Draft, January 1999

TOWARDS AN R&D STRATEGY FOR ISRAEL*

By

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I. Why a New Approach to Technology Policy is Needed

The proposed reduction in and recent negotiations, discussions and lobbying concerning the R&D budget of the Office of the Chief Scientist (OCS) at the Ministry of Industry and Trade highlight the importance of approaching the question of government policy in support of R&D not only in a more systematic and analytic fashion than has been the case up to now in Israel but also through adoption of a radical new perspective. It must have been clear for some time, and certainly is clear starting this year, that keeping the pace of past government disbursements in support of business sector R&D (see Table 1[a, b] and Figure 1[a,b]) is not going to happened without a fundamental restructuring of policy.

In the past the rate of growth of government disbursements to such R&D largely depended on the 'demand' for R&D embedded in projects submitted to the OCS — the rates of support (risk-sharing through conditional loans[1]) to R&D remained, until recently, more or less fixed. This in turn, was presumably linked to the rate of growth of high-tech industry in general. In the past year (and probably more so in the future) there has been a reduction in the 'universality' of R&D support flowing from the main R&D support program of the OCS as well as some deviations from neutrality in incentives. So far this has not led to 'sector/technology selectivity' but rather to differences in

* This paper was sponsored by the Sapir Forum in the context of its project on "Technology, Education and Production Productivity towards the year 2000". Thanks to Orna Berry, Moshe Justman and Dan Kauffman for helpful comments. **A finalized version of this paper was published in *The Economic Quarterly* , December 1999 (in Hebrew).**

[1] This tool for supporting R&D is not strictly a subsidy to R&D although its risk-sharing characteristic is like that of a subsidy.

incentives between large and small firms, etc. A situation of 'competition' among projects satisfying the new criteria has (or may also) emerge, given the tighter and less flexible budgets available.

Table 1a. OCS R&D Grants ($ millions)

	Grants	Percent change from previous year
1989	125.2	4.3
1990	136	8.6
1991	178.6	30.8
1992	199	11.7
1993	231	16
1994	316	36.7
1995	346	9.4
1996	348	0.5
1997	330	–5.4
1998	254	–23

Source: OCS.

Table 1b. Activities of the OCS, 1997

No. of firms requesting support	623
No. of project support requests submitted	1,311
No. of project support requests approved	1,007
Grants approved	$397 million
Royalties paid by companies	$103 million
No. of projects underway in 26 'incubators'	212

Source: OCS.

While the budget constraint is certainly part of the problem, the need to restructure the policy mechanisms in support of R&D/innovation and technology development also follow from weaknesses in the existing system. While considerable 'innovation' has occurred in policy (see below) during the 1990s even more radical changes have occurred in both the external and internal environment facing the country. The main factors are

- Changes in Israel's *National System of Innovation (NSI)* during the 1990s.
- Understanding how this system works is becoming increasingly difficult.

- Innovation/R&D and technology policy (for simplicity: 'technology policy') have become increasingly complex, a fact that mandates some changes in the policy making system.
- The NSI may have to continue to change in the future and policy may play a role in this process.

Figure 1a. OCS Approved R&D Grants and Royalties Collected

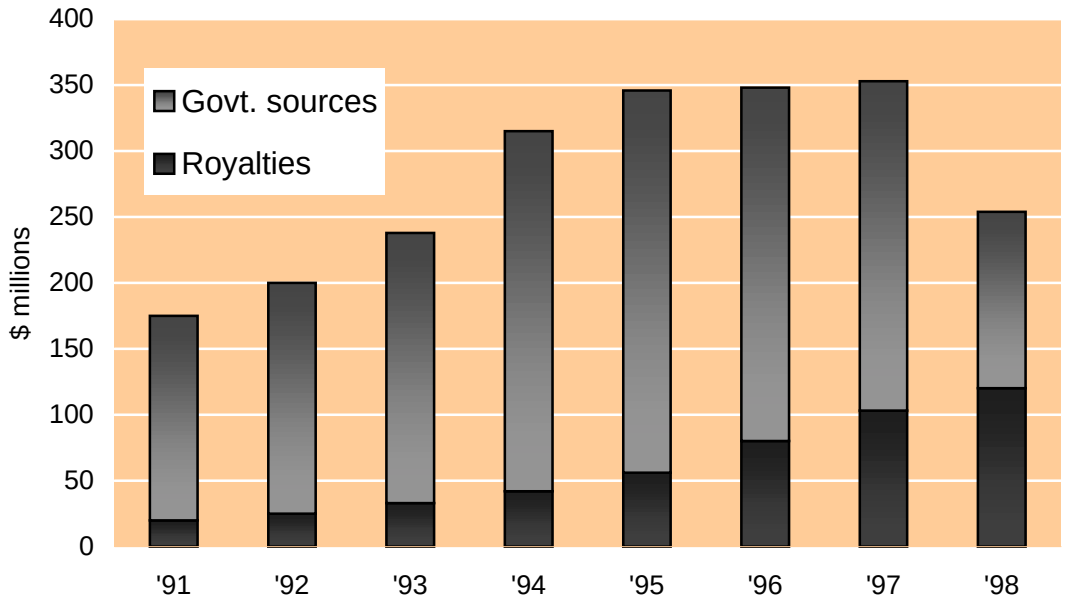
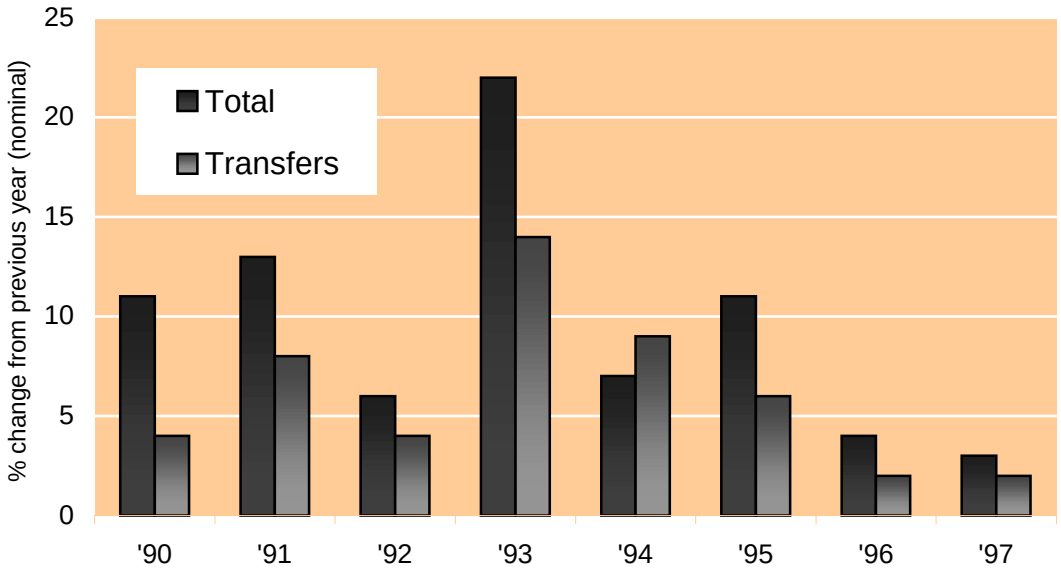


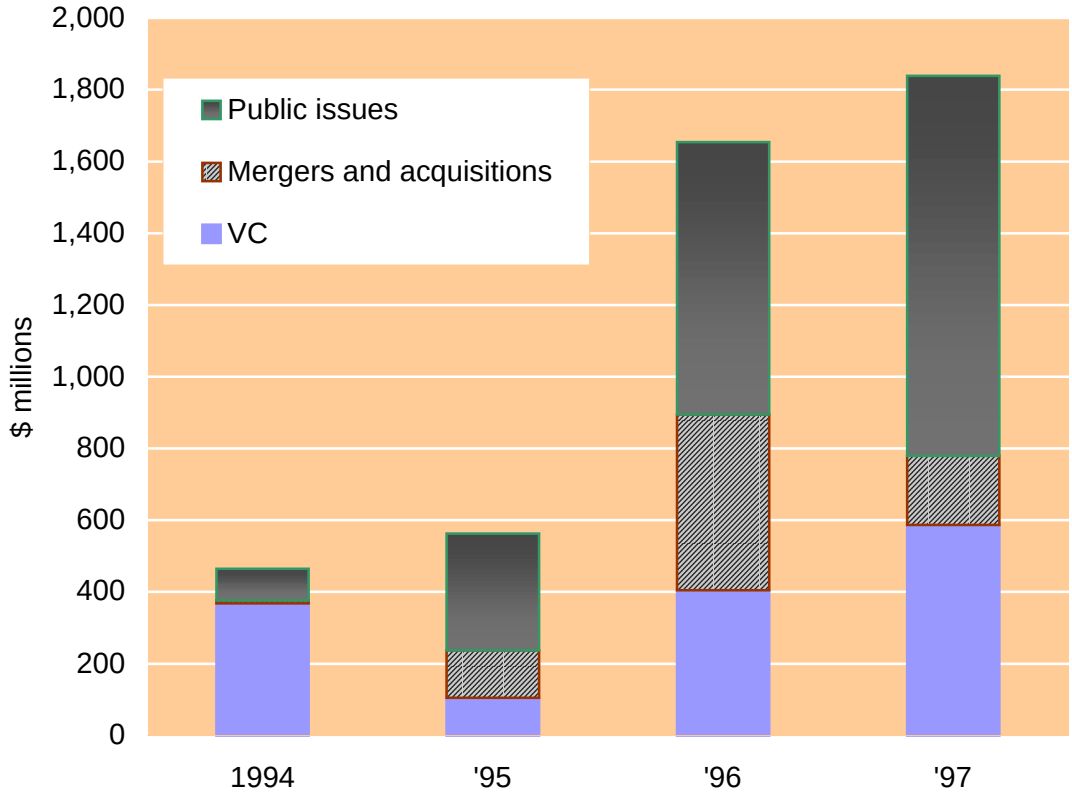
Figure 1b. Expenditure of Government Ministries on R&D



Source: CBS.

