The impact of government support to industrial R&D on the Israeli economy

Final report

English translation from Hebrew

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Introduction

This report summarizes a research conducted by the undersigned for the Ministry of Finance and the Office of the Chief Scientist ("OCS") in the Ministry of Industry, Trade and Labor. The objective of the research was to estimate the impact of government support to industrial R&D on the Israeli economy. By combining the results of several econometric models estimated using data from the manufacturing industry and the R&D surveys from 1996 to 2003, we are able to present estimates, of a kind never previously presented in Israel, regarding the expected total increment to industrial GDP resulting directly from the government's support to R&D.

We would like to express our gratitude to the chairman of the professional steering committee, Dr. Yehoshua (Shuki) Gleitman whose vast experience and useful remarks were of great benefit to the quality of the research. We thank the members of the steering committee, Mr. Yair Amitai (MATIMOP), Mrs. Simcha Bar-Eliezer (Central Bureau of Statistics), Mr. Yaackov Barkay (Ministry of Finance), Mr. Ruby Guinel (Manufacturers Association of Israel), Mr. Michel Hivert (MATIMOP), Mr. Gad Levin (coordinator of the committee - MATIMOP), Mrs. Lidia Lazanes (Office of the Chief Scientist at the Ministry of Industry, Trade and Labor), Mrs. Haya Miller (MATIMOP), Dr. Michel Strawchinsky (Bank of Israel), and Mr. Hagai Ido (Ministry of Finance) who contributed their insights and expertise throughout the entire work process.

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1. Summary and conclusions

For many years, the Israeli government has allocated vast resources to the support and promotion of civil research and development (R&D) activities by the private sector. This support has totaled approximately 3 billion NIS over the years 1991-2007[1]. The objective of this research was to quantify the impact of government support to industrial R&D on the Israeli economy, and in particular, to provide policy makers with a quantitative estimate of the industrial GDP increment expected from each additional Shekel of government support directed to industrial R&D in Israel.

Public support of R&D carried out by the business sector is justified in the presence of market failures that without government intervention results in an equilibrium where private investment in R&D is sub-optimal from a social viewpoint (Arrow 1962)[2]. The main failure ensues from the fact that investing in R&D yields new knowledge whose assimilation or adoption by firms that did not bear the development costs cannot be prevented fully. This phenomenon is known as R&D spillovers. The private return to R&D, which forms the basis for decision-making in firms, does not include the spillover component and is therefore smaller than the total return to the economy. Further market failures occur in the capital markets when entrepreneurs and firms fail to transfer business risks in full to risk-neutral players such as banks and insurance firms due to asymmetric information between the different players.

The objective of government support to R&D is to ensure that knowledge is "produced" at an optimal level from a social viewpoint. Due to the existence of knowledge spillovers and various constraints over investment decisions in firms, the government aims to increase R&D expenditures of firms to a level higher than the level obtained due to

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[1] Source: Office of the Chief Scientist in the Ministry of Industry, Trade and Labor. The data represent net support after deduction of royalty payments received over the years by the government.

[2] Arrow, K. J., 1962, "Economic Welfare and the Allocation of Resources for Invention", **in The Rate and Direction of Inventive Activity,** Princeton University Press: Princeton, pp. 609-625.

private considerations of profit and loss only. This may be achieved by removing constraints to investment or by providing direct support for the execution of R&D activities, thereby enabling firms to obtain a return that is equal to the social return and choose their investments accordingly. In light of the aforementioned, this report was required to present quantitative answers to the following questions:

1. What is the new R&D level that directly results from government intervention and that otherwise would not have been undertaken?

2. What is the GDP increment to the economy related to this new R&D?

The first question, known in the economic literature as the issue of crowding out/additionality, concerns the proportion between firms' private resources and public funding. One may consider a situation in which a firm is granted government financing for a research project that would have been carried out by that firm even without the same government support. This situation is referred to in the literature as crowding out - a situation in which government support "crowds out" private funds that would have been used to finance the project had the government support not been granted. Naturally, in the event of crowding out, public funds do not create new R&D, but simply replace private financing. On the other hand, it is possible that government funds constitute an incentive for additional investing greater than that which would have been carried out under private market terms. This situation, known as additionality, refers to a situation in which public funds stimulate firms to invest in R&D up to a level that is higher than the one that would be achieved solely as a result of firms' private considerations.

The second question is connected to the increment in GDP that stems from a successful R&D process. This increment is comprised of the direct effect to the GDP of the firm that performed the R&D and the indirect (spillover) effect over other firms in the industry. Therefore, we must estimate: (1) the impact of R&D investment on the executing firm's performance, and (2) the R&D spillovers impact - i.e. the impact of one firm's R&D on the performance of other firms in the industry.

The results of this report are based on a unique database compiled by combining the surveys of the manufacturing industry and the surveys of R&D in the manufacturing industry for the years 1995-2003. The database comprises detailed information about some 2,800 industry establishments (plants) including, inter alia, data on added value, sales, investments, employees and R&D expenditures. Concurrently, an analysis was conducted using data from the R&D surveys of the computer services, software and R&D branches, which include approximately 470 establishments during the years 1997-2005. At this point, we would like to note that the database suffers from a significant scarcity of observations of firms that engaged in R&D in the traditional manufacturing branches. This fact makes it difficult to draw statistically robust conclusions regarding these branches.

The main results from the research are as follows:

A. The R&D increment derived from government support

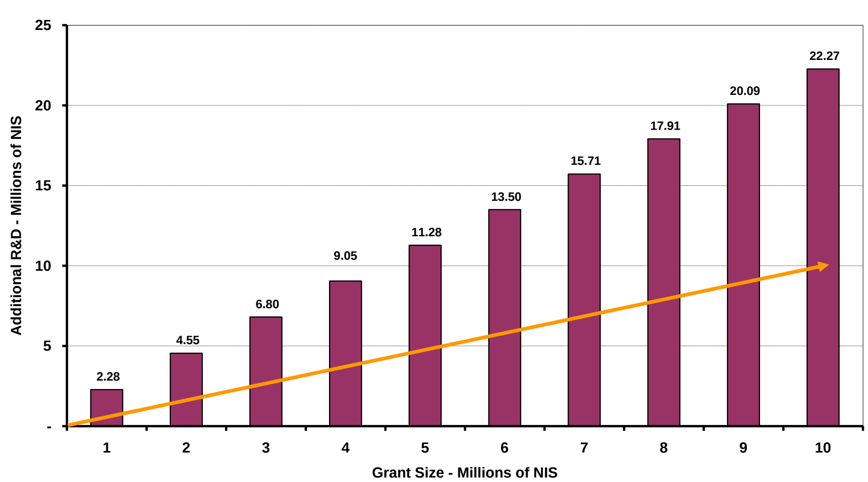
Government support induces the "creation" of new R&D, which, were it not for the support, would not have been undertaken, of up to 2 to 3 times the amount of the grant given (depending on the level of grant). This result refers to the marginal government support and is statistically significant and robust throughout different economic branches both in the manufacturing industry and in the computer services, software and R&D branches, and with regard to firms whose technological level and size differ from one another. It follows from this that the support mechanisms implemented during the years covered by our analysis did not crowd out private funds (namely, did not finance investments which would have been taken up anyhow) but rather result in statistically significant R&D investment additionality regardless of the branch or size of the supported firms.

The estimates show that in the manufacturing industry branches, a government grant amounting to NIS 1 million creates an increment in private R&D expenditures amounting to NIS 1.28 million – meaning a total increment of NIS 2.28 million of R&D expenditures in the economy. In the computer services, software and R&D branches, the increment in private R&D expenditures is NIS 1.81 million, and the total R&D increment to the economy is NIS 2.81 million. These are lower bound estimates for additionality de facto, since they were estimated based on gross grants data without deducting royalty payments to the government.

The following figure presents the central results derived from analyzing the additionality that stems from government R&D support. The columns (Y axis) represent the total R&D increment to the economy as a result of government grants (X axis). The diagonal line is a 45° line. Similar findings were attained for R&D government support in the computer services, software and R&D branches.

Total R&D increment in the economy as a result of government grants (additionality) – manufacturing industry

2003 NIS, million



B. Total returns to the economy

The returns to the economy derived from R&D government support are very high – even in branches where most R&D investments are made (high-technology/medium-high technology) and in which data observations abound. The returns to the economy derived from government support were estimated using two separate production function models (Griliches ,Blundell & Bond), well known in the economic literature. The results obtained in regard to both the private returns to R&D and the spillovers estimates are consistent with the results from research on the subject elsewhere.

