publicly-funded programs, vs. civilian programs of the kind operated by the Ministry of Industry and Trade.

c) Public Funding of R&D

Recently there have been numerous studies examining the impact of public funding, and public subsidies, of R&D performed in the private sector. Although not directly aimed at defense-related R&D, a relatively high fraction of public R&D funding and support is directed at research with defense applications.

Hall and Van Reenen (1999) survey econometric evidence and methodologies used in studying the effectiveness of fiscal incentives for R&D in OECD countries. They conclude that “a dollar in tax credit for R&D stimulates a dollar of additional R&D”. David and Hall (2000) provide a theoretical framework within which they can explain the “plethora of sometimes confusing and frequently contradictory estimates of the response of company financed R&D to changes in the level and nature of public R&D expenditure”. Using a unique firm level data set from Israel, Lach (2000) concludes that “an extra dollar of R&D subsidies increases long-run company financed R&D expenditures by 41 cents on average”.

In contrast to these firm or industry level studies, Guellec and van Pottelsberghe (2000) use aggregate data for 17 OECD Member countries over the period 1983-1996 to conclude that a dollar of direct government funding of R&D performed by firms, (via grants or procurement contracts), increases business funded R&D by an additional 70 cents. They also conclude that defense research performed in public labs and universities *crowds out* private R&D, mostly through its impact on wages of R&D workforce.

Finally, the scarcity and poor quality of data related to defense-R&D is probably responsible to the absence of research on this particular form of inventive activity, and its related economic impacts. Again, the difficulty associated with causality inference is haunting any conclusion drawn even from those countries that provide R&D data broken by sectors. The Appendix reports the defense-R&D data for 14 OECD members for 1997, and Figure 2 presents that data against average annual real growth in percapita GNP in the preceding 7 years. The correlation of these two measures for those countries exceeds 0.6. Keeping in mind that defense-R&D is mostly present in countries with significant defense-manufacturing industries, it is difficult to draw too many conclusions from such correlations, for reasons we have discussed earlier.

d) Case Studies and Measuring the Inventive Output of Defense R&D Expenditures

The impact on technological and scientific development of defense-oriented public support is, in some cases, remarkable and undisputed. An interesting case in point, which is impressively summarized in the monograph *Funding a Revolution: Government Support for Computing Research*, by the Computer Science and

Telecommunications Board, U.S. National Research Council (1999), allows us to appreciate the national scale and vision necessary for embarking on an ambitious far reaching program well before its success or ultimate impact can be realized. This study makes it clear how defense motivated public funding, coupled with a visionary scientific management, has virtually created the “computing revolution”, including developments such as relational data bases, the Internet, theoretical computer sciences, neural networks, and virtual reality.[9]

It can be claimed that the impetus provided by early US federal government funding of research in information technology, (IT), mostly through DARPA, (US Defense Advanced Research Project Agency), is responsible, along with a host of other institutional and economic attributes, for the dominant position of the US in the global economy today. Likewise, federal investments in space technology, (including the creation of NASA following the successful Russian launching of Sputnik), and similar defense-related investments in air and space weapon and defense systems helped to bring about significant discoveries in fields like materials, propulsion, radar, and global positioning systems.

When Israel decided to embark on the ambitious program of designing and producing a combat aircraft in the 80’s, (the Lavi), the impact of such a huge technological project on scientific and engineering know how in the economy was a significant consideration. Indeed, when that program was curtailed by the government at the end of the decade, the shock wave in the Israeli engineering sectors and universities was felt for many subsequent years.[10]

There is no denial that certain programs of “national scale”, with major government funding, and often involving national security goals at the heart of the national consensus, can sometimes create technological spillovers that enable discoveries and developments in other areas. However, we do not hear much about failures in this

[9] In addition to emphasizing the need for public funding for such long-range programs, involving diverse scientific disciplines and collaborative industry-academy research efforts, this book also describes the particular management and administrative features which made it a success.

[10] The current debate in Israel about the need for “national leadership” in turning Israeli research capabilities in bio-technology into a successful industry, although unrelated to defense R&D, represents another example of a potential governmental role in providing an initial “push” to an industry that may flourish on its own once established.

regard, which must be as frequent as the success stories which capture our imagination. Although instructive in terms of leadership skills, management techniques, and the vision needed for pushing such projects through, such successful “case studies” provide little guidance on how to pick the “right” technologies or projects capable of providing external benefits above and beyond their direct mission.[11] Moreover, it may well be that the government merely does well in picking projects which are likely to succeed even without public support, (a common identification problem sometimes referred to as the “treatment effect”). Finally, conclusions based on historical case study methods may be misleading in failing to recognize critical factors contributing to the successful result, which are no longer in force. Putting it more generally, historical case studies are not particularly suited to identify causal relationships among intertwined forces at play.