Israel's NSI has become *more open and more linked to a global system.* One of the most striking examples is the link between the emergence and development of new high-tech, start-up companies (SUs) and the US Stock Market. This phenomenon has become important in the last years (see Figure 2 and Table 2 for some basic data on SUs and venture capital in Israel). It implies not only greater opportunities but also greater risks. In our opinion, while this enhances the 'dynamic' comparative advantage of Israel in high-tech industries, it still does not justify a national strategy for the development of the business sector exclusively dominated by high-tech.[2]

Figure 2. Capital Recruitment Abroad for Industry



[2] The fact that Israel has a comparative advantage in high-tech industry does not, by itself, mean that effective technology support program (maybe not only focused on R&D) should not be directed to mid- and low-tech industry, which contributes almost four fifths of total industrial employment (see below). Note that these industries contribute a relatively small share of total industrial exports. I think that — pending intensive research on this issue — the point still holds, in principle, even if several mid- and low-tech sectors seem not to be globally competitive at present. Section III describes two alternative 'visions/strategies' for the development of the business sector in Israel. Both emphasize high-tech but differ (among other things) on the extent to which the technological and restructuring objectives of mid- and low-tech industry are made explicit.

Table 2. Start-Up Companies in Israel

- Some 300 start-up companies are processed by the Chief Scientist's Office each year, of which approximately 200 apply directly to the Office and the rest — via the 'incubators' system.
- About 2,500 Israeli start-up firms operate in Israel in 1998.

A second feature is *enhanced complexity of the System of Innovation*. A much more varied set of agents comprise the system today, compared to 1990. A central feature is the new financial segment — Venture Capital companies (VC), which are the mirror-image of the SUs. Their presence creates a number of very important issues in particular whether VC-finance is a substitute or a complement to regular OCS finance. While from a pure 'neoclassical' perspective there seem to be grounds to assume strong substitution between both forms of finance of R&D/Innovation, reality seems to be more complex (Gelvan and Teubal, 1997; Teubal and Klein, in preparation) — for example, there is an important body of opinion stating that VC-investments will not take place without OCS R&D support. Adequate restructuring of R&D support policy ('*HaKeren Haregila*', which supports 'classical' R&D intended for product/process innovations in individual companies) requires a significant input of research on this issue. Creation of conditions for this and other policy-relevant, policy-supporting research is probably one of the main challenges of the present policy system. Despite some recent improvements, existing outlooks and routines are probably not yet focused towards the systematic generation of understanding and knowledge pertaining to the new policy challenges facing the country.[3]

The above also highlights some of the important challenges facing Israel's policy system (or *sub*-system, if we see the set of policy mechanisms as part of the NSI). While up to now the policy portfolio consists of a set of *Horizontal industrial/tech-*

[3] One should be aware that changing a policy that, broadly speaking, has been implemented for two and a half decades is not an easy task even if, as is the case nowadays, awareness of the

nology support program (HTPs) involving (relatively) neutral incentives to R&D (both 'classical' and 'generic, pre-competitive'); investments; exports; management support and (lately) training — the restructured set of programs should involve a mix between horizontal programs and *targeted programs.* This implies a greater amount of selectivity than previously. An outstanding example of a successful targeted policy was that leading to the creation of *Yozma* in the early 1990s. This government-owned venture capital company was instrumental in triggering the emergence of a local VC industry, which by now comprises around 50 funds with yearly investments in Israeli SUs of several hundred million dollars (see Figure 2). The point here is that *targeted programs* directed to the generation of new components of the NSI could become essential elements of the policy package required nowadays.[4]

Finally, we should not underestimate the changes which Israel's NSI might have to undergo in the next few years, especially given the instability of the country's economy and the need to consolidate the achievements and the potential of high-tech. One possible aspect which requires a substantial research input to verify and articulate its potential importance is the issue of *clusters* in the Israeli economy of the next decade. This might mean transforming an aggregate of firms in a particular sector or area, e.g., clothing or biotechnology, into an interconnected whole involving strong vertical and horizontal links and new institutions generation industry specific public goods.[5]

The generation of clusters is becoming a major objective of industrial-technological policy in the developed world (see, e.g., Roelandt, 1999). It may be that success of high-tech areas such as communications and software in the 1990s in Israel is related to the development of successful clusters; while the difficulties encountered by mid-/ low-tech industry or biotechnology could be related to difficulties in generating adequate cluster configurations for those sectors. If so, a new category of *cluster policies* must emerge. These might be more or less targeted and may involve either cluster creation or cluster reinforcement. The central point in these policies is the co-ordinated integration of a number of functions or technological activities within a particular program. Both assessing the desirability of clusters for this country and

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need and a disposition to attempt such a change already exist. Note that the royalties component of total disbursements of the '*Keren Regila*' is very significant in percentage terms.

[4] One category of targeted policies is 'cluster policies' — see below.

[5] For a recent proposal to generate industry-specific public goods, see Romer (1996).

designing and implementing cluster policies will require new capabilities and new routines within Israel's R&D/Innovation policy system.

I.1. Weaknesses of the System

The present global economic context and its dynamism requires that the government adapt its policies with a much greater frequency than has been usual in the past (e.g., every 15 or more years). A first step is to seriously reassess Israel's R&D/Innovation and technological policies. We hypothesize that the major possible weaknesses are:

- Absence of government 'strategic decision making' and, more specifically, of an explicit process designed to identify the technology policy needs of the country.
- Insufficient information about the existing system of support.
- Non-utilization in a systematic way of 'objective' program evaluation (only recently has the first major evaluation been completed and it focuses on only one of a set of programs).
- Based on an inadequate conceptual framework — too simplistic for the increased complexity of the present innovation system.
- Urgent need to enhance policy capabilities within the relevant government agencies, particularly non-operational planning and strategic making capabilities at the OCS, the Treasury and other ministries and government agencies (this includes the capacity to interact with loci of such capabilities in academia and elsewhere).
- Weak coordination among the various components of the innovation system and among the various government programs supporting them. This follows from absence of an holistic view of policy and from an historically determined policy system involving separate and unconnected modules of specialized programs.
- The informational, conceptual and capabilities vacuum makes decision-making too vulnerable to interest groups and lobbying. This could work both ways. For example, the activities of non-professional lobbies or organizations which target the budget (independently of functional contribution to the economy or even society) thereby causing budget cuts in essential program as well as lack of resources to initiate new programs.

I.2. Objectives of the Paper

The above weaknesses provide the background to this paper. They also lie at the heart of its specific objectives which are:

a. To suggest possible weaknesses of existing policies and policy mechanisms which support innovation/R&D and technology development at (and relevant to) the business sector.
b. To suggest building blocks for a new conceptual framework for technology and innovation/R&D processes *and* policy.
c. Methodological issues in program evaluation.

Most of the paper will deal with objectives b. and c., and only indirectly with a. The two following sections deal with conceptual framework issues — Section II with the *national systems perspective* on innovation/R&D; and Sections III–V with the *policy framework*. Section VI analyzes one aspect of the policy framework — program evaluations — an important component of the policy system. Some methodological issues, such as the role of quantitative estimations of past impacts of technology policy programs, are raised.

Finally in the concluding section I summarize by suggesting 'how to think about technology policy' and suggest a series of actions to improve the present policy system.

II. The Conceptual Framework — A National Systems of Innovation Perspective

Viewing business sector R&D and innovation as the outcome of a *national system of innovation* comprising a set of agents involved in the production, diffusion and utilization of technological and other useful knowledge (business enterprises, other organizations and institutions, government); the links among them and with the rest of the world; and "rules of the game" — rather than exclusively as an aggregate of the activity of individual enterprises — has a number of implications, both in terms of how the system works and with regard to policy. Thus, the impact of any specific decision ('*Pitaron nekudati*') must consider not only direct effects on the agents involved but also effects derived from potential interactions with other parts of the system; the cumulative effects of such interactions may generate an impact which may be contrary to what was predicted in the first place. For example, (sudden) cuts in R&D support, even if justified from a simple market failure perspective, may reduce the value of

Israeli stocks in Wall Street, an event that may trigger a wider set of repercussions in terms of foreign investments in Israel and the overall desirability of linking or trans-acting with Israeli companies. This in turn may trunkate a cumulative process of consolidation of high-tech industry, achievement of critical mass in promising areas, and consequent lost opportunities for the emergence of a group of medium sized and mid-large companies with felt presence in world markets. Thus, even if a simplistic market failure approach would signal the desirability of undertaking such cuts, from an overall perspective this action might not be desirable. On the other hand, continuation of past rates of growth in government R&D may increase the visibility and hence political vulnerability of the overall R&D budget in the future. The effect could be even larger cuts tomorrow, with potentially very harmful effects on the standing of Israel as a technologically advanced and high-tech country.