The results of the analysis show that most of the R&D spillovers are derived from medium-large firms (turnover of NIS 50-300 million) and very large firms (turnover greater than NIS 300 million). The results attained reflect a minimal multiplier of 5 to 6 times between the government investment and the total future industry GDP increment (for a grant of NIS 5 million) to firms with a sales turnover of NIS 50-300 million; and a minimal multiplier of 1.5 to 2 between the government investment and the total future industry GDP increment (for a grant of NIS 5 million) to firms with a sales turnover of NIS 300+ million.

Higher returns are attained in the medium-low, medium-high and low-technology branches. The main finding, nonetheless, is that even within the high-technology branches where the vast majority of R&D expenditures in manufacturing are concentrated, and which have received high levels of government support throughout the years – a multiplier of 4.7 to government funds is attained. That is to say, that even in branches with high levels of R&D and government support and a large quantity of data observations available - positive and high returns of government support to private R&D are attained.

C. Additional findings

1. This research presents for the first time data regarding the dynamics of the support of the Office of the Chief Scientist to firms (at the establishment or plant level) in the manufacturing industry, computer services, software and R&D branches. The facts indicate that the support of the Office of the Chief Scientist is granted for two consecutive years to approximately 70% of the firms and for three consecutive years to approximately 50% of the firms. That is to say, a firm whose request was approved for the first time in a certain year has an average expected probability of 70% to receive continued support in the following year and a 50% probability to receive support for three consecutive years. From the viewpoint of the firms, the data reflect a considerable degree of uncertainty regarding the probability of change in the level of support granted. Among the firms which are granted support for two consecutive years, 50% will receive a support that is about 50% higher than the support received in the previous year, and the other half will receive support that is about 40% lower than that received in the previous year. Nonetheless, an analysis similar to this one, of the data file from the Office of Chief Scientist at the single project level, rather than at the firm (establishment) level, as was conducted in this research, is called for.
2. A large degree of heterogeneity was found between the firms in regard to economic variables relevant to policy-making. For instance, average R&D expenditures as a share of firms' GDP in manufacturing amounted to 8% in the years 1994-2006. The standard deviation, that measures the spread around the average, equaled approximately 50%! The distribution median was only 2% - about one fourth of the average. Furthermore, the distributions within groups of technological intensity and size do not provide a more homogenous picture.
3. A systematic examination of the data reveals a high and persistent concentration of firms' GDP and R&D expenditures between and within the relevant branches. In particular, examining the share of large firms in the total branch GDP/revenues reveals that about two thirds of manufacturing production originates in

approximately 10% of the firms only. A picture just as extreme emerges from the R&D surveys in the computer services, software and R&D branches.

4. R&D expenditures are also concentrated mainly in a limited number of large firms. In the high-technology branches, where most of the manufacturing industry R&D expenditures are concentrated (86%), about one third (!) of R&D expenditures are made by the four largest firms. In other words, four high-technology firms alone are responsible for approximately 30% of the overall R&D expenditures in the entire Israeli manufacturing industry.
5. The marginal return to R&D investments is similar to that received on capital investments in the high-technology branches alone. In all other branches, the return on R&D investments is 6 to 200 times higher than the return to investment in physical capital. Due to scarcity of observations in some of the branches, we estimate that the reasonable return ratios are up to 8 times in favor of industrial R&D investments. The facts show that from the viewpoint of resource allocation in the economy– R&D investments are, in most cases, to be preferred over capital investments.

Based on the analysis and findings above, we present the following <u>main conclusions:</u>

1. The high additionality found demonstrates that the government support mechanism is effective and succeeds in selecting projects, which would not have been taken up were it not for government support. In light of the aforementioned, it is reasonable to assume that a similar performance is to be expected with regard to current support mechanisms in branches for which extensive past data is unavailable (biotechnology, nanotechnology).
2. The high return to the economy stemming from R&D government support justifies the shifting of government budget allocations to this activity. This conclusion certainly applies to the relatively high levels of support provided in the years 1996-2003, and even more so to the support levels currently provided. These allocation

shifts should be traded off vis-à-vis government support schemes that bear lower returns.

3. The official set of publications which guides policy makers should explicitly show and refer to the high level of firm heterogeneity between and within different seemingly homogenous branches - in regard to relevant variables such as GDP, R&D expenditures, workers, etc. We believe that average changes in the variables are not enough to enable the formulation of efficient policy tools.
4. Enabling the Office of the Chief Scientist to commit in advance to multi-year financing should be considered. We believe that if firms would be aware in advance of the financing time horizon, they could be spared the uncertainty associated with the approval of requests on a yearly basis. It seems that in the case of high-risk processes such as R&D, where part of the rationale for government support is the reduction in business related risk, it is important not to create a new uncertainty associated with required regulatory processes for the approval of support. This issue can be examined optimally using the Office of the Chief Scientist data at the project level.
5. R&D spillovers is but one of the instances in which government intervention is justified in the context of R&D. Thus, for example, the survival and growth of small firms depends, inter alia, on access to capital markets, the distance from product markets, and efficient risk management, which, in most cases, necessitate government intervention.
6. Lastly, we found it beneficial to include, as an appendix to this document, a set of recommendations and discussion points with regard to data collected in the framework of the manufacturing industry surveys and the R&D in the business sector surveys. By doing so, we hope to provide policy makers with clear, focused answers to some of the questions, brought to our attention whilst preparing this research, which were left unanswered due to insufficient data.

1. Summary and Conclusions

The structure of the report is as follows: the second chapter presents the main research question of this work and the chosen methodology to address it. The third chapter describes the databases used within the framework of this research and their sources. Subsequently, we present comprehensive, descriptive statistics regarding firms in the manufacturing industry, computer services, software and R&D branches in Israel. The fourth chapter presents the results of the research. It presents econometric estimates enabling a methodical examination of the amounts of new R&D created in the economy as a result of R&D government support. These results are integrated into a combined model that enables the estimation of the total returns to the economy derived from government support to industrial R&D in the years 1996-2003.

2. Objectives and research methodology

In this chapter we present the question of this research and the methodology used to answer it optimally: As specified in the tender, the objective of the research is to estimate the impact of government support to industrial R&D on the Israeli economy. The conceptual framework for the analysis of this impact is presented below:

2.1. General

The term "Research and Development" is defined and widely accepted as a methodical process for the creation of scientific or novel technological[3]. The economic output of the R&D process lies in the application of this knowledge to improve products and/or existing production processes and/or to develop such processes from scratch. The transition from a phase of generating knowledge via research to an application within the framework of a firm contributes to productivity growth and provides the firm with competitive advantages in the marketplace. It is commonly thought, as shall be presented later, that R&D processes are characterized by a social return that is higher than the private return - a fact that according to economic theory justifies the subsidizing of R&D activity. Relying on this principle, the Israeli government has been supporting and encouraging firms to perform processes of knowledge accumulation as mentioned above (support of R&D).

The objective of the research presented here is to estimate quantitatively the returns expected in terms of GDP for each Shekel of industrial R&D government support –- at the level of the firm. The question of the research may be broken down into two

[3] Research and Development – a methodical, original activity aimed at creating scientific knowledge or new technological knowledge or alternatively to develop a novel application of existing scientific or technological knowledge. See the introduction chapter to the R&D in manufacturing survey, the Central Bureau of Statistics.

secondary questions. The first question refers to the extent of the impact that the level of executed R&D has over industrial performance in Israel, and the GDP of the manufacturing industry in particular. The second question refers to the impact that government R&D support has over the level of industrial R&D executed by firms.

The outline of the research can therefore be formulized by the following simple differential equation:

$$\text{(1)} \qquad \frac{dY}{ds}\Delta s = \frac{\partial Y}{\partial RD} \cdot \frac{\partial RD}{\partial s} \cdot \Delta s$$

Where Y is the GDP at the firm level, RD is the R&D stock of that same firm and s is the R&D government grant provided. Thus, the left-hand side of the equation shows the change in GDP as a result of an sΔ increment of government R&D support. This change is comprised of the expected change in GDP as a result of the increase in R&D (first right-hand side expression in the equation) multiplied by the expected change in R&D as a result of the change in the level of government support (second right-hand side expression in the equation). The research methodology presented below outlines the empirical path required to quantify each of the expressions mentioned.

The total effect of a successful R&D process is comprised both of a direct effect on the firm effectuating it and an indirect effect on other firms in the industry (spillovers). In order to quantify the first right hand expression above, one must quantify: (1) the impact of the R&D investment on the performance of the executing firm and (2) the impact of the R&D spillovers. That is to say, the R&D impact of that same firm on the performance of other firms in the industry. In section 2.2 below, we present two widely accepted models used to estimate production functions that include R&D components and R&D spillovers.