Another way to measure the effect of defense-related R&D expenditures on inventive activities is their relative share in the total expenditure on scientific and engineering research performed in universities. This approach suffers from the usual drawback of “measuring inputs”, rather than output. Nevertheless, it is difficult not to be impressed by the DoD accomplishments in this regard,[12]:

- Approximately 70% of DoD funded basic research investment is executed by universities;
- DoD Basic Research, (7% of total federal basic research support), is aimed at those areas that are likely to prove instrumental in the development of next generation military systems, and is performed mostly by universities. Scientific disciplines supported include: physics, chemistry, mathematics, computer sciences, electronics, material sciences, mechanics, terrestrial science, ocean science, atmospheric and space sciences, biological sciences, and cognitive and neural sciences. Over the years, DoD Basic Research has supported the work of 69 Nobel Prize winners in areas such as nano-technology, computational chemistry, and most recently on transition states in chemical reactions;

[11] Artificial intelligence, funded initially by DARPA and eventually abandoned, may be a case in point, although it can be claimed that this program ultimately led to the development of neural networks.

[12] Mostly based on Statements by the Under Secretary of Defense, Science and Technology, Jacque Gansler, and his deputies, before the Congress and Senate Armed Services Subcommittee, (March 12, 1998, April 1999, March 1, 2000).

- Private industry performs about 50% of the work funded by DoD's Applied Research Program, and about 65% of DoD's Advanced Technology Development Program.
- Another outcome of DoD sponsored research is the Global Positioning System, "which revolutionized warfare, and has literally thousand civilian uses, and evolved from basic research investment in satellite navigation, atomic clocks, and communications";
- DoD basic research comprises "over 70% of the total annual federal investment at US universities in electrical engineering; over 65% in mechanical engineering; over 20% in computer sciences, metallurgy and materials, and oceanography; and over 15% of the total annual federal investment in aeronautical and astronomical engineering, chemistry, and mathematics";
- DoD funds about 40% of all R&D activities in engineering in US universities, and is the third largest federal sponsor of R&D at colleges and universities, behind only the National Institute of Health and the National Science Foundation.[13]

It is important to keep in mind major differences between Israel and the US when reviewing the success of DoD R&D and Science and Technology programs.

- Scale effects allow the US to embark and support research programs which would be impractical for a small country like Israel. As mentioned above, the RDT&E's budget alone is more than four times the entire Israeli defense consumption, which in turn is about the size of the Science and Technology Program budget within the RDT&E.
- The US military needs are of a different scale than those of Israel;
- The huge US and allied forces military markets offer some compensation for the fixed-cost and other non-recurring engineering components in military R&D. The absence of those in a small country like Israel, with additional tight restrictions on exporting the developed technologies, all but eliminate any direct economic justification for the required investments.

[13]The American Association for the Advancement of Science, (http://www.aaas.org/spp/R&D).

Potentially, one can use patent data for evaluating the inventive output of public expenditures on defense-related R&D, which may be particularly suited to the increased frequency of collaboration with research institutions and private entities with commercial interests. Patent data includes personal details on the inventor and the identity of the assignee, in addition to the technical description. This data could allow estimation of the direct impact of government-funded defense-R&D projects on patent assignments. Moreover, one could try to exploit *patent flow of citation* methods, such as those used by Jaffe and Trajtenberg (1998), to estimate the technology spillover from defense-related inventions to other applications. Finally, one could try to use the personal information on inventors contained in documents of patents attributable to publicly funded defense projects, in order to follow subsequent technological achievements of these inventors, and identify possible links to their prior work on defense projects. I am not aware of such work in the context of defense-related R&D, perhaps due to scarcity of unclassified information on such patents.