These extreme examples suggest the complexity of the processes — economic, policy-related and political — which may have to be taken into account when deciding on R&D policy today. The present technology policy system is frequently incapable of articulating the relevant issues.

In general, a NSI *perspective* would focus on the dynamics of the transition from one system of innovation to another, e.g., for a number of European countries, transition from a system without SU and VC to one with these characteristics. The backbone of this transition process is ‘restructuring’ of business enterprises, a term which includes numerous processes within incumbent enterprises as well as the creation of new enterprises. Depending on the type of change occurring in the environment, the term ‘restructuring’ during NSI transition may involve new patterns of product/market specialization; the adoption of new technologies; undertaking of cooperative generic R&D, or other activities previously non-existent in the business sector; the adoption of new management techniques or organizationl repositioning of the enterprise; the forging of links, networks or clusters, etc. Frequently, this restructuring co-evolves with new institutions/organizations not belonging to the business sector, e.g., universities, technology centers, university-industry-government consultation committees or fora, etc., and with changes in the ‘rules’ or conventions, e.g., pertaining to intellectual property rights, anti-trust, etc. Policy may play a critical role in the process since numerous market and system failures as well as institutional constraints may block the transition (Teubal, 1998a,b).

The most salient features of a NSI perspective for our purposes are the following:

- *A dynamic perspective* focusing especially, but not exclusively, on learning processes in the business enterprise sector (e.g., learning to conduct cooperative, generic R&D); and on cumulative effects. Thus the restructuring of some enterprises may trigger, due to learning and other enabling factors, a cumulative process leading to the restructuring of others.[6]
- The *complementarity* between business enterprises on the one hand and the structure supporting them on the other; and related to this, the importance for the system of innovation transition of *new system components*, e.g., VC companies or technology centers, to reinforce the restructuring process of business enterprise (idem with respect to new institutions and rules of the game).
- An explicit *analysis of the 'demand'* for new elements associated with enterprise restructuring, e.g., new technology; new technological activities such as R&D or cooperative, generic R&D; new organizational forms; etc.
- *Co-evolution* among business enterprise restructuring on the one hand and other components of the NSI on the other (e.g., universities, VC companies, etc.). Similarly, co-evolution between enterprise innovation capabilities and policy.

We will be more specific. All business enterprise restructuring processes *potentially* could involve considerable learning pertaining to both technological and non-technological aspects, e.g., how to identify and generate good R&D projects; how to link R&D to marketing; how to choose partners for cooperative research; etc. A set of technology promotion programs which succeeded in promoting such a learning process[7] may lead to cumulative effects with the implication that ever wider circles of enterprises, including those not directly benefiting from government subsidies, may 'restructure'. This implies two things: first, program design should consider learning as an objective of the program (thus the objective of R&D incentives would be not only to

[6] This means that the dynamism or success of a NSI will not only depend on the scope of R&D undertaken but also on learning processes — both those related to R&D and to enterprise restructuring more generally speaking. The NSI perspective also implies that learning is to some extent 'collective' and interactive (see Edquist, 1997, Chapter 1). It also may be highly dependent on institutions (which, in my opinion, should also include the institutions and mechanisms of policy).

[7] This is a form of 'collective learning' since at the early phase of introduction/diffusion of R&D into the business enterprise sector almost every firm (potentially) learns from every other firm (Teubal, 1996,1997a). Needless to say, there are other forms of collective learning, such as those pointed out by Saxenian (1994) in her analysis of Silicon Valley's cluster of high-tech companies.

do/increase R&D — what is termed 'additionality' — but also to *learn how to do R&D*); second, follow-up programs focused on new groups of enterprises may have to be implemented in order to exploit past learning for further driving the restructuring process.[8] In the Israeli context this might mean making a special effort to diffuse R&D throughout the mid- and even low-tech segments of manufacturing, and with no less vigor than the attempts — through *Magnet* — since 1992 to introduce and diffuse cooperative, generic R&D throughout high-tech industry.[9]

Certain types of business sector restructuring might be impossible to achieve without the emergence of new system components. Thus, the emergence of a vigorous SU segment within high-tech manufacturing and services might be impossible without the creation of a VC industry (similarly, the full restructuring of mid-/ low-tech industry may be impossible without a network of intermediate organizations e.g., industry-owned technology centers). Frequently this type of restructuring necessitates a policy targeted at the new NSI component (such as *Yozma* in Israel's case) rather than an exclusive focus on directly supporting companies.[10] Moreover, the above-mentioned restructuring could be viewed as the outcome of co-evolution between a certain segment of business enterprises (SUs) and the new NSI component (VC companies).

Alternatively, achieving a successful restructuring of the business sector requires both cumulative learning and 'timely' system effects. This, in turn, generally requires a *portfolio of policies*, with policies directly acting on enterprises being implemented in a coordinated way with policies targeted to some specific component of the national system of innovation.[11]

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[8] This also means that market failure may well be the effect of government policy, not only its 'cause' or justification (Lipsey, 1998; Teubal, 1998)

[9] The term 'generic R&D' may have different meanings and implications. For example, in the context of mid- and low-tech especially, it could refer to new processes rather than to new products; and it may set the base for product differentiation rather than for full-fledged innovation.

[10] Note that *Yozma*, which is only one of a number of possible new NSI components that facilitate innovation, also invested about 30% of its capital directly in SUs.

[11] Naturally, a cumulative restructuring process involves a coordinated increase in both demand for and supply of the relevant items, e.g., enterprise R&D or the services provided by VC companies. The effect of collective learning, e.g., about R&D, is to generate demand for R&D on the part of the business sector — no less than in reducing cost. The new components of the system of innovation, e.g., a technology center, may in the first instance reduce cost (enhance supply), but it may affect demand as well.

A *policy portfolio perspective* implies that at any point in time a NSI is characterized by a mix of policies — in our context, policies directly supporting innovation and policies promoting the supporting structure (or other components of the system). This portfolio may differ from country to country and must also change throughout phases of the NSI transition.[12] In addition, the above mix between different types of policies may be biased in several respects. In previous work two such biases were suggested: an *activity bias* and an *enterprise bias.* A preliminary look at the Israeli case would suggest that its policy portfolio is biased in favour of advanced (high-tech) companies and in favour of what may be termed 'innovation' rather than 'diffusion'. Table 3 shows a possible and less recognized bias in R&D policy favouring high-tech.[13]

Table 3. Government Participation in Financing Industrial R&D (percent)

	1985/85	1991
Food, beverages and tobacco	3.6	5.6
Textiles, clothing, leather and its products	0.1	4.4
Paper and its products, printing and publishing	0	1.0
Rubber and plastics	9.7	9.0
Chemical products and petroleum	14.7	21.4
Mining and quarrying, wood, non-metallic minerals	0	7.7
Basic metal and metal products	10.3	4.0
Machinery	4.4	13.3
Electric equipment	8.1	38.5
Electronic equipment		21.8
Transportation and misc. industries	10.5	17.9
Total	*9.0*	*20.5*

Source: CBS.

[12] The portfolio perspective must, therefore, be 'dynamic'.

[13] Note that any discussion of bias in the policy portfolio implies something about the vision or strategy of the economy as reflected in the configuration of the new system of innovation towards which the economy is going. Thus the biases mentioned in the text reflect a vision/strategy which is not based exclusively on high-tech but which involves a balance between high-tech and other activities (see *Strategy 2* for Israel, pp. 4). Note that until the implementation of *Magnet* in the early 1990s there was also a clear bias in policy towards direct support of innovation in enterprises and against investment in technological infrastructure.

III. A Technology *Policy* Framework

How to think about and how to approach the design and implementation of technology and innovation policy? It seems to us that the complexity of the task necessitates first and foremost the setting out of a *hierarchical information and knowledge structure* which enables a program or programs in a particular area to be linked to broader national objectives and technology/innovation strategies. An attempt to do so follows (see Table 4). It proceeds from the broad/general to the specific. It will become clear as we proceed that there could be numerous roles of government in generating and implementing this framework, e.g., through the commissioning of search and research; enabling effective interaction among various types of agents to take place; and even building its own policy capabilities for this purpose. The government's role in generating a country's *policy framework* should be distinguished from its more traditional and better-understood role of promoting specific activities pertaining to innovation and technology.

Table 4. Elements of a Policy Framework

- National objectives, changes in the external environment and available resources.
- Vision/strategy.
- Possible changes in NSI and new priorities in science, technology, innovation and industry.
- Changes in the policy portfolio.