In order to quantify the second right-hand expression above, we must examine what would the R&D expenditures of each firm have been, if government support had not been granted. Clearly, no database enables to directly answer this question. There is no "parallel universe" from which we can learn what would have been the R&D investment considerations of a firm had it not received government support. In section 2.3 below, we shall present a combination of two estimating methods accepted in the contemporary economic literature that allow for the execution of the required comparison.

Lastly, it is possible to join the two derived estimates above into one combined model enabling a forecast of the GDP change in the industry branches that stems from government support to R&D in these branches over the years.

2.2 Estimating the returns to the economy from R&D activity

R&D activities performed by firms generate novel technological knowledge; generally, a firm does not succeed in retaining exclusively this knowledge. The term "technological spillovers" refers to the part of generated knowledge which spreads among firms, branches, sectors and states – with no remuneration or compensation to the entity which created that knowledge. Therefore, the returns to the economy from firms' R&D activities comprise both the private returns to the firm executing the R&D plus the returns to other firms as a result of technological spillovers.

The main and widely accepted argument for government intervention aimed to promote R&D is the existence of a market failure that leads to sub-optimal private investments in R&D from a social viewpoint (Arrow 1962).[4] This market failure occurs basically because

[4] Arrow, K. J., 1962, "Economic Welfare and the Allocation of Resources for Invention ", in **The Rate and Direction of Inventive Activity,** Princeton University Press: Princeton, pp. 609-625

the spillovers of new knowledge and its adoption by firms that do not bear the development costs cannot be fully prevented. This phenomenon is known as a positive externality. In such a situation, the total social benefit from knowledge is greater than the direct benefit expected to be gained by the developing firm by virtue of its investment in R&D. In other words, the entity that makes the investment decision (the firm) will be inclined to invest less than the amount that would have been decided on by all the beneficiaries of the fruit of that same investment (both the investing/developing firm and other firms).

In addition, R&D investments are characterized by a high level of uncertainty and therefore, in this context, one can also expect credit markets to provide less-than-needed credit due to inherent inefficiencies in risk allocation and asymmetric information between entrepreneurs/developers and investors (see Romer 1190, Griliches 1998)[5]. It is commonly held that the phenomenon of credit shortage has a higher impact on small firms whose access to capital markets is limited than on large, well-established firms.

Griliches 1979 defined two kinds of technological spillovers: Pure knowledge spillovers and rent spillovers. A knowledge spillover is defined as the spread of knowledge stemming from R&D activities among various firms in an uncontrolled, unguided manner that leads to or supports technological improvements. Such spillovers can take place in diverse ways such as: adoption of new technologies – leading to their learning and assimilation by the adopters in a process called reverse engineering, cooperation agreements, transition of employees between firms, etc. Rent spillovers refer to situations where the prices of technologically improved products drop relatively rapidly as a result of the improvements. In situations as such, technological spillovers are manifested in the transfer of value from the firm which improved the product to a firm which purchases the product as an input for production.

[5] Griliches , Z., 1998, R&D and Productivity, University of Chicago Press: Chicago.
Romer, P., 1990, Endogenous Technological Change", Journal of Political Economy, 98.

The spillovers phenomenon and its importance to the technological and economic progress of economies have been well known to and accepted by economists for several decades. Formulating government policy for the support of R&D – considered to be the main source of spillover - requires, therefore, knowledge about the scale and intensity of this phenomenon de facto. Nonetheless, there are serious constraints with regard to the identification and quantification of the connections and the scope of this phenomenon. We present bellow a methodological framework for estimating the extent of knowledge spillovers within and between the manufacturing industry branches in Israel. Our framework is based on current leading empirical methodology from the economic literature.[6]

2.2.1 Technological and market proximity between firms

The activities of firms take place simultaneously in two main spheres: The technological sphere where the production process is performed and the sphere of the target markets for the products ("the marketing sphere"). Accordingly, different firms can be more or less close to one another in each of the abovementioned fields. Thus, for example, in the 80's, Kodak and Polaroid competed over their target markets (roll films) yet the technologies at the basis of their products were quite different. The companies were close in terms of their target markets and distant in terms of their production processes. An additional example is software firms, which use the same kind of production technology - use of the same programming language – to sell different applications to different markets (a private market or an institutional market, etc.).

[6] See:

(1) Jaffe, 1986, Technological Opportunity Spillovers of R&D: Evidence from Firms' Patents, profits, and Market Value", American Economic Review, 76(5), pp. 984-1001.
(2) Bloom, Shankerman and Reenan, Identifying Technological Spillovers and Product Market Rivalry: Theory and Evidence from a Panel of U.S. Firms", mimeo July, 2004

The performance level of the firms will be affected by successful R&D activities of other firms according to their proximity in the two discussed spheres, and in opposite manners: A successful execution of R&D activities by firm A will have a positive impact on firms that are close to it in terms of production technologies, through knowledge spillovers, which will enable them to improve their production processes too. But the same successful execution of R&D activities by firm A will have a negative impact on firms that compete with it in the end-product markets (but are technologically distant) since they will suffer from relative inferiority (or will lose a technological advantage they possessed). The positive impact can be thought of as a complementary effect of R&D and the negative impact can be referred to as the rivalry effect of R&D.

The positive impact of R&D between firms grows as their production technologies are closer and the distance between their target markets is greater. A great proximity both in production technology and in target markets can generate a total R&D impact that is positive, insignificant, or even negative. This contrasts with the common notion regarding the positive connection between R&D and the performance of firms in the same industry - a fact that calls for reconsideration the desirable scope of government interference and its impact on the economy's branches. Naturally, it is likely that a successful R&D activity undertaken by a firm will probably have no impact on firms with distant production technologies and target markets.

Bloom, Shankerman and Van Reenen (2005) examined a sample of American firms between the years 1980-2001. They were the first to present a model combining the rivalry effect and the spillover effects of R&D. The research showed that both R&D effects are quantitatively significant, and that their overall impact on the economy was positive. That is to say, the positive impact of R&D on production technology was found to be greater than the negative R&D impact via the target markets of the products. It is important to note, early on, that we do not have any data enabling us to separate the two types of effects with regard to the Israeli manufacturing industry. Thus, we only estimate the total effect of R&D spillovers and their impact through the target markets.

2.2.2. Building potential spillover pools

The impact of R&D is estimated by building "potential spillover pools" for each firm in the sample at any given time. These pools reflect the total sources from which knowledge may spill over to any firm. For any given firm, spillover pools are built on the basis of the R&D expenditures/R&D stock of other firms weighed by the level of proximity between the specific firm and each of the other firms. Weighting by the level of technological proximity implements the notion that knowledge complementarities exist between firms that are close to each other on the sphere of production technology. Oppositely, weighting by the level of proximity in target markets implements the notion of knowledge rivalries which exists between rival firms.

A technologically-weighted spillover pool between close firms shall be defined for each firm i at a given time as the sum of the R&D expenditures/R&D stock of all the other firms weighting their technological proximity to firm i:

$$(2) \qquad TSP_i \equiv TechSpilloverPool_i = \sum_{j \neq i}^{n} TechClosseness_{i,j} R\&D_j$$

Where $R\&D_j$ are the R&D expenditures/R&D stock of any firm at a given time and n is the total number of firms. The spillover impact derived from this pool for each firm is expected to be positive.

2.2.3 Econometric methodology

We estimate the level of R&D spillovers using two models widely accepted in the economic research literature for estimating production functions. Their basic assumption is that one can write the production of a firm as an explicit function of its level of capital investments, materials purchases and workers. At the same time, the total productivity component of the firm can be expressed as a function of its own R&D investments (private returns on R&D) and the potential spillovers stock (technological complementarities vs. rivalries in target markets).

In the first model presented herein and developed by Prof. Zvi Griliches, an R&D capital stock is built for each company similarly to the physical capital stock.[7] The underlying assumption is that returns on R&D investments last over several years (like equipment and physical machinery). Therefore, in regard to R&D activity, the R&D capital stock is the influencing factor over a firm's financial results. This model is among the most widespread, accepted models for estimating production functions with R&D investments. Please refer to appendix 3 for a detailed description of the manner in which the variables of capital and R&D stock are built in this context. Nonetheless, many researchers have criticized the Griliches model due to the specific structure it imposes on the evolution of firms' productivity over time (represented by the development of the R&D capital stock). In particular, we must assume a depreciation rate for R&D investments in order to build the R&D capital stock, and we must assume that the capital stock at any given time is a linear function of past R&D expenses/investments. In this respect, other models were developed for estimating production functions which do not necessitate the assumptions above. The second model estimated within the framework of this research was developed by Blundell and Bond (1998). In this model, productivity and its evolution over time are estimated from using available data (see appendix 6)[8].