4. Israel Unique Situation

The unique combination of several characteristics of the Israeli economy raises some questions concerning the relevance of the empirical findings reviewed in Section 3 to Israel. In particular, Israel's particular defense needs, the small size of the Israeli economy, and its technically skilled work force – may have a fundamental affect on the external benefits to be gained from public investment in military R&D.

a. Israel security needs and level of resources dictate extracting higer "military power multipliers" from resources allocated to defense. In particular, innovative military technologies, rather than a massive army, have been viewed as strategically crucial for Israel given its relative small size, the fact that it is surrounded in all directions by potentially hostile countries, and its unwillingness to withstand large casualties and prolonged wars. These considerations have led to heavy reliance of the IDF on high-tech military technologies.

b. Having no natural resources, the "human capital" of the workforce in Israel is its most valuable economic resource, and the only one that can be further developed to support a sustained economic growth. Moreover, the composition of the Israeli workforce has a relatively high share of hi-tech workers, engineers, and scientists, and is less costly than the workforce in other industrialized countries.[14]

c. Past experience may prove, (this needs verification), that the defense sector had provided both the resources and the opportunities to develop new technologies for military applications that also have wide civilian applications, (e.g. satellite communications and microwave technologies). Even though the experience with civilian conversion of military technologies is dismal, both in Israel and abroad, the technical capabilities and know-how accumulated through military R&D are valuable resources for technologically related civilian hi-tech applications.

d. The problem-solving and improvising nature of addressing urgent military needs has produced a workforce with valuable qualifications for the rapidly changing high-tech civilian world. Indeed, it is claimed, (but needs verification), that a disproportionate large number of "graduates" of elite technological units in the IDF have been recruited by and/or initiated many technological start-ups in Israel.[15]

e. The recent phenomenal rise in the Israeli high-tech civilian sector now allows the Israeli defense establishment to outsource significant portion of its basic R&D activities. The customary need for secrecy in order to maintain "surprise element", coupled with a rigid hierarchical structure and non-market orientation of government agencies in

[14]Out of every 10000 workers in Israel, 135 are scientists and engineers, vs. 85 in the US. Out of every 1000 workers in Israel, 9 are employed in R&D, almost twice as many as R&D workforce concentration in Japan and the US, (Hi-Technion, Technion Alumni Association, vol. 17, December 2000, p. 67).

[15] Dvir and Tishler (1999) emphasize the high proportion of successful high-tech entrepreneurs in Israel with prior experience gained from service in elite units of the IDF.

general, and the IDF in particular, create obstacles in outsourcing military R&D and applying commercial technologies to military purposes. Still, given Israel's academic and private sector high-tech capabilities, and the intense usage of high-tech in both defensive and attack weapon systems, (in particular, information-based technologies), the potential economic benefits from greater reliance on the private and academic sectors in applications of commercially developed technologies and R&D capabilities deserves a serious examination.

f. Venture capital funding sources have dramatically increased in Israel along with its proven high-tech capabilities. This has all but eliminated the financial constraints from setting up new high-tech companies, which could further enhance defense-R&D capabilities in "dual use" technologies, (although shortage of skilled workers, scientists and engineers remains an increasingly severe and often binding constraint on R&D expansions in high-tech firms).

g. The existence of strong ties between defense-related R&D and universities in Israel, (through commissioned work for the IDF/MOD performed at universities, the fact that many academic researchers contribute to the reserve service in their areas of expertise, and the fact that the government funds the bulk of the activities in both research universities and the IDF/MOD) – create a unique opportunity for enhancing the links between technological education and research at Israeli universities and R&D for generic technologies with military applications. The MAGNET program operated by the Office of the Chief Scientist at the Ministry of Industry and Trade provides a model for such cooperation among industry and academy, with common interests in developing generic technologies.

h. Scale economies are often mentioned as an argument *against* getting too involved in defense-related R&D in Israel. This argument has two faces.

First, it is true that the Israeli market is relatively small, and to the extent that defense R&D is concentrated in a small number of specific large-scale defense projects the potential economy-wide benefits may be insufficient to offset the adverse growth impacts. In particular, while a major discovery stumbled upon in the US might generate a huge return through the US dominant position in the world economy – the same discovery achieved in Israel could create much smaller economic benefits. This suggests that absent public funding of defense-related R&D, the private sector is unlikely to fund the "socially desirable" level of such research by its own means.

Second, the fear that the Israeli defense purchases are too small and unstable to warrant investing in defense-related R&D infrastructure is not warranted by the facts, (see Lifshitz, 2000, (in Hebrew), pp. 379).

The upshot of the agglomeration of all these features implies that increased public funding of defense-related R&D in Israel may have unusually high economic and educational indirect benefits, above and beyond the direct military ones. What needs to be examined are the extent to which these assertions are true, and whether a different allocation of public resources, (e.g. through the Office of the Chief Scientist of the Ministry of Industry and Trade), can achieve such outcomes more effectively. Notice that the validity of the conclusion that military R&D can contribute to economic growth in Israel must consider not only the public funding aspect, but also the issue of of *who performs* the R&D: universities, private companies, government-owned defense corporations, the IDF itself, etc.