III.1. Broad Vision of the Future of the Economy and Elements of a Strategy for the Transformation of the Business Sector

Frequently, such a vision/strategy does not exist, is not explicit enough, or must be changed. We believe that government must facilitate the process of generating or changing it. Changed conditions (both external, such as globalization and the Asian and World financial crises, and internal, including available resources) and/or changed national objectives, both economic and non-economic, should trigger a redefinition of vision/strategy.[14]

[14] "*Foresight Programs* represent a space in which a shared vision of the future may be created to reduce the uncertainty surrounding innovation," quoted from L. Georghiou (1998), one of the academic initiators and promoters of the Foresight Programs in the UK (currently being considered and/or applied in continental Europe). This type of program, rather than leading to precise forecasting of technologies and market trends, is a mechanism for con-

There seem to be two alternative visions/strategies for the development of Israel's business sector[15] — Strategy 1 and Strategy 2. *Strategy 1* considers high-tech as the key sector whose growth will assure economic growth and set the base for solving the other problems of society. *Strategy 2* is also based on the assumption that Israel has a comparative advantage in high-tech but unlike Strategy 1 it seeks to strike a balance between growth of this sector and restructuring and growth of mid-/low-tech industry. where most of industrial employment is located.[16]

Strategy 1 does not attempt to make explicit the future role of mid-/low-tech industry in the economy, and therefore it pays insufficient attention to policy directed to these sectors. It also focuses on technology support for high-tech industry (e.g., on R&D subsidies) and to some extent on supporting the facilitating structure (e.g., universities to generate more high level manpower). Strategy 2, on the other hand, explicitly recognizes the potential of (parts of) mid-/low-tech industry to advancing growth and employment, e.g., by becoming sophisticated *technological users.* A healthy non-tech sector need not hamper high-tech growth, quite the contrary. It also recognizes and attempts to make explicit the role of non-technological factors in generating a high-tech sector which may contribute to growth according to expectations (see Box). For example, Strategy 2 must grapple both with the issue of assuring a continuation of the flow of high-tech SUs *and* promoting the emergence of a set of mid-/large-high-tech companies (this would be one out of a set of possible configurations for Strategy 2).[17]

Strategy 1 is based both on well-founded intuitions about the potential of high-tech industry in Israel and on a preliminary set of data and simple correlations, the nature and implications of which has not yet been elucidated. Figure 3(a,b) and Table 5, respectively, show the significant growth during 1975-97 of high-tech exports relative to the exports of industries based on unskilled labor; and a link between sectoral R&D intensity within a broad category of industries called 'high-tech' and export growth during 1996-7. Table 5 shows the increases in employment and production shares of 'advanced' sectors such as metals, electronics, and chemicals, oil, rubber and plastics

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solidating 'reasonable', consensual visions of the future.

[15] In what follows we focus almost exclusively on industry due to time constraints. A major effort should be undertaken to extend the discussion in the future to the services sector.

[16] Approximately 300,000 out of 380,000 employed in Industry (see Table 5).

[17] It is an open question whether the policies actually pursued in Israel are closer to Strategy 1 or to Strategy 2. While closer to the former in the past, they gradually seem to be moving closer towards a Strategy 2 configuration.

during 1975-97. The question is: are data and analyses of this sort sufficient for adopting an 'exclusive high-tech' strategy or whether a Strategy 2 view is at least as appropiate.[18] This requires additional analysis and possibly additional information.

Table 5. Distribution of Turnover and Employment, by Industry: Selected Years, 1975–1997 (percent)

	1975	1980	1990	1996	1997
Turnover (constant prices)					
Food, beverages and tobacco	22.2	19.2	17.5	16.9	16.7
Textiles, clothing and leather	11.3	10.3	8.6	6.0	5.8
Light industry[a]	9.5	9.4	11.1	11.8	11.3
Mining and quarrying and non-metallic minerals	7.4	6.8	5.2	7.0	6.5
Chemistry, petroleum, plastic and rubber	12.1	14.0	15.5	16.8	16.9
Metals and electronics	30.2	29.7	33.6	34.1	35.3
Total excluding diamonds	*92.7*	*89.4*	*91.5*	*92.5*	*92.5*
Diamonds (net)	7.3	10.6	8.5	7.5	7.5
Total	100.0	100.0	100.0	100.0	100.0
Employment					
Food, beverages and tobacco	13.4	13.6	14.7	14.6	14.7
Textiles, clothing and leather	19.0	17.5	16.1	12.3	11.3
Light industry[a]	12.7	13.2	14.9	16.3	16.6
Mining and quarrying and non-metallic minerals	6.0	5.5	4.0	4.8	4.8
Chemistry, petroleum, plastic and rubber	8.9	10.1	10.5	11.3	11.2
Metals and electronics	37.1	36.9	36.6	38.7	39.8
Total excluding diamonds	*97.1*	*96.8*	*96.7*	*98 .0*	*98.4*
Diamonds (net)	2.9	3.2	3.3	2.0	1.6
Total	100.0	100.0	100.0	100.0	100.0

[a] Wood, furniture, paper, printing, jewelry and miscellaneous.

Box — **Alternative Visions/Strategies**

Strategy 1:
- Almost exclusive focus on high-tech and R&D support
- The strategy is largely implicit
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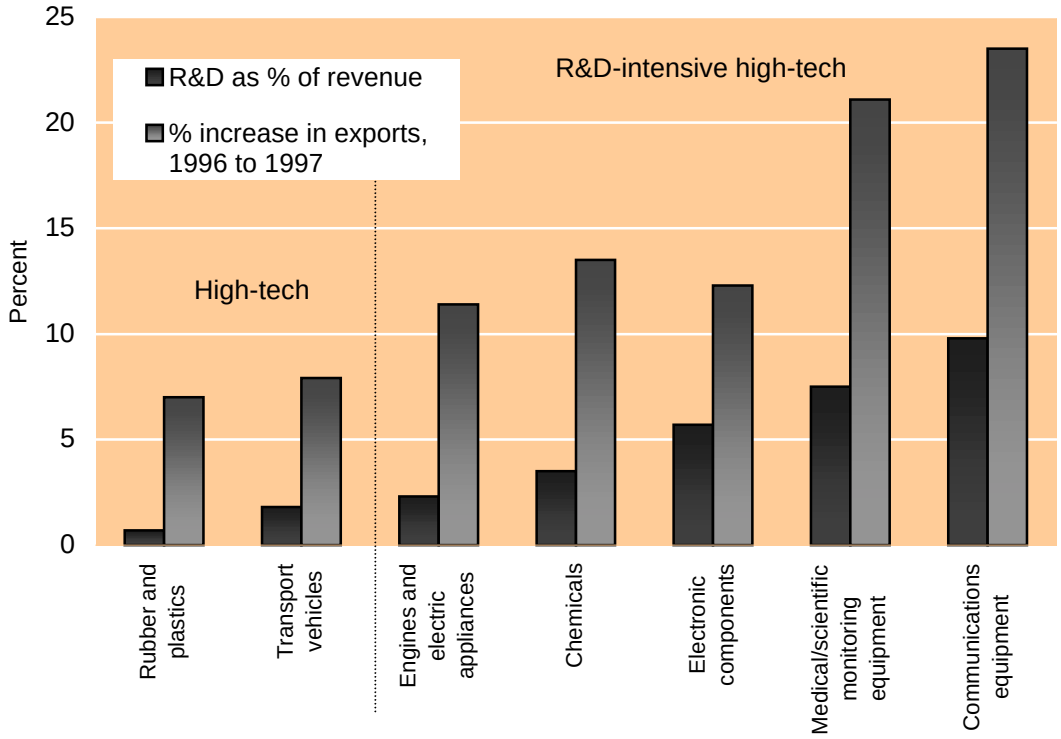
Strategy 2:
- Recognition of Israel's comparative advantage in high-tech
- Policies should consider both the R&D and the non-R&D aspects of successful high-tech growth
- An effort should be made to make it explicit
- Seeks a right balance between high-tech and mid-/low-tech industries (where most employment is located)

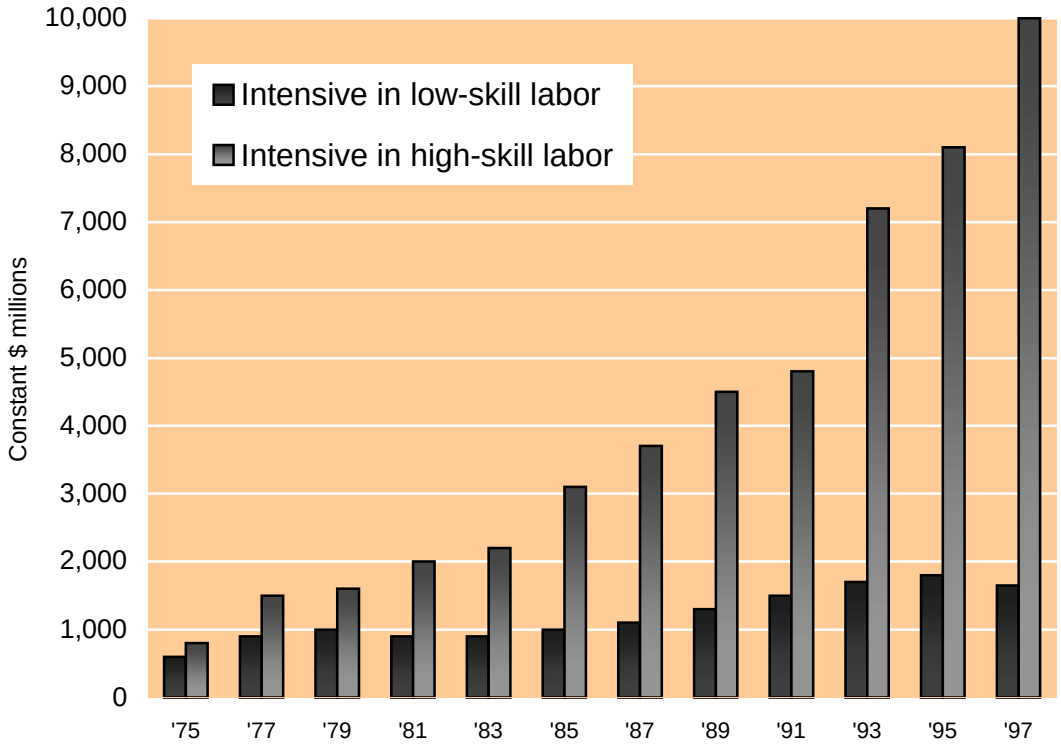
[18] For example, an equally simplistic view of the data on the rubber and plastics sector could be interpreted as meaning that small government disbursements in support of R&D would lead to very high rates of growth of exports of the sector.