[7] Griliches, Z., 1979, Issues in Assessing the Contribution of Research and Development to Productivity Growth", Bell Journal of Economics, 10, pp. 92-116.

[8] Blundell, R. and Bond, S., 2000, "GMM Estimation with Persistent Panel Data: An Application to Production Functions", *Econometric Reviews,* 19(3), 321-340.

The estimated equations for each firm at any given time may be written in the following general form:

$$(3) \qquad Y_i = (\underbrace{R\,\&\,D_i}_{Own\,\mathrm{R\&D}}, \underbrace{TSP_i}_{Others'\,\mathrm{R\&D}}, K_i, L_i, Controls, TechControls)$$

Where Y_i is production or added value (GDP), $R\&D_i$ are R&D expenditures (Blundell and Bond model) or the R&D capital stock (Griliches model). The variable TSP_i is the relevant spillover pool for each firm at a given time. K_i is the physical capital stock of a firm and L_i stands for work inputs. The control variables are used to eliminate fixed time effects from the explained variable. Typical control variables are: annual dummy variables, firms' industry codes, etc.

Control variables of special importance in the context of estimating technological spillovers are the technology groups to which firms belong – TechControls in the equation above. These variables are set to capture the impact of "technological opportunities" which can be used by firms that belong to similar technology groups. These impacts are not spillover impacts yet may be interpreted as such whenever they are not explicitly controlled for.

2.3 Estimating the impact of government support on the level of executed R&D (additionality/crowding out)

The objective of government intervention in the area of R&D is to bring about the execution of new R&D which would not have been executed otherwise. This, with the aim that knowledge is "produced" at an optimal level from a social viewpoint. The government interest is to increase R&D expenditures in firms to a level that is higher than that would be effectuated based solely on private considerations of profit and loss.

This is achieved by providing firms with incentives so that the private level of return they see, including the government subsidy, is equal to the social return and the firms choose their investments accordingly.

The main question asked in this context is that of the crowding out/additionality associated with the ratio between public funds and a firm's private resources. Let us consider a situation in which a firm is granted government financing for a research project which it would have taken up even without government support. Such a situation is referred to in the literature as crowding out – a situation in which government support "crowds out" private funds that would have been used to finance the project had it not been for the government support. Naturally, in a crowding out situation, public funds do not create new R&D but simply replace private financing. From the economy's point of view this situation is undesirable. On the other hand, it is possible that government funds serve as an incentive for additional investing beyond the level that would have prevailed under private market terms only. This situation is named additionality and refers to a situation in which public funds stimulate firms to invest in R&D up to a level that is higher than that which they would have invested in, based on their private considerations alone.

The estimation of R&D expenditures spent by a subsidized firm on R&D had it not been for government subsidies is the foundation stone on which the estimation of the impact of government support to R&D is based. Naturally, we do not directly observe these expenditures, and here lies the main difficulty of analysis. Furthermore, directly comparing the R&D expenditures of firms which were granted financing to those of firms which were not granted financing would be conceptually flawed in this context. This is due to the selection process which characterizes government support. The sample of firms that were granted government financing for their R&D activities **is not a random sample** of the population of firms. Any comparative process must bear this in mind. Otherwise, the results attained will be biased. Nowadays, fortunately, the economic literature offers methods that enable the estimation of the impact of government support schemes through a structured comparison of subsidized firms to "counter factual" unsubsidized firms whilst controlling for their observed characteristics.

In order to estimate the impact of government support to industrial R&D, the non-parametric "propensity scores" method was used.[9] The propensity scores method is a statistical tool through which we can define the similarity between firms - subsidized and unsubsidized – in terms of their inclination or propensity to receive an R&D grant. By doing so, we can create a sort of control group against which we can compare the impact of a subsidy on the subsidized firms (effect of treatment on the treated). The objective of the analysis is to create a situation in which we are able to identify firms whose characteristics are such that they have a similar or equal probability of receiving government support ex-ante. Among them, we assume that the granting of a subsidy is random and is not coordinated with the firms' characteristics as specified above. Therefore, we are able to compare firms that were granted government R&D support in the general population with those of the control group that were not granted R&D government support.

Estimating the propensity scores is firstly achieved by estimating the probability to receive a grant among all the firms. This is done using probit type regressions, which enable the estimation of the probability of receiving government financing according to the known characteristics of a sample of firms - including those which eventually did not receive financing (amount of employees, import volume, sales, etc.):

$$(4) \qquad \Pr obability \text{ of Subsidy} = F(x_i\hat{\delta})$$

[9] See:
Czarnitzki, D., and Fier A., 2002, Do Innovation Subsidies Crowd out Private Investment? Evidence from the German Service Sector, ZEW Discussion Paper No. 02-04, Manheim.

Where δ is a vector of relevant predefined parameters, whose value is unknown and X is a vector of observable variables among the firms of the sample. Following the estimation of the regression, one can calculate for each firm the specific probability of receiving a subsidy. These values are called propensity scores. Where $\hat{\delta}$ is the estimate for the vector of parameters in the population and x_i are the variable values of a specific firm. Following the calculation of the propensity scores for each firm, one can create pairs of firms where: (a) one of them received financing and the other did not; (b) both have an almost identical propensity (score) of receive financing ex-ante; (c) both are similar in their size and the technological field characteristics. Thus, in fact we create a control group which comprises a "parallel universe" in which we observe unsubsidized firms that are similar as much as possible to the firms that were granted government support - **on a firm on firm basis**.

The next phase involves a comparison between the R&D expenditures of subsidized firms to those of unsubsidized firms in the control group. We conduct the comparison by estimating a linear regression with the following general structure:

$$Y_{i,t} - Y_{j(i),t} = \alpha_i \cdot \underbrace{X_{i,t}}_{\substack{\text{observables } i \\ \text{besides} \\ \text{subsidies}}} + \alpha_j \cdot \underbrace{X_{j(i),t}}_{\substack{\text{observables } j \\ \text{besides} \\ \text{subsidies}}} + \underbrace{\beta}_{\substack{\text{subsidy} \\ \text{effect}}} \cdot s_{i,t} + \underbrace{\lambda_t}_{\substack{\text{time} \\ \text{specific} \\ \text{effect}}} + \underbrace{\varepsilon_{i,t}}_{\substack{\text{random} \\ \text{effect}}} \qquad (5)$$

Where:

i = firm that received R&D support (subsidy)

j = a firm that belongs to the control group, is a match of firm i but that did not receive R&D support.

$Y_{i,t}$ = R&D expenditures of a firm i that received a subsidy (net, following deduction of government support).

$Y_{j(i),t}$ = R&D expenditures of firm j that belongs to the control group, is a match of firm i but that did not receive a subsidy.

$X_{i,t}$ = a vector of variables impacting firms' R&D expenditures.

α = a vector of the coefficients for all observed variables impacting the explained variable besides the subsidy variable.

$s_{i,t}$ = the level of subsidy received.

β = the impact of the government subsidy on R&D expenditures – the main coefficient for the purpose of analysis.

λ_t = impacts derived from unobserved variables mutual to all firms (boom or bust in the economy, rise of general input prices such as petroleum, etc.)

$\varepsilon_{i,t}$ = random shocks.

Under the functional assumptions in the specification above, one can demonstrate that the coefficient β is equal to the impact of a subsidy on the subsidized firms, which we could have estimated, if we had data regarding what their R&D expenditures would have been without the subsidy – i.e. counter factual data, see Lach (2002) for a more detailed discussion of the estimation method[10]. This coefficient, our focus of interest, measures to what extent are the R&D expenditures of subsidized firms bigger or smaller than those in other non-subsidized firms.

The additionality/crowding out estimates and the estimates of the returns to R&D in production terms can be combined into a single model that enables the estimation of the total returns to government R&D support. If we assume a certain level of government R&D support, the estimates obtained regarding the additionality/crowding out of R&D support enable us to estimate the volume of additional investment in R&D - beyond the investment that would have been executed without the subsidy - that is expected to be undertaken in the economy as a result of this R&D subsidy. Then, this new R&D

[10] Lach, S., 2002, **"**Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel**",** *The Journal of Industrial Economics*, December, Vol. L, No. 4, pp. 369-390.

investment can be translated into production (added value or GDP) figures using the estimates of the returns to R&D that may be obtained as described above.

3. Description of the data

This chapter describes the data used in the framework of the research, its sources and the initial processing undertaken in order to present descriptive statistics with regard to manufacturing firms and firms in the computer services, software and R&D branches in Israel. The importance of the data presented here lies in the fact that they show, for the first time in Israel, additional characteristics of the distribution of economic variables in these branches (variance, median and percentiles), beyond the average figures published in the official publications of the Central Bureau of Statistics. Thus, we present a broader picture of the economic phenomenon in focus - R&D, enabling thus policy makers to learn about the high level of firm heterogeneity characteristic of the researched branches.