5. Potential Research Questions

The following is a list of hypotheses/questions, which can be pursued to evaluate the links between defense-related R&D and economic growth in Israel.

5.1 Breeding grounds for Hi-tech Workforce and Startups:

R&D performed on behalf of the IDF and the Israeli Ministry of Defense (MOD), within and outside the armed forces, provides breeding grounds for highly skilled and entrepreneurial workers, capable of creating and working in successful hi-tech companies.

- Evaluating the contribution of defense related R&D to hi-tech workforce in Israel: Analyzing IDF and MOD workers that "graduated" from their initial government related jobs to the business sector, and establishing the link between their military and subsequent civilian occupations;
- Evaluating the contribution of defense related R&D to the dynamics of the hi-tech sector in Israel: Listing of startup companies created on the basis of professional experience and contacts obtained during and through service in the IDF and MOD;[16] The contribution of defense to births, deaths, expansions and contractions in Israeli companies;
- Scope and distribution of MOD R&D activities over time, performed "in house" vs. "outsourcing"; As the civilian R&D capabilities and expertise in defense related fields increases in Israel – it is expected that more R&D can be outsourced, thereby creating potential spillovers more directly.

5.2 Technological Spillover from MOD to Business:

Specific technologies and capabilities developed initially for military use, that have non-military economic value; Listing such developments, their scope, funding sources, market size, marketing success, etc. If patents assigned to defense contractors in Israel is available, one can try to exploit it for estimating the direct "value" of public funding of defense-related R&D, as well as indirect values through patent citation and tracing the career developments of the inventors, (see subsection 3.d).

[16] Gabbay, Feigenbaum and Bar-Am (2000) have examined the impact of "social networks" among hi-tech IDF employees on the success of their civilian startup companies. Dvir and Tishler (1999) emphasize the high proportion of successful high-tech entrepreneurs in Israel with prior experience gained from service in elite units of the IDF.

5.3 MOD as a Major Hi-tech Client:

The MOD constitutes a major client in the Israeli hi-tech market. What are the effects of its presence and acquisition budgets on the development of the Israeli hi-tech sector? What impacts did the military R&D needs had on the development of special educational and research capabilities among Israeli universities, (e.g. in the faculty of Aeronautical Engineering at the Technion), and to what extent did those departments expanded into non-defense directions?

5.4 Firms Conduct with MOD Contracts:

There is room here for empirical and theoretical research on performance and incentives, at the firm level, of defense-related activities.

a. The impact of government defense related contracts on private R&D can be estimated as in Lichtenberg (1988), using firm-level data, compared with a control group of industrial firms that did not have such government contracts, (see subsection 3.b). While competitive defense contracting methods are much more developed in the US compared to Israel, the methodology used by Lichtenberg can be used for a similar study in Israel, provided the relevant firm and contract data is made available. Moreover, recent defense contracting in Israel may have involved some competitive or multi-sourcing features, which have been in use in the US for the last two decades. If this is the case, then we can estimate the comparative impact of such contracting methods.

b. Developing structural models of firm's R&D decisions, incorporating unique features of MOD contracts and business associations, including forward looking reputation, technological development, and acquisition considerations.

6. Conclusion

The central role played by national defense considerations in Israel and the economic importance of its highly-skilled workforce create a unique situation which calls for careful evaluation of the “social value” of defense-related R&D. This paper reviewed some aspects of this unique situation, and some analyses in the literature of the impact of defense-R&D and military expenditures in general which did not incorporate these unique features. Particular research questions which can help in the evaluation of the broad economic impact of defense-related R&D are offered here, with the hope that the data needed to carry them out will be made available to researchers.