Figure 3a. The Relation between R&D Intensity and Increased Exports



Source: CBS, R&D Survey, 1997.

Figure 3b. Industrial Exports, 1975-1997, by Type of Industry



Source: Bank of Israel, *Annual Report* , 1997.

At this stage we will only make a few points. First, we suggest a more restricted definition of 'high-tech', one that excludes typical areas such as plastics, and portions of the chemical industry which are neither strongly R&D-intensive nor unskilled-labor based. This would lead to a three-way classification of industry, with high-, mid- and low-tech components — as shown in Table 6.[19] A related point is the level of aggregation: a four-digit classification of industry might show a number of food industry sectors as growing very rapidly while a number of high-tech sectors might be growing slowly. Secondly, we should remember that at least part of the observed change in structure favoring high-tech could be *policy driven*, i.e., a reflection of a program support portfolio favoring these industries. Third, even if structural change has and should continue to favor high-tech industry, this does not mean that a set of more efficient programs could not be implemented for the restructuring of mid- and low-tech industry. There is undoubtedly a lot a research to be done in this area.

Table 6. Employment and Turnover by Industrial Branch, 1997

	Turnover (NIS billions)	Employment (thousands)
Low-tech		
Food, beverages	32	55
Textiles, clothing	11	43
Wood, furniture	6	7
Light industry	22	63
Percent of total	40	44.2
Mid-tech		
Mining, quarrying and non-metallic minerals	13	18
Chemicals and petroleum	24	22
Plastics and rubber	8	20
Metals and its products, machinery and equipment	28	74
Percent of total	39	35.2
High-tech		
Electric and electronic equipment	33	61
Transport vehicles	7	16
Percent of total	21	20.5

Source: CBS.

[19] This would accord with the Pavitt taxonomy (Pavitt, 1984), which is widely recognized as the relevant one in the literature when discussing technology and innovation.

III.2. Possible Changes in the System of Innovation and Implied Innovation/Technology Policy Priorities

The *desired* changes in Israel's NSI depend on the strategy/vision adopted, but the link is not one-to-one. Thus, implementation of Strategy 2 is consistent with a set of possible configurations of the future NSI such as that of Table 7, with its emphasis on clusters and on a set of mid- and large-size high-tech companies which have achieved reasonable market shares in some markets. As mentioned, strategy 2 may or may not imply the stimulation of a network of intermediate institutions supporting mid-low tech sectors.[20]

Technology and innovation policy priorities should not be confused with *national* objectives such as economic growth and equity. National objectives are expressed first and foremost in terms of vision/strategy which, in turn, translate into a 'desirable' future NSI such as that mentioned above.[21] Most of the priorities for technology and innovation policy flow from this future view of the NSI. For example, if one of the high-tech clusters aimed at is biotechnology, then one science/technology/innovation priority could be to reinforce university and university-industry research in biotechnology, to stimulate and support biotech start-ups, to fill gaps in existing infrastructure, etc. If our NSI should attempt to include a segment of mid-large companies in high-tech areas, then this may imply technology/innovation priorities in the area of cooperative R&D and facilitating joint ventures locally no less than acquisitions by foreign companies. Other objectives and priorities could exist, some of them substitutes for the one mentioned, some complements (see Table 8).

[20] For some industrialized countries of Europe changes in their NSI might include-creating a strong New Technology Based Firms' segment; a Venture Capital component; and the restructuring of Government Laboratories and Universities. Israel already posesses SUs and Venture Capital companies, they are not new components that have to be *created.*

[21] National objectives also translate into macroeconomic targets; the structure of government budgets, defense policy, international relations, etc.

Table 7. Changes in the National System of Innovation

High-tech
• Creation/strengthening of clusters (communications, software, biotechnology,etc) involving SUs and other companies
• Emergence of a set of mid- and mid-large companies
Mid-/low-tech
• Creation/strengthening of clusters
• (Possibly)World-class manufacturing
Other organizations and institutions*
• University system
• Training and colleges
• Finance and venture capital
• Improvements in the policy system

***** To be specified.

Table 8. Priorities in Science,Technology, Innovation and Industry Policy

High-tech
• Continued flow of SUs while assuring better management and more effective transition to mid-sized companies
• Continued growth and restructuring of mid/large companies
• Promotion of cooperative R&D
• Stimulation of strong local partnerships and joint ventures
• A 'balanced' approach towards mergers and acquisitions
• New configuration of links with Universities?
• Promotion of independent specialist firms in areas such as design, contract manufacturing, advisory and marketing services,etc.
Mid-/low-tech
• Promoting R&D and technological transfer/learning
• Promoting new patterns of specialization
• Restructuring of mid-/large companies
• Network of Intermediate institution (technology centers, self-organized industry boards, etc.)

III.3. Possible Programs/Policies During the Various Phases of NSI Transition

It is useful to think of promotion programs, in the first instance, as belonging to one of two kinds: horizontal or targeted. To these we must add cluster policies (Table 10). In terms of objectives, they may either be oriented to individual enterprises directly or be focused on non-business sector components of the NSI (the supporting structure). Finally, they may involve either 'neutral' or 'selective' incentives. On this basis it could be possible to characterize the structure of the existing portfolio of programs. As mentioned above, it would also be possible to identify *biases and gaps* in the existing portfolio.

The above would set the stage for assessing the changes that have to occur during the various phases of NSI transition. One possible set of changes is shown in Table 9. Policies supporting "R&D exploitation" refer to programs and other non-R&D support measures supporting those priorities of high tech (see Table 9) dealing with the creation and strengthening of mid\large companies. I am not capable of specifying these policies at this stage

In addition to promotion programs, other policies should be considered. These would include institutional and legal issues — intellectual property; bilateral agreements, the 1984 R&D Law (issues of transfer of knowledge abroad and domestic R&D implementation), etc.

Table 9. Possible Changes in the Policy Portfolio

- Integrated cluster creation and cluster reinforcement policies (see Table 10).

Specific to Hi-Tech

- Targeted support of university research and training in specific areas (computer sciences, chemistry, etc).
- Policies Supporting "R&D Exploitation"

Specific to Low-/Mid-Tech

- Effective extension of classical R&D and *Magnet* to mid-/low-tech business sectors.
- Possibly: Horizontal program supporting technology transfer and learning.
- Possibly: Horizontal program supporting self-organized industry boards.
- Targeted support of critical skills (university, colleges, etc.).

Table 10. Integrated Cluster-Creation Policies

- Search/research: identifying areas/configurations where clusters may promote both high-tech and mid/low tech sectors.
- Coordination: (partial) integration of existing horizontal programs — R&D, *Magnet*, investments, training, management, export support.
- Reinforcing weak links in the value chain: e.g., Phase 1 regulation and testing for new pharmaceuticals
- Networking Policies: Promoting horizontal and vertical links:
  Adapt *Magnet* to needs of mid-/low-tech.
  Stimulate creation of 'clubs' for informal interaction, information exchange, search and potential collaborations.
  Promote forums for exchange of experiences and information.
- Institutions
  Sectoral for information exchange, search and industry-specific public goods.
  Promote specialized links with universities, training institutions and colleges.
  Horizontal and targeted support of intermediate, linking institutions.
- Financial aspects*
- Promotion of specialized firms*

* Requires further specification.

IV. Other 'Policy Framework' Issues

IV.1. Justifying Government Intervention

It is clear that the government plays an enabling role in helping to establish or articulate national objectives and a vision of the future of the economy/society; in identifying a possible strategy and possible NSI configurations; and in setting priorities for technology/innovation. There are also limits to the applicability of market failure analysis in the choice of alternative promotion programs, due to the *pervasiveness* of externalities (Nelson, 1987) — which means that identifying externalities'-based, market failure from a certain activity is not a sufficient condition for prioritizing such an activity — and due to system effects (Teubal, 1998).

There could be a role for market failure analysis in the *implementation* of technology/innovation *programs*, particularly as regards the decision whether or not to extend incentives to specific *projects* (Lall and Teubal, 1998). Its contribution to help

guide government initiatives as regards to institutional change and the mechanisms and capabilities of policy makers is also limited.