Upon deciding to conduct this research and its methodology, it was agreed upon with the Central Bureau of Statistics that a database will be specially prepared for the purpose of this analysis. The database was prepared and processed by employees of the Central Bureau of Statistics based on the surveys of the manufacturing industry and the surveys of R&D in manufacturing and in the computer services, software and R&D branches. The tables, regressions, and results appearing in this work are the basis for the analysis and have been prepared by the Central Bureau of Statistics guided by Dr. Shlomi Parizat and directed by Prof. Saul Lach.

3.1. Databases

A concise review of the structure of the surveys and the variables is presented below. A full specification of the list of variables in each survey is presented in appendix 1.

The manufacturing industry survey comprises detailed firm-level data. The actual unit from which data are collected in the framework of the surveys described here is the establishment, which may alternatively be part of a bigger firm or be a firm by itself. The terms firm and establishment are thus used alternatively throughout this report referring either to firms or establishments. The data include reports of sales volume, R&D expenditures (in a partial manner), input purchases, capital investments, production (output and added value or GDP) employees, labor hours, exports and additional important economic variables. The survey is conducted once a year among a representative sample of manufacturing firms[11]. One can therefore "append" the data for each firm over the years and create a firm-level panel data set[12]. The data from the manufacturing industry surveys are from years 1995 to 2003. The survey of R&D in the manufacturing industry is conducted according to a similar methodology to that of the manufacturing industry surveys, but examines only manufacturing firms that undertook research and development activities during the surveyed year. The data base contains detailed economic variables regarding the firms' of research and development – number of employees engaged in R&D activities and their earnings, and education; firms' R&D expenditures, R&D financing from sources outside the firms (including from the Office of Chief Scientist, other governmental entities, international funds, and so forth), acquisition of patents or their development as well as other economic variables related to the firm's activities (total revenues, exports, etc). The manufacturing industry R&D surveys contain firm-level data from a representative sample of manufacturing firms that were engaged in R&D between years 1996 to 2004. An overlapping exists between the establishments participating in the surveys of manufacturing and the surveys of R&D in manufacturing (in particular regarding the large ones). Therefore, the data from both surveys may be merged in order to create a unified file of analysis – as was done here (see appendix 5).

The R&D survey of the computer services, software and R&D branches is conducted identically to the manufacturing industry R&D survey regarding firms from 2-digit code

[11] Firms that belong to the 2-digit industry branches 13 to 39 according to the Israeli Central Bureau of Statistics' "Unified classification of economy branches, 1993".

[12] Panel data is the term given to a set of data which enables researchers to monitor the development of economic activity of a single firm in the course of time.

branches 72 - computer services and software, and 73 – research and development firms[13]. The following tables present data regarding the quantity of observations in each survey.

Table 1: Size of samples – manufacturing and R&D in manufacturing surveys

Year	Number of establishments		
	Manufacturing surveys	R&D in manufacturing surveys	Both surveys merged
1995	2,081		
1996	2,028	180	133
1997	1,993	196	118
1998	1,944	211	125
1999	1,904	218	126
2000	1,857	212	122
2001	1,815	195	111
2002	1,758	224	116
2003	1,722	217	115
2004		202	
Total	**17,102**	**1,855**	**966**

The manufacturing industry surveys include an average of approximately 1,800 observations (establishments) a year spanning 22 sub-branches (at an aggregation level of 2 digits). Therefore, the amount of observations in the manufacturing industry surveys enables the analysis of the data within 2-digit industry branches. The R&D surveys of the manufacturing industry branches include only about 200 firms a year (from the same 22, 2-digit industry branches) and the merged set of data (establishments participating in the same year in both the manufacturing industry survey and the manufacturing R&D survey) includes an average amount of observations of approximately 120 firms per year. A similar average amount of yearly observations exist in the R&D survey of the computer services, software and R&D branches - table bellow. Further on, we shall

[13] The computer services and software branch (72) includes activities such as data processing, maintenance of information banks, software or programming services, consultation regarding computerization, etc.. The research and development branch (73) includes firms engaged in basic research in natural sciences, life sciences, etc. (as distinguished from research and development activities performed in other economic branches). Start-up firms are included in this branch. Data regarding firms that took part in the OCS Technological Incubator program at the time of conducting the survey were excluded from the sample.

specify how we deal with the relatively low level of observations and the constraints this imposes on the resolution (aggregation) level of the analysis.

Table 2: Size of samples – R&D survey in the computer services, software and R&D branches

Year	Number of firms			Distribution	
	Computer services & software	R&D firms	Total	Computer services & software	R&D firms
1997	57	61	118	48%	52%
1998	65	71	136	48%	52%
1999	79	86	165	48%	52%
2000	77	89	166	46%	54%
2001	81	82	163	50%	50%
2002	114	109	223	51%	49%
2003	115	107	222	52%	48%
2004	95	130	225	42%	58%
2005	87	108	195	45%	55%
Total	**770**	**843**	**1,613**	**48%**	**52%**

The following table presents the quantity of observations in the manufacturing samples by the level of firms' technological intensity[14]. Grouping the observations by technological intensity allows for a greater quantity of observations within groups which are relatively more technologically homogenous. Please note below that the low-technology category in the manufacturing R&D surveys is represented by an average of only 8 observations per year, a fact that limits significantly the ability to draw statistically significant conclusions.

[14] See the 2-digit branch classification according to technological intensity, within the manufacturing branches, in appendix 12.

Table 3: Observations by technological intensity - manufacturing

Quantity of observation per year by survey				
Technology Intensity	**Survey**	**All years**	**Yearly average**	**Distribution (all years)**
High	**R&D in Manufacturing**	1,119	124	60%
Medium high	**R&D in Manufacturing**	392	44	21%
Medium low	**R&D in Manufacturing**	275	31	15%
Low	**R&D in Manufacturing**	69	8	4%
High	**Manufacturing**	1,922	214	11%
Medium high	**Manufacturing**	2,542	282	15%
Medium low	**Manufacturing**	5,639	627	33%
Low	**Manufacturing**	6,999	778	41%

Additional information important to our analysis is the survival rate of establishments in the various surveys - e.g. what is the probability that an establishment surveyed in 1995 will appear also in the sample of year 1996? Each year, establishments may shut down, merge, or exit the sampling framework. The greater the number of years an establishment appears in the sample, the higher the quality of results which can be based on the data. The following tables present the distribution of the number of years an establishment takes part in the samples from the three relevant surveys.

Table 4: Distribution of the number of years an establishment takes part in the samples – R&D in manufacturing surveys and manufacturing surveys

Number of years in samples	**Number of establishments**		**Distribution**	
	Manufacturing surveys	**R&D in manufacturing surveys**	**Manufacturing surveys**	**R&D in manufacturing surveys**
1	354	174	12%	36%
2	265	55	9%	11%
3	210	50	7%	10%
4	202	27	7%	6%
5	165	28	6%	6%
6	137	28	5%	6%
7	152	19	5%	4%
8	108	55	4%	11%
9	1,245	48	44%	10%
Total	**2,838**	**484**	**100.0%**	**100.0%**

Please note that an important difference exists in the way the data is presented in the above table and in table 1. Whilst the table above presents the quantity of *establishments* in the samples (regardless of the participation year or even if the establishments participated in the sample for several years), table 1 presents the quantity of *observations* in each year (an establishment that appears in different years is counted as a separate observation each year)[15]. This distinction is important since naturally, within the data, there should be a clear connection between the economic performance of the same establishments in two (or more) proximate years; any analysis of the data must take this fact into account.

The table above shows that in the manufacturing industry surveys 44% of the establishments appear in all years of the sample. The median of the number of years an establishment is present in the sample is 7. The R&D in manufacturing surveys show a different picture: 36% of the establishments are present for only one year and the median is only 3 years. The availability of long-horizon, continuous time series data is therefore low in the R&D in manufacturing surveys[16]. The following table presents a similar picture for the R&D surveys in the computer services, software and R&D branches.

[15] This can be demonstrated by a simple example: assuming that 10 establishments participated in the sample in the first year and that the same plants participated in the second year, the quantity of observations shall be 20 (10 a year) whilst the quantity of establishments remains only 10.

[16] This is due to, among other things, the fact that establishments that were granted the support of the Office of Chief Scientist have a higher probability of participating in the sample of the R&D in manufacturing surveys in the same year in which they received the support (even if they would not have participated otherwise).