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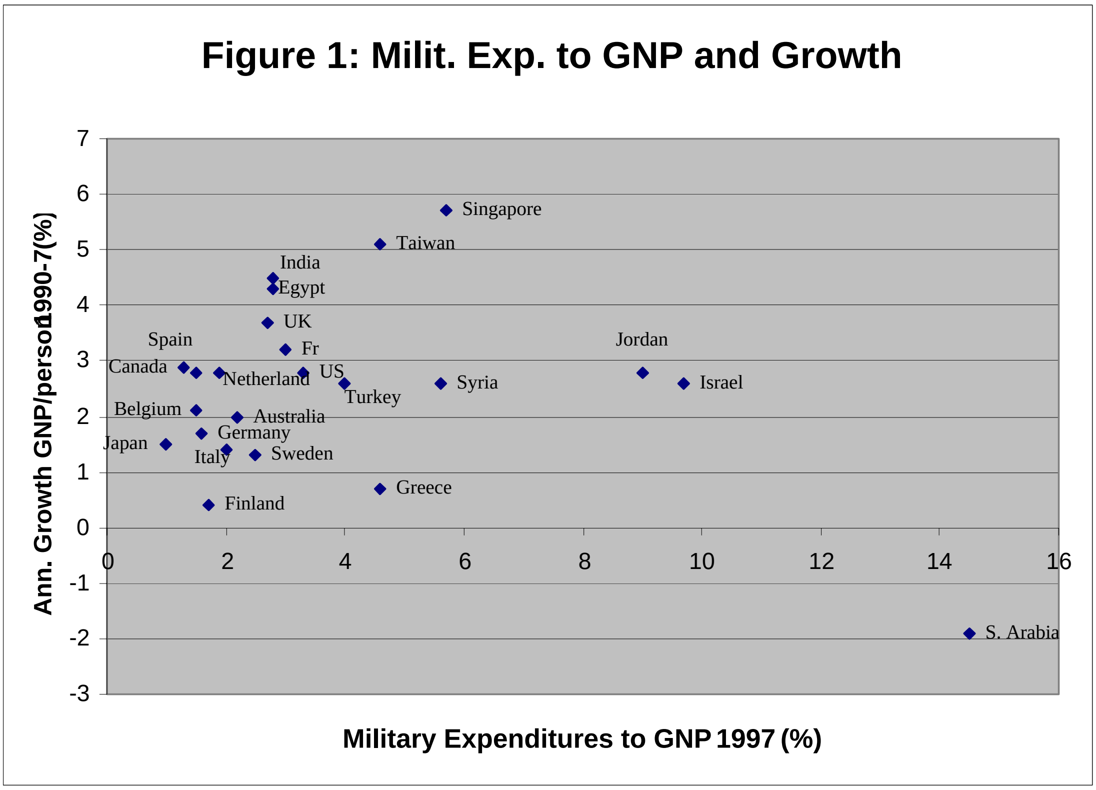
Figure 1: Milit. Exp. to GNP and Growth
Ann. Growth GNP/person 1990-7(%)
Military Expenditures to GNP 1997 (%)
Singapore
Taiwan
India
Egypt
UK
Spain
Fr
Jordan
Canada
Netherland
US
Turkey
Syria
Israel
Belgium
Australia
Germany
Japan
Italy
Sweden
Greece
Finland
S. Arabia

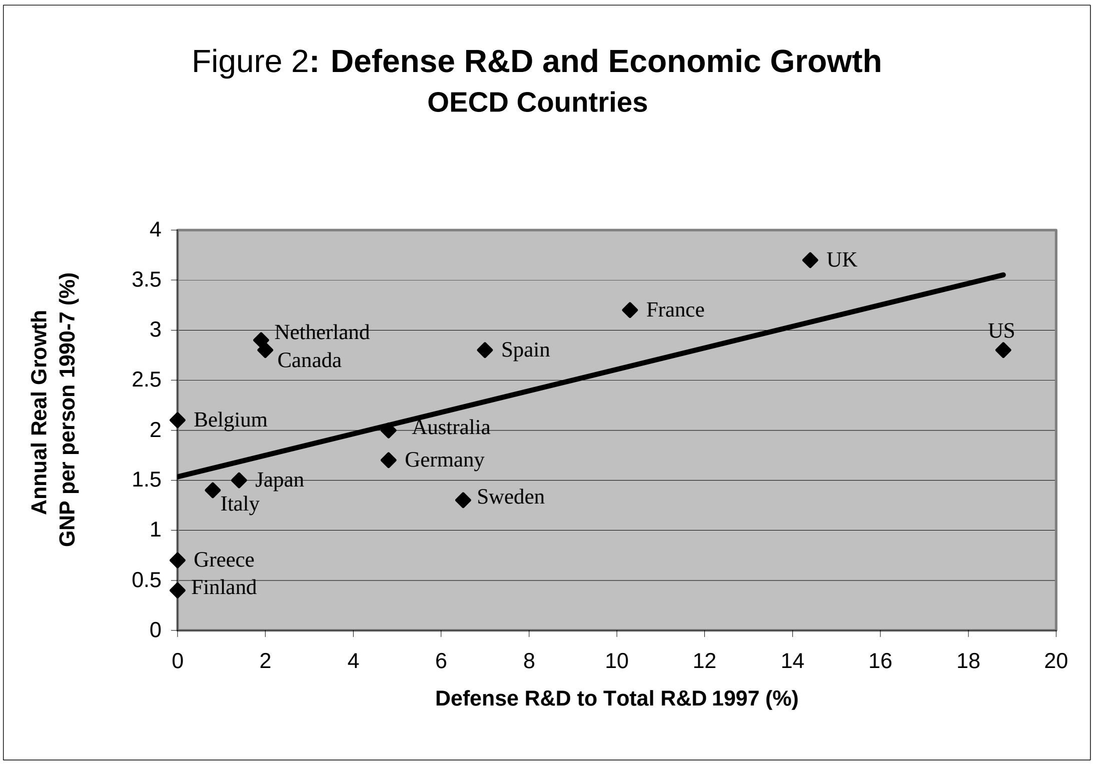
Figure 2: Defense R&D and Economic Growth
OECD Countries
Annual Real Growth GNP per person 1990-7 (%)
Defense R&D to Total R&D 1997 (%)
UK
France
Netherland
Canada
Spain
US
Belgium
Australia
Germany
Japan
Italy
Sweden
Greece
Finland