A simplistic market failure approach characterizes many policy decision makers as well as academics in Israel. As shown from the example on pp. 1-2, this may be misleading, and a major objective in the proposed policy system is to introduce and diffuse a broader, more realistic conceptual framework surrounding innovation/technology and innovation/technology policy. The resultant 'policy framework' will be much more than market failure analysis, since it will incorporate a large number of relatively novel elements which reflect the current structure and operation of the economic system.

IV.2. Adopting a Multidisciplinary and Multi-Methodology Approach

A multidisciplinary and multi-methodology approach is necessary for *creating a policy framework* as well as for utilizing it to *generate new/restructured policies.* A central role should be played by Appreciative (Conceptual) Theory, which lies between historical accounts of events, on the one hand, and both formal theory and empirical, quantitative work on the other (Nelson and Winter, 1982; Nelson, 1995, 1997). This does not reduce the importance of formal theorizing and quantitative, econometric work; on the contrary, by setting the latter in a broader context it may be possible to harness these components of accepted methodology of economics to the policy needs of Israel in science, technology and innovation.[22] Note that Appreciative Theory is the only method by which the varied components of the policy framework would hold together into a coherent whole.

Specific methodological issues also arise in connection with the evaluation of specific programs (in the next section). Quantitative attempts at measuring the impact of a specific government program should be complemented with studies — both

[22] It is important to note that Appreciative Theorizing is a critical preliminary stage for new and especially complex phenomena such as those discussed in this paper. It would be less important in a world of greater stability in technology and markets, where the basic processes are known. In those cases, academics may undertake formal theory, suggest hypotheses for empirical analysis, and undertake econometric work without recourse to Appreciative Theory. Moreover, in those cases such work could be policy relevant. Concerning the subject matter of this paper, it is important to recognize that understanding the new processes, e.g., the impacts of globalization and SUs, it is important to combine case studies, surveys and Appreciative Theory. The latter would build on the former. All three would be important for policy. Formal theory/empirical work would then enter the stage and make a further contribution to policy.

quantitative and qualitative — of other programs which complement or substitute it. For example, if one objective of the classical R&D scheme is to diffuse R&D to the mid- and low-tech segments of industry, this requires assessing the 'technological needs' of such segments, a process which should begin with case studies and end in broad, representative surveys. Thus, part of the analysis of interaction among the various programs should be quantitative; others will be only partial assessments of directions of impacts based on focused surveys and case studies; and qualitative assessments of the magnitude of such impacts (see also Section IV).

IV.3. The Targets of Specific Programs and Program Design

Determining the targets of a technology policy program is not easy for a number or reasons, even when the objective being served is 'economic growth'. One reason is that the economic impact may occur several years after the initiation of program implementation, a fact that creates the need for 'intermediate' targets.

An important intermediate target for horizontal programs of the type implemented in Israel refers to the *diffusion of new innovation routines/processes throughout the business enterprise sector* (or innovation capabilities more generally; see Teubal, 1997, 1998c). This would fit in very well with Strategy 2, while not being inconsistent with Strategy 1. It should be distinguished from simple 'additionality' and from the generation of new and sophisticated technological capabilities within high-tech firms and the promotion of high-tech start-ups (as has been the case with *Magnet* in the past 5 years).

This 'diffusion objective' of an R&D support program could refer to more run-of-the-mill R&D/innovation capabilities within the mid- and low-tech sectors of Israel's business sector. It could also relate to other technological activities, such as technology transfer or technology learning. Whatever the activity considered, widespread diffusion of the latter capabilities would signal a capacity of non-high-tech sectors to generate value added and enhanced exports in the future.[23]

[23] As already mentioned, diffusing R&D beyond high-tech industry is not contradictory with a perspective claiming that Israel has an advantage in high-tech relative to other types of industry. It is not an either-or situation, but rather one of striking a good balance. Concerning the 'classical' R&D support program, 'diffusion' in the broad sense just mentioned does not yet seem to have been taken seriously by policy makers in Israel (this may be an error from the growth perspective since, as mentioned, success in such policy would contribute to transforming

Program design

Program design is a central feature of any horizontal technology policy such as those implemented in Israel. It is much more than setting the rate of incentives to R&D (following a simplistic market failure analysis), the traditional emphasis of economists. First of all, program design should set the basis for implementation of a *learning perspective* on policy, one where the objective is not only providing incentives to a particular activity, say R&D, but assuring that a cumulative, collective learning process about R&D takes place within the business enterprise sector (Teubal, *op. cit.*). Next, the boundaries of the activity supported should be defined, preferably in flexible way, especially at the early stage of policy implementation. Finally, explicit attention should be paid early in program implementation to the building up of policy capabilities within the government agency in charge. This should be part of *program design.* It will facilitate program restructuring in the mature phase of the *technology policy cycle* All of these are parts of program design (see Teubal, *op. cit.*).

IV.4. Specification of Search/Information Needs

Several different types of information and knowledge in forming the policy process could be put into decision-making.

- Evaluating existing technology support and innovation programs.
- Assessing the innovation and enterprise restructuring needs of the various segments of the business sector.
- Information on clusters in the business sector.
- Assessing future needs for and capabilities of the various components of the structure supporting enterprise innovation (university research and training; technological infrastructure; finance).
- Implications of globalization and other changes in the environment facing the country.

The information and knowledge generated will be useful in several phases of the policy process: consolidating a vision and strategy; visualizing reasonable actions

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mid- and low-tech industry into sophisticated technology users). As suggested in Table 9, this may require focusing not only on R&D but also on technology transfer and learning. Another implication is that a high (social) rate of return on government expenditure supporting R&D is

towards a future NSI adapted to our needs; as inputs for setting priorities in technology and innovation; restructuring new programs or designing new ones; and policy implementation. Various alternative methodologies will be used to access the information and for generating useful knowledge.

I will be more specific with respect to three of the above types of policy-relevant search/research.

IV.4.a. Evaluating existing programs directly supporting enterprise innovation

It is imperative to evaluate, beyond the 'classical' R&D support scheme, the other most important technology support programs. These will include

- Evaluation of the *Magnet* Committee's activities.
- An integrated view of support for high-tech startups, one that includes both the support received in various phases by the classical R&D support scheme as well as the support and finance by incubators and venture capital.
- Support for the introduction of management techniques (including innovation management techniques) within small and medium enterprises, both mid-/low-tech and high-tech.

Section VI shows that it is important to adopt an integrated perspective to such evaluations.

IV.4.b. Assessing the innovation and enterprise restructuring needs of the various segments of the business enterprise sector

Relevant information may come from the information and conclusions of program evaluations and/or from other explicit surveys targeted to those segments for which no information exists (e.g., segments of enterprises not extensively covered by existing evaluations). For example, an assessment of the innovation and restructuring needs of the mid- and low-tech segments of enterprises would require knowledge both about the 'diffusion' of R&D as an activity to these segments and about the technology needs from sources outside the individual enterprise (i.e., not from intramural R&D). The latter may require an explicit survey to this effect. Note that while the information that

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not the only objective of technology policy; reaching large numbers of enterprises in all sectors is no less important. This might constitute a desirable change of Israel's NSI.

is likely to come from an evaluation will focus on firms undertaking the relevant activity (e.g., R&D), the information collected from the complementary survey — if properly designed — will result from a focus on firms that have not undertaken the relevant technological activities no less than from a focus on other firms.

An important piece of knowledge relates to the restructuring of mid- or mid-/large high-tech companies in Israel (Tadiran, Elbit, Telrad, and the Military Industries). It is important to develop a shared consensus of where these industries — large chunks of which have been sold to multinationals — are going, and whether there are grounds for changes in government policy to induce restructuring configurations adapted to the needs of the country (note that a lot of what happens is not purely the result of market forces but also the result of heavy government involvement in numerous areas such as governance, taxation, R&D support, etc.)

IV.4.c. Assessing the future needs for the various components of the structure supporting innovation in the business secto (technological infrastructure; finance; and university research and training)

Quantitative measurement of the rate of return to government support of R&D depends on the state of affairs concerning human and venture capital. To be fully effective for policy purposes, they ought to be considered together with trends in the supporting structure (manpower, science, finance) and jointly with policy actions in these other areas. Thus, the desirability of increasing support to R&D may make no sense if there is no change in the output of highly qualified personnel, while it may be highly desirable in a coordinated policy context with new schemes designed to enhanced such personnel are simultaneously implemented.

More specifically, it is important to assess

- The functioning of venture capital in Israel.
- The projected needs of technological manpower and ways to satisfy them.
- Potential needs for new technological infrastructure, both that supporting mid-/low-tech and that supporting high-tech industry.
- The state of science and university research as far as the direct and indirect needs of the business sector are concerned.

V. The Policy Process, Key Agents, and Co-Evolution

V.1. The Policy Process and Desired Changes in the Existing Policy System

The policy process is the process that is directly and indirectly involved in generating the various components or elements of the 'policy framework' as well as the process of program implementation. It includes both the search/research activities which feed into actual decisions and feedback from 'downstream' implementation which may affect 'upstream' activities (e.g., a program implementation evaluation which will feed back into a new program or a new set of priorities). Needless to say, due to fundamental uncertainty and to the complexity of the relationships involved, the technology/ innovation policy process — and the innovation process — cannot be regarded as linear; rather, it involves a number of feedback loops.