Table 5: Distribution of the number of years an establishment takes part in the sample – R&D survey in the computer services, software and R&D branches

Number of years in samples	Number of firms			Distribution		
	Computer services & software	R&D firms	Total	Computer services & software	R&D firms	Total
1	80	69	149	34%	29%	31%
2	34	47	81	14%	20%	17%
3	43	21	64	18%	9%	14%
4	25	29	53	10%	12%	11%
5	15	16	31	6%	7%	7%
6	10	10	20	4%	4%	4%
7	7	14	21	3%	6%	4%
8	9	10	19	4%	4%	4%
9	16	20	36	7%	9%	8%
Total	**238**	**236**	**474**	100%	100%	100%

3.2. Descriptive statistics

This chapter presents descriptive statistics of the main economic variables of firms in the manufacturing, computer services and R&D branches. An emphasis is placed in showing the very high degree of firm heterogeneity (differences among firms) and the high industry concentration levels observed in terms of production, employment and research and development activities. It is our position that it is important that policy makers, who so far based their decisions on the existing set of formal publications comprised of (in most cases) averages alone, get exposed to the great variety and heterogeneity among firms in the different branches. Thus, enabling public policy to address the needs of different firms in a diversified way rather than be shaped on the basis of an "average" firm.

3.2.1. Firm heterogeneity

It is highly important to understand the level of firm heterogeneity in terms of production levels, size, and R&D expenditures. If we make do with aggregated statistics (averages, sums) as the only source of information, changes in economic variables over time may conceal problems and hardships faced by the industry. For instance, the factual information that the total level of R&D expenditures has doubled over the last decade does not include the distribution of growth between firms of different technological levels and impedes us from knowing that most of the growth stems from high-technology branches, and that low-technology branches hardly changed their R&D expenditures. Furthermore, this data alone does not allow asserting if the majority of growth stems from small/large firms, in the north/south/center region of the country, etc. Therefore, proper planning of public policy requires an examination of the characteristics of the distribution of R&D expenditures in order to identify failures that can and should be overcome by adequate policy tools.

The following table presents the average, median and standard deviation of R&D expenditures (as a rate of revenues) in the manufacturing industry, by firms' technological intensity, size, and revenue per employee. The table clearly and poignantly demonstrates the level of firm heterogeneity within the manufacturing industry:

Table 6: Main characteristics of the R&D expenditures distribution - manufacturing industry, 1996-2004 on average

R&D expenditures as a percentage of total revenues Firms that executed R&D					
	Average	Standard deviation	Median	Standard deviation divided by average	Median divided by average
All manufacturing	**8%**	**50%**	**2%**	**6.5**	**0.3**
Technology intensity	**Average**	**Standard deviation**	**Median**	**Standard deviation divided by average**	**Median divided by average**
High	**13%**	58%	9%	4.5	0.7
Medium high	**3%**	7%	1%	2.1	0.5
Medium low	**2%**	66%	1%	38.5	0.6
Low	**1%**	13%	0%	24.6	0.7

R&D expenditures as a percentage of total revenues Firms that executed R&D					
Number of workers (percentile)	**Average**	**Standard deviation**	**Median**	**Standard deviation divided by average**	**Median divided by average**
Up to 47 (0-25%)	**16%**	165%	6%	10.0	0.3
47 – 108 (26-50%)	**10%**	45%	3%	4.3	0.3
108– 296 (51-75%)	**10%**	46%	4%	4.6	0.4
296 – 779 (76-90%)	**5%**	22%	1%	4.6	0.2
Above 779 (above 90%)	**8%**	52%	4%	6.3	0.4

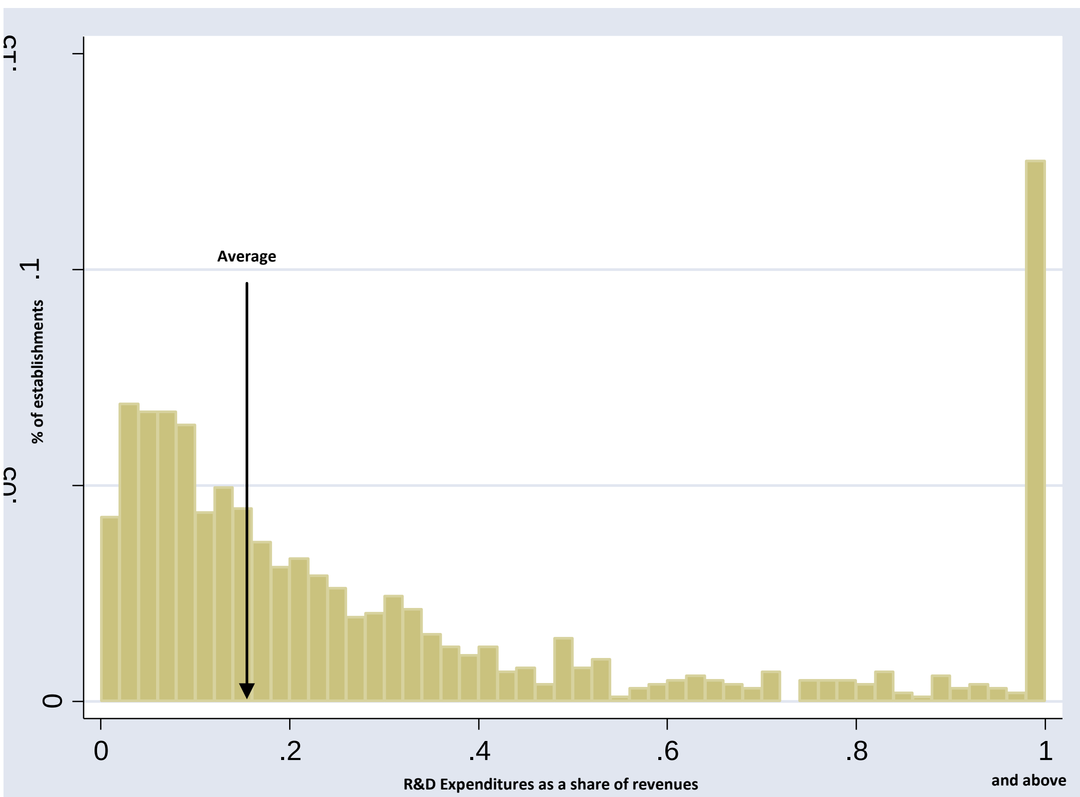
Range of revenues millions of 2003 NIS (percentiles)	Average	Standard deviation	Median	Standard deviation divided by average	Median divided by average
Up to 15 (0-25%)	**54%**	472%	16%	8.8	0.3
15 - 57 (26-50%)	**12%**	26%	3%	2.2	0.3
239 –57 (51-75%)	**9%**	13%	4%	1.5	0.4
880 – 239 (76-90%)	**11%**	12%	7%	1.1	0.6
Above 800 (above 90%)	**5%**	7%	2%	1.4	0.4

Range of revenue per employee thousands of 2003 NIS (percentiles)	Average	Standard deviation	Median	Standard deviation divided by average	Median divided by average
Up to 336 (0-25%)	**11%**	18%	3%	1.6	0.3
336 –592 (26-50%)	**8%**	12%	3%	1.5	0.4
592 –935 (51-75%)	**9%**	11%	4%	1.3	0.5
1466–935 (76-90%)	**9%**	9%	6%	1.0	0.6
Above 1466 (above 90%)	**4%**	8%	1%	1.8	0.2

The table above shows that average R&D expenditures in years 1994-2006 were 8%. The standard deviation (that measures the spread around the average) was approximately 50%! The distribution median was only 2% - about a quarter of the average. Clearly, it is very difficult to understand the real economic characteristics of relevance based on the average alone - in particular when dealing with R&D activities.

Furthermore, the distribution by firms' technological intensity does not provide a clearer picture. The average share of R&D expenditures in high-technology firms during the relevant years was 13%, yet with a high standard deviation that is indicative of high firm heterogeneity. Nonetheless, the averages within the groups by technology intensity are closer to the groups' respective medians. In order to provide an interpretation regarding how informative the average and median really are in this context one must closely examine the entire distribution of R&D expenditures. The following figure displays the distribution of R&D expenditures as a percentage of revenues in high-technology establishments through years 1996-2004:

Figure 1:
Distribution of R&D expenditures as a percentage of revenues in high-technology establishments, 1996-2004



We can see that many establishments spend all their revenues and more on R&D. These are not productive firms in the conventional meaning of the term but are relatively small firms in pre-sales, product development phases that "burn" money previously invested on them (mainly by venture capital investors or the government). Close examination of the data indicated that indeed this is the case. The presence of this type of establishments must be taken into account in the overall examination of R&D production since it will tend to bias downwards the measured returns on R&D investments.