Appendix: **Military Expenditures and Defense R&D 1997**

International Comparison

Country	GNP (US$ bill. Ppp)	GNP percapita (US$ ppp)	Military expenditures percapita (US$ ppp)	Milit. Expnd. to GNP (%)	Defense R&D percapita (US$ ppp)	Defense R&D to Milit. Expnd (%)	Defense R&D to Total R&D (%)	Avg. Ann. Growth GNP percapita 1990-97 (%)	Avg. Ann. Growth GNP 1990-97 (%)
OECD									
Australia	362	19500	429	2.2	18.0	4.2	4.8	2.0	3.1
Italy	1156	20100	402	2.0	2.0	0.5	0.8	1.4	1.6
United States	7783	29100	960	3.3	149.0	15.5	18.8	2.8	3.8
Belgium	235	23100	347	1.5	0.0	0.0	0.0	2.1	2.4
Germany	1737	21200	339	1.6	25.0	7.4	4.8	1.7	1.9
Netherlands	332	21300	405	1.9	9.0	2.2	2.0	2.8	3.4
United Kingdom	1222	20700	559	2.7	55.0	9.8	14.4	3.7	4.0
Greece	132	12500	575	4.6	0.0	0.0	0.0	0.7	1.1
Japan	3076	24400	244	1.0	10.0	4.1	1.4	1.5	1.8
Spain	617	15700	236	1.5	10.0	4.2	7.0	2.8	3.0
Finland	101	19700	335	1.7	0.0	0.0	0.0	0.4	0.9
France	1301	22200	666	3.0	49.0	7.4	10.3	3.2	3.6
Canada	659	21800	283	1.3	7.0	2.5	1.9	2.9	4.0
Sweden	168	19000	475	2.5	51.0	10.7	6.5	1.3	1.4
Middle East									
Israel[a]	96	17300	1690	9.7	n/a	n/a	n/a	2.6	5.6
Egypt[a]	77	1180	34	2.8	n/a	n/a	n/a	4.5	3.8
Jordan[a]	7	1600	145	9.0	n/a	n/a	n/a	2.8	6.9
Saudi Arabia[a]	211	10500	1523	14.5	n/a	n/a	n/a	-1.9	1.5
Syria[a]	45	3000	168	5.6	n/a	n/a	n/a	2.6	6.3
Turkey[a]	412	6700	268	4.0	n/a	n/a	n/a	2.6	4.5
Asia									
India[a]	357	400	11	2.8	n/a	n/a	n/a	4.3	5.7
Singapore[a]	99	28800	1650	5.7	n/a	n/a	n/a	5.7	8.5
Taiwan[a]	285	13100	602	4.6	n/a	n/a	n/a	5.1	6.1

Sources: (1) US Census Bureau, Statistical Abstract of the United States 1999, and 2000;
(2) Israel Central Bureau of Statistics, Annual Statistics 2000, (Vol. 51), Table 23.2;
(3) US State Department, Military Expenditures Main Statistical Tables, 1998;
(4) Author calculations.

ppp: Purchasing power parity

[a] Dollar figures for these countries are not available at ppp, and are converted at current exchange rates.