The literature in various fields dealing with innovation/technology policy has proposed several different characterizations of the policy process. These relate to issues of initiative, capabilities, breadth and scope of interactions; the role of supporting search/research, links with political institutions, issues of client capture of policy agencies and policy lock-ins, etc. My objective here is not to survey the vast literature in this area (which mostly goes beyond traditional economic analysis) but to raise a number of questions which might be of relevance for the Israeli context. These include:

- Who is involved and how are priorities set. Characterization of the process: top-down, bottom-up, or mixed; extent of interaction with stakeholders and other affected agents; extent of use of systematically collected information, etc.[24]
- The patterns of generation and use of policy-relevant information? For example, does a systematic evaluation of 'need' precede the implementation of new programs? What is the role of policy-relevant academic research in the process?
- Feedback mechanisms from the business enterprise sector: do they exist? how useful are they by themselves or together with additional information?
- To what extent is developing policy capabilities considered a part of the policy process itself?

[24] For examples of almost 'pure' bottom-up policies directed to clusters see Roelandt (1998).

- What steps must be taken to initiate a process of consolidating a policy framework for Israel?
- What profiles of policy making could be relevant for Israel and what supporting institutions would be required.

A significant effort should be put into the above and other aspects of Israel's policy system. Likewise in order to arrive at an assessment of possible improvements in the mechanisms and institutions of policy. 'Models' of policy-making implemented abroad should be analyzed and assessed.

V.2. Key Agents Triggering the Process

What are the key agents of change in Israel, i.e., those inducing a process of re-orientation and restructuring of policy as well as triggering changes in its NSI? Agents of change could exist in all sectors, government, business or academia.[25]

Policies could be or could contribute to the triggering process. What is the initial set of change-inducing policies and institutions; and follow up policies and institutions?

V.3. Co-Evolution Between Policy and Processes of Industrial Transformation

Are actual policies stimulating innovation/restructuring in outmoded trajectories of some business segments, thereby reinforcing inherent inertial tendencies in large organizations? Such cases seem to have existed in the past in other countries, e.g., the 'lock-in' into imitative R&D in Korea according to Ernst 1998 (apparently less so according to L. Kim, 1997); EU policies biased against real product innovation (Edquist *et al.*, 1996), etc.

Are they or have there been *policy lock-ins* that blocked the enactment of new policies — even when such policy restructuring may have been critical for the evolution of a country's business sector? Israel's policy-making experience would seem to include a combination of inertia — in the transition from the regular R&D support program to

[25] The Kachalsky Committee of the mid-1960s in Israel (whose recommendations led to the creation of Chief Scientists at various Ministries and also to the 'classical' R&D support program of the OCS in 1969), and the process leading to the *Magnet* Committee in 1992 are examples of successful policies involving strong academic involvement. *Yozma* is a good example of a successful policy initiated by the political and policy-making system of Israel in the early 1990s.

Magnet — and active adaptation to changing circumstances (in the creation of *Yozma*). Sometimes inertia may be broken by radically changing circumstances (e.g., massive Russian inmigration) or by widening the circle of agents that could influence policy, e.g., enabling academics to influence policy making.

The general issue is to assure endogenous adaptation and change in the policy process in order to create a *virtuous cycle* where an explicit distinction is drawn between two or more phases in the transition of the NSI (Teubal 1998). Thus:

1) Program (or Policy) **a** would stimulate Phase A in NSI transformation.
2) These changes in the business sector, together with changes in the policy process and institutions, create new 'policy needs' or — if one is neoclassical enough — new sorts of market failure.
3) The new 'policy needs' lead to new programs/policies (Program/Policy **b**) which, when implemented,
4) induces Phase B in NSI transformation, etc.

Lock-in may truncate the process. Continuous transformation of Israel's business sector may necessitate continuous transformation in policy and in policy-making institutions — part of which involving a capability and disposition to consider new priorities which emerge from past policy successes.

VI. Program Evaluation in a Multiprogram World: Methodological Issues

During the 1990s the government of Israel launched a series of new programs: *Magnet* (a program supporting high-tech consortia involving firms and academic institutions); support of start-ups in the incubator program, support of venture capital; and support of consulting and management techniques in the conventional SME sector. These programs add to the existing set, which is dominated by a 28 year old promotion scheme supporting 'classical' R&D at the enterprise level (a 'horizontal program' whose aim is to develop new or improved products and processes by individual enterprises).

VI.1. Evaluating the Impact of Past Policies

In this multi-program context two problems arise: the links between programs and the need to evaluate the economy's overall program portfolio. The former means that the impact of any one program may depend rather closely on the implementation of other

programs, a fact to be considered in program evaluation. Thus, when evaluating the classical R&D support program of the Office of the Chief Scientist (a process now underway) it may be of critical importance to assess the extent to which centure capital companies in Israel are successfully financing R&D. The successful emergence of this new segment of Israel's financial system, in turn, was the result of successful government policies undertaken in the early 1990s (the *Inbal* and especially *Yozma* schemes). Moreover, it is clear that in the early years of development of the sector the incentives provided by the 'classical' R&D support program were of critical importance; the impact of the classical R&D program may well have depended on the impact of *Yozma* and vice versa.

It follows that addressing the evaluation of the classical R&D support program independently of other programs may give an incomplete picture of the impact of government policy. If the period of evaluation runs from 1985 to 1995, it may be that the impact is *greater* than what one would surmise from an exclusive focus on the evaluation of classical R&D support — to the direct economic impact we must add an indirect effect of classical R&D support in stimulating the emergence of a venture capital industry in Israel. On the other hand, if evaluation of the classical R&D support program focuses on the last years it would have to consider both VC-finance and OCS finance, and would have to ask whether the former is a substitute for or a complement to the latter.[26] The upshot is that in a multi-program world an evaluation of the economic impact of one program without considering other, related programs, may lead to wrong answers. The major implication is that *technology policy program evaluation should encompass a group of (strongly) interrelated programs and it would be conducted in an integrated and coordinated fashion.*[27]

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[26] A priori, there seem to be grounds to assume that the link between direct support of R&D and support of VC has shifted from complementarity in the early 1990s to substitution at present (see Gelvan and Teubal, 1997, for a presentation of the former type of link between the two types of support). Despite this, a preliminary look at 15 start-ups in the computer networking and communications areas in Israel shows a much more complex relationship. Simple substitution is not necessarily the case, owing to the frequently need to assure entrepreneurs a measure of control over their operations in the early phase of low company valuations and large financial needs to support expansion (see Teubal and Klein, in process).

[27] This should not be construed as justifying an evaluation of the aggregate R&D government support of enterprises, where the aggregate would cover not only different types of R&D (e.g., support for 'classical' R&D together with support of cooperative, pre-competitive/ generic R&D), but also support from different government agencies. It would be difficult, under

A second implication of the existence of a set of interrelated programs concerns the evaluation of the impact on national objectives of the portfolio of programs supporting technology and innovation. In Teubal (1997b, 1998a) I introduced the notion of *activity bias* and *enterprise bias*. The former relates to the balance between direct support of innovation in enterprises (e.g., through horizontal programs such as those implemented in Israel) and targeted promotion of the supporting structure — training and research at universities; venture capital, the technology infrastructure, etc. Several countries in Asia and in Latin America (and apparently in Europe, too) have historically shown a bias in favor of the technology infrastructure, i.e., very little direct support of innovation and R&D within business enterprises.[28] Israel's situation was (since the 1970s) the opposite: an emphasis on direct support to R&D. While overall this emphasis was justified and successful during the 1970s and part of the 1980s — due to a strong university system and the ample supply of high-level technological manpower; and due to success in stimulating high-tech industry — there was oversight and negligence in the promotion (or lack of promotion) of specific components of the support structure, such as the delay in creating the *Magnet* Committee (an infrastructural program). Even more so today the program portfolio should again strongly support university training (and research) at least in selected fields of science and technology.[29]

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this approach, to interpret the results obtained and to articulate policy conclusions. I do think that evaluations should be program-based but that these should consider links among programs as well.

[28] This bias would seem to follow from two sources: (i) A linear view of innovation — which would imply that once science and research are supported at universities and at the institutions comprising the technological infrastructure — enterprise innovation would flow automatically; and (ii) ideological reasons against direct support of innovation and R&D in the private enterprise sector. Fortunately, neither of these views took hold in Israel and direct support for industrial R&D was a long-term, consistent and massive program (Teubal 1984, 1993).

[29] Having said that, it is highly probable that the program portfolio has discriminated and still discriminates against those components of the technological infrastructure which support mid- and low-tech industry, e.g., intermediate institutions such as the very successful Plastics and Rubber Industry Technology Center. Thus, while the 1990s have seen a reduction in the bias against the infrastructure supporting high-tech, it has not yet eliminated the gaps or infra-structural biases against mid-/low-tech.

VI.2. Policy Implications of Program Evaluation[30]

A second reason for adopting a more systematic approach to technology and innovation policy pertains to *the complexity of the relationship between evaluation of a program and extracting policy conclusions from such an evaluation***.** More specifically, I will show that *the links between the two may be tenuous and complex in a multiprogram world*.