The third panel of the table above displays the distributional characteristics of establishments' R&D expenditures, by their size as defined by the number of employees. The categories are shown according to their distribution quartiles (percentiles 25, 50 and 75) and with a separate representation of the distribution tail (the upper decile). One can see that relatively small establishments spend a higher share of their income on R&D activities (on average). This is mainly due to their low income and less because of absolute high R&D expenditures. Nonetheless, it is important to see that high standard deviations characterize all size groups. Thus, firm heterogeneity among establishments remains high even within size-homogeneous groups.

The fourth panel of the table above displays the distributional characteristics of establishments' R&D expenditures by size as defined by revenues. The categories are shown according to their distribution quartiles (percentiles 25, 50 and 75) and with a separate representation of the distribution tail (the upper decile). It can be seen that as sales increase, the standard deviations of the average share of R&D expenditures decline; this indicates that grouping the firms by their volume of sales allows for more informative central indexes (average, median) in comparison to other modes of classification (as above: technology intensity and size by number of workers). A similar picture emerges from the fifth panel on the table above, which displays the data by the level of revenue per employee.

The phenomenon analyzed above is present as well (even more intensely) in the computer services, software and R&D branches. The following table displays the central distributional characteristics of establishments' R&D expenditures as a percentage of income in 2005:

Table 7:
Main characteristics of the R&D expenditures distribution - computer services, software and R&D branches, 2005

R&D expenditures as a percentage of total revenues Firms that executed R&D					
	Average	Standard deviation	Median	Standard deviation divided by average	Median divided by average
Computer services, software and R&D firms	**39%**	**378%**	**26%**	**9.6**	**0.7**

2-digit industry branch	Average	Standard deviation	Median	Standard deviation divided by average	Median divided by average
Computer services and software	**36%**	259%	26%	7.3	0.7
R&D firms	**44%**	502%	23%	11.4	0.5

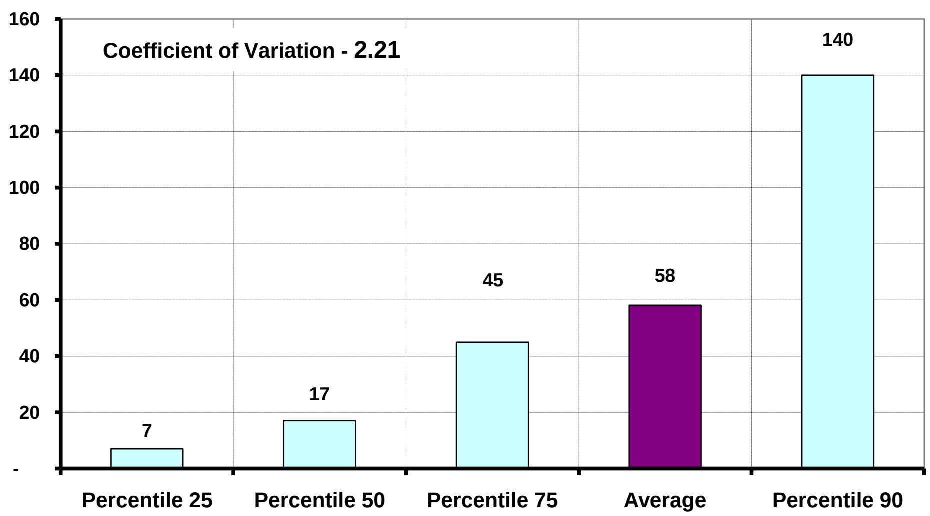
By number of workers (percentiles)	Average	Standard deviation	Median	Standard deviation divided by average	Median divided by average
Up to 18 (0-25%)	**49%**	621%	14%	12.6	0.3
18 - 38 (26-50%)	**42%**	557%	27%	13.3	0.7
38 – 96 (51-75%)	**47%**	562%	30%	12.0	0.6
96 - 280 (76-90%)	**32%**	38%	27%	1.2	0.8
280 - 2615 (above 90%)	**37%**	231%	21%	6.3	0.6

R&D expenditures as a percentage of total revenues Firms that executed R&D					
Range of revenues millions of 2005 NIS (percentiles)	**Average**	**Standard deviation**	**Median**	**Standard deviation divided by average**	**Median divided by average**
Up to 2 (0-25%)	**731%**	4839%	272%	6.6	0.4
2-14 (26-50%	**39%**	82%	16%	2.1	0.4
14-63 (51-75%)	**41%**	28%	32%	0.7	0.8
63-225 (76-90%)	**31%**	25%	27%	0.8	0.8
225-3325 (above 90%)	**34%**	**32%**	18%	0.9	0.5

Range of revenue per employee thousands of 2005 NIS (percentiles)	Average	Standard deviation	Median	Standard deviation divided by average	Median divided by average
Up to 82 (0-25%)	**1219%**	6213%	543%	5.1	0.4
82-335 (26-50%)	**45%**	70%	21%	1.6	0.5
335-653 (51-75%)	**62%**	35%	78%	0.6	1.3
653-1235 (76-90%)	**33%**	21%	27%	0.6	0.8
1235-6482 (above 90%)	**16%**	12%	9%	0.8	0.6

Finally, the following figure displays the main characteristics of the R&D employees distribution among manufacturing establishments in Israel. One can see that the average number of employees is significantly above the percentile 75 of the distribution. Therefore, the average is not informative enough regarding the amount of employees in most of the manufacturing firms engaged in industrial R&D in Israel. In this excellent example the average is irrelevant to describe the status of over three quarters of the firms. It is therefore important to provide policy makers with more detailed information regarding the distribution of the relevant economic variables (such as quartiles and the upper decile).

Figure 2: Select distributional characteristics of R&D employees in manufacturing establishments[17]



3.2.2. Industry concentration of production and R&D

Beyond the important result about the existence of high firm heterogeneity in R&D expenditures, it is important to conduct an orderly examination of the degree of industry concentration in the relevant branches. In particular, we present below the share of the large firms in the total branch GDP/revenues and show that approximately two thirds of total manufacturing GDP stems from approximately only 10% of manufacturing firms.

[17] The coefficient of variation is an index calculated by dividing the distribution's standard deviation by the average. In this context, one can see that the standard deviation of the distribution is 2.21 higher than the average.

Table 8: Industry concentration of GDP – manufacturing industry surveys, 1996-2003[18]

Establishments GDP distribution by size groups manufacturing industry surveys		
Percentile	**Revenue range in millions of 2003 NIS**	**GDP %**
0 - 25	Up to 4	0.9%
25 -50	4-16	3.4%
50 - 75	16-55	10.8%
75 - 90	55-158	17.5%
90 -100	Above 158	67.4%
Total		100.0%

Table 9: Industry concentration of revenues – R&D in the manufacturing industry surveys, 1996-2004[19]

Establishments revenue distribution by size groups R&D in manufacturing surveys		
Percentile	**Revenue range in millions of 2003 NIS**	**Revenues %**
0 - 25	Up to 15	0.4%
25 -50	15-57	2.5%
50 - 75	57-239	9.6%
75 - 90	239-880	21.8%
90 -100	Above 880	65.6%
Total		100.0%

The distributions of revenues and GDP in both surveys (manufacturing industry surveys and R&D in manufacturing industry surveys) show that manufacturing production is highly concentrated. According to the data above, 75% of establishments contribute about 10% of total GDP of the manufacturing branches. Furthermore, we can see a good correlation between the data of the R&D in manufacturing surveys (revenues data)

[18] The data refer to all firms in the industry and not only to those that conducted R&D.
[19] The data refer only to firms that conducted R&D.

and the data of the manufacturing industry surveys (GDP data). A similarly extreme picture emerges from the surveys of R&D in the computer services, software and R&D branches:

Table 10: Industry concentration of revenues -
R&D surveys in the computer services, software and R&D branches, 2005

Establishments revenue distribution by size groups Computer services, software and R&D branches		
Percentile	**Revenue range in millions of 2003 NIS**	**Revenues %**
0 - 25	Up to 2	0.1%
25 -50	2-14	1.4%
50 - 75	14-63	7.6%
75 - 90	63-225	17.6%
90 -100	Above 225	73.3%
Total		100.0%

There is no significant change in the GDP and revenues distributions if data are analyzed by 2-digit industry branches or groups of technological intensity. High concentration is therefore a basic phenomenon in the discussed branches of the economy, and should be addressed and dealt with by researchers and policy makers.

Also, R&D activity in the manufacturing industry branches in Israel presented a high level of concentration. The following two figures display the distribution of R&D expenditures in years 1996-2003 in comparison to the distribution of GDP in the same period - by groups of technological intensity.