Evaluating the classical R&D support program in isolation may suggest more efficient intra-program reallocations. It can hardly be expected, however, to tell us whether *Magnet* or any other program (actual or potential) should be the main beneficiary of any suggested reallocation of funds within the overall civilian R&D support system. The problem pointed out here is related to (but goes beyond) the links among programs mentioned above. We have seen that past links among programs may affect program evaluation; but a restructured policy should take into account future links among programs as well. Thus, even if the evaluation of the classical R&D grants scheme showed a very strong direct and indirect economic impact,[31] *policy restructuring — in light of the successful development of venture capital and the shortages of highly qualified scientific and technological personnel — might have to emphasize other, possibly indirect ways of supporting innovation and R&D in the business sector*. If so, the *direct* policy relevance of that particular program evaluation could be questionable since the relationship between past program evaluation — even one following the 'ideal', integrated configuration mentioned above — and policy conclusions is tenuous and complex. A more systematic analysis of the program

[30] In what follows I will not discuss issues of model specification in econometric work on the impact of R&D. For example, in studies of the impact of R&D and of government support of R&D on firm productivity that follow the production function approach, a major issue is that firm productivity is linked to its own R&D rather than to the R&D performed by others, thereby excluding the possibility of externalities — the major reason for government support in the first place. Another major issue not considered in such an econometric perspective is the learning-to-innovate perspective developed in Teubal (1996, 1997a), with its emphasis on the development of technological and organizational capabilities. For a summary discussion of some of the problems emerging from this approach see Griliches (1997). It seems to me that a greater effort should be made to incorporate the results of Appreciative Theory and case studies/surveys before proceeding with econometric estimation — especially so if the objective is to guide policy.

[31] The indirect impact being, as mentioned, the stimulus it gave to the emergence and development of venture capital in Israel.

evaluation-policy restructuring link is called for.[32] [33] Without the complementary adoption of a broader conceptual framework and in the absence of complementary information on trends and related programs, it may be that the rich data base and quantitative analysis of the classical R&D program will not contribute sufficiently to consolidate a new operational conceptual framework with which to underpin technology policy in Israel in the next decade (a 'lost opportunity').

Moreover, due to complexity of the connections between single program evaluations and policy restructuring, and the extremely abstract and simplistic conceptual framework underpinning existing policies, there is always the danger that the results of the ensuing quantitative studies may be interpreted in such a way that they will lead to the wrong conclusions for policymakers.

VII. Summary and Conclusions

The objective of this paper is largely methodological. In line with the approach followed in previous work dealing with policy(Justman and Teubal 1986,1995) we are asking 'how to think about technology and innovation policy', rather than providing concrete recipes for action. In our opinion this is justified because of the complexity of the national innovation system in Israel and the awesome tasks faced by policy makers which such complexity entails.

Our answer is that we should think about such policy differently from what was common in the past. Moreover, while Israel's policy was at least 'mildly' successful and probably quite successful in the past, a significant reconfiguration and restructuring is required in order to successfully confront future challenges and in order to exploit new technological and business opportunities. Technological and innovation policy comprises at least three categories of actions: priorities, incentives and institution (Lall and

[32] Alternatively, if an impact study or evaluation would point to a reductions in classical R&D this still could be unwarranted since, as already mentioned, several potentially harmful dynamic processes may set in. These could include: (i) the dynamic implications of drastic reductions in support, e.g., through cumulative effects in the US stock markets; (ii) the willingness of foreign enterprises to invest in Israel; (iii) effects on employment; etc.

[33] The simplistic view of policy as a simple implication of analysis/evaluation, particularly quantitative analysis, is linked to the absence of awareness of the increasingly important distinction between 'the economics of R&D/innovation/technological change' and the emerging

Teubal, *op. cit.*).We have probably been good at incentives, but we certainly are weak, vis-a-vis future needs, concerning priorities and institutions.

The first task in our opinion is to try to consolidate, in a consensual way and with the help of objective information and analysis (including those of academics and experts), a vision and strategy about the future of the business sector of this country. This should take into account both economic and non-economic national objectives (the latter would include defense, integration into world markets and technology, social objectives, etc) and would be embedded in a broader vision of the Israeli economy and its society. In other contexts, there is talk of the "information society" (European Commission, 1996) and the Learning Economy (European Commission, 1998). We should analyze what configuration (if any) of such visions could be relevant for Israel. More specifically, for the business sector we have identified two strategies (Strategy 1 and Strategy 2), both of which involve prioritizing high-tech industry and associated supporting structures (including university research and training). The difference resides in making explicit both the non-high-tech component and the high-tech component of the strategy for the business sector.

Strategy 1 does not attempt to make explicit the future role of mid-/low-tech industry in the economy, and therefore it gives insufficient attention to policy directed to these sectors. It also focuses almost exclusively on technology support for high-tech industry (e.g., R&D subsidies) and to some extent on supporting the facilitating structure (e.g., universities, to generate more high-level manpower). Strategy 2, on the other hand, explicitly recognizes the potential of (parts of) mid-/low-tech industry to advancing growth and employment, e.g., by becoming sophisticated technological *users.* Also it make explicit the role of *non-technological factors* in generating a high-tech sector which may contribute to growth according to expectations. For example, a reasonable (though not the only) configuration of Strategy 2 must grapple both with the issue of assuring a continuation of the flow of high-tech SUs *and* promoting the emergence of a set of mid-/large high-tech companies with significant or important shares in world markets.

Both healthy and timely restructuring and at least mild development of mid- and low-tech industry should also be considered under Strategy 2. Restructured policies directed to these segments, possibly in conjunction with a cluster perspective, may

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field of 'technology policy'. Again the link between the two are strong, but knowledge of the former is insufficient for an individual to become knowledgeable in the latter field.

significantly enhance the capacity of mid-/low-tech industry to adapt to the changing environment with only marginal increases in government disbursements.

Related to issues of strategy and immediately following it are questions of *priorities* for science, technology, innovation and industry. A limited number of suggestions are made, especially as far as the business sector is concerned (and much less, due to less knowledge, concerning science and other components of the system of innovation). But as mentioned above, our capacity to identify priorities is limited because of limited information and the need to create new mechanisms for setting priorities.

The required actions can be summarized as belonging to three main categories:

- *Actions which increase the information and knowledge about the system* (e.g., the'needs' of various business segments; program evaluations; trends in industries and in world markets, etc).
- *Improving the conceptual framework*, particularly the system of innovation approach (including the role of 'clusters' of various types) and the 'policy framework'.
- *New or improved mechanisms/institutions of policy*, for setting priorities with a systems and evolutionary perspective, for program coordination, etc.

Concerning information and knowledge about the system, there is for example an enormous gap in systematic knowledge about the workings of SUs, their links with VC and implications of this for policy. This example is interesting because in some sense the system is flooded with information about these phenomena and undoubtedly significant 'collective learning' is taking place in this regard. The issue is not lack of information per se, but lack of *structured* knowledge about the phenomena and their policy implications. Moreover, we are far from being able to integrate such knowledge into the broader perspective of Israel's system of innovation and its evolution.

Concerning the institutions of policy, it is important to develop new mechanisms for decision making which accommodate two elements: first, multilateral interaction between policy makers, agents of the business sector and academics; second, systematic *search and research* to support decisions. Interactive mechanisms seem to be successfully implemented in Denmark, Holland and other industrialized nations (see, e.g., Johnson, 1997); while Finnish government's Science and Technology Council plays an important role in setting priorities for that country (E. Ormala, 1998). An example of a search and research intensive process leading to the establishment of a new program in Israel is the Industrial Development Policy Group of the Jerusalem

Institute for Israel Studies, which undertook a series of background studies that contributed to the establishment of the *Magnet* Committee in 1992 (Teubal and Boehm, 1998). This pattern has not been the usual one in this country in the technology and innovation area. One possibility in this regard is the creation of a *strategic R&D forum*, involving representatives of academia, industry and government, with a strong staff and research component, and having basically an informational and bridging function.[34]

This paper also raises significant methodological issues concerning technology and industrial policy. Policy is too important to to beft exclusively in the hands of government officials or economists following simplistic conceptual frameworks or purely quantitative/econometric approaches. Appreciative theory, case studies, qualitative analyses, etc. are critical to attempt to understand new phenomena such as start-ups, venture capital, the implications of globalization; for pre-evaluations of complex programs (like *Magnet*); and for articulating a new conceptual framework. These efforts will also help those designing and implementing formal, quantitative evaluations, which will then make an even greater contribution to policy. Moreover, interaction and interactive learning is of the essence for arriving at appropiate policy configurations. Thus, government officials, entrepreneurs, and academics should be involved, to a greater extent than previously, and in a more systematic fashion.

As with other systems undergoing transformation and modernization, Israel's policy subsystem should open up in parallel with the opening up and modernization of its Innovation system. I hope this paper will contribute to this endeavor.

[34] One of the major functions of such a forum would be to assess the policy needs for 'exploitation' of the results of R&D, particularly R&D coming from SUs, in ways which contribute significantly to the economy. This is a very complex issue in this era of globalization since, at least in theory but also seemingly in practice, in some areas, large 'private' profits could be linked with limited 'national economy' benefits.

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