Figure 3: GDP distribution by technological intensity - manufacturing industry surveys, 1996-2003

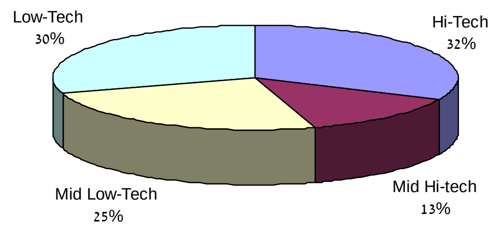
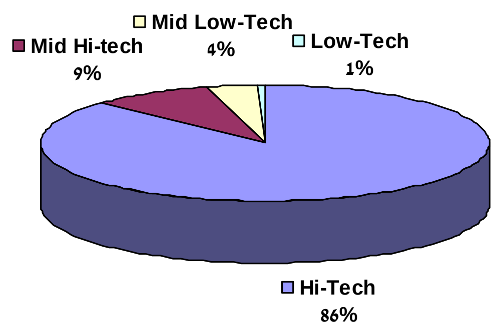


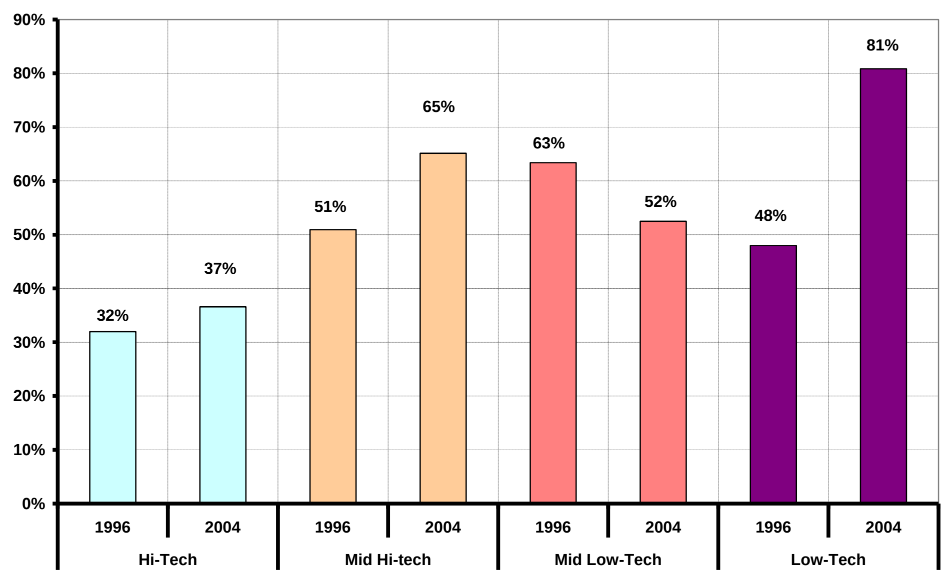
Figure 4: R&D expenditures distribution by technological intensity - manufacturing industry surveys, 1996-2003



The GDP of low-tech industry branches constitutes approximately 30% of total GDP in the manufacturing industry branches; nonetheless, the weight of R&D expenditures in these branches equals only 1% of total R&D expenditures in the manufacturing industry. The asymmetry in the amount of R&D investments in comparison to GDP is also evident in the high-tech branches constituting 32% of GDP and 86% of total R&D expenditures. This picture can partially be explained by the classification by technological intensity, which is based on the level of R&D expenditures in the various industry branches. Yet, it is important to emphasize that the level of R&D activities of low-tech manufacturing branches in Israel is low also when compared internationally[20].

The high levels of industry concentration appear not only between the different levels of technological intensity but are also pervasive within each of the categories. The following figures display the CR4 index, which is a widely accepted index for measuring the level of concentration in industries and markets. The index is displayed for technological intensity groups within the manufacturing industry for years 1996 and 2003. The index shows the share of the four largest firms (in terms of their volume of R&D expenditures) in total R&D expenditures within each technological group. This is presented with the objective of examining the differences between technological intensity categories as well as the change over time in concentration within the groups:

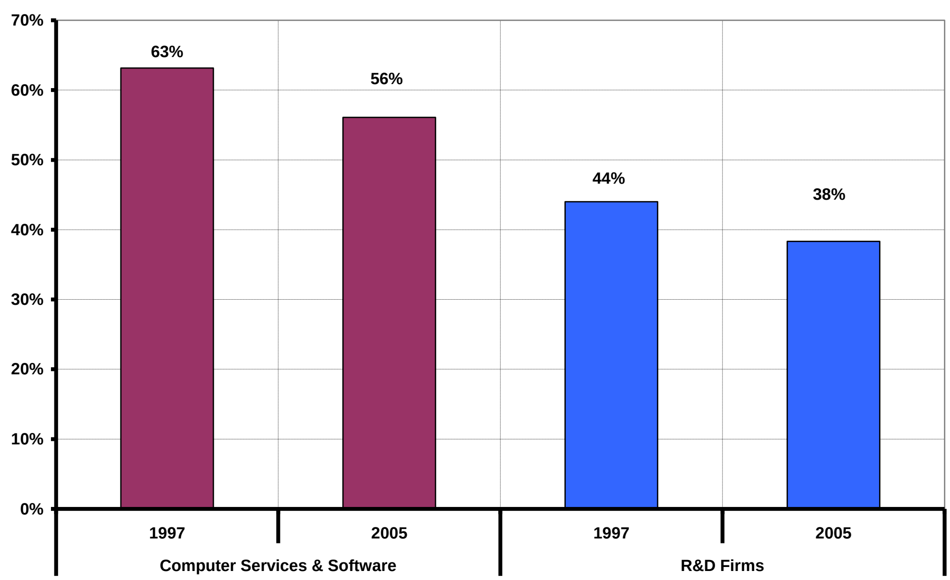
Figure 5:
CR4 index of industry concentration in R&D expenditures within technological intensity groups - surveys of R&D in the manufacturing industry, 1996 Vs. 2004



[20] See, inter alia, the report of the commission for the examination of means to empower the Israeli geo-economic periphery and low-tech industries, headed by Mr. Israel Makov, chapter 1.

The following figure displays the CR4 index for the computer services, software and R&D branches in years 1997 and 2005:

Figure 6: CR4 index of industry concentration in R&D expenditures - surveys of R&D in the computer services, software and R&D branches, 1997 Vs. 2005



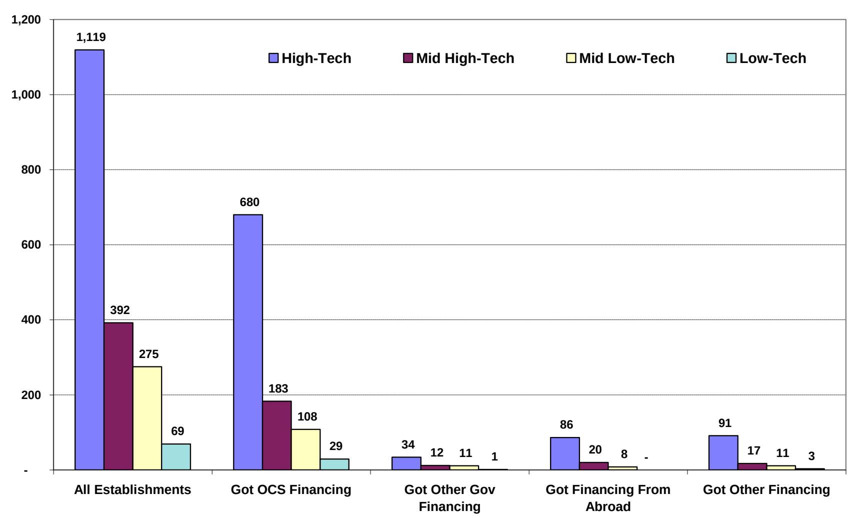
The two figures above show high, prolonged industry concentration of R&D activities in the examined branches. The lowest level of industry concentration is observed in the high-tech branches, where most of industrial R&D expenditures are found (86% - see above). Nonetheless, even in these branches, approximately one third of R&D expenditures is undertaken by the four largest firms. In other words, four high-tech firms alone are responsible for approximately 30% of total R&D expenditures in the entire Israeli manufacturing industry. It should be reminded that the small quantity of observations in the low-tech industry branches may influence the results displayed in the figure above. Nevertheless, it appears these branches are no exception in regard to the general levels of concentration observed in the data.

3.2.3. Financing sources for R&D activity

R&D expenditures in the manufacturing industry and in the computer services, software and R&D branches are financed partly by the executing firms and partly by government organizations and international funds. This chapter presents select data regarding the share in financing and the dynamics of government R&D support at the firm level. We would like to note that aggregate data on R&D financing appear in official publications of the Central Bureau of Statistics and therefore we saw no need to include them here[21].

The following figure displays the quantity of manufacturing establishments by groups of technological intensity and the type of financing received for R&D activity:

Figure 7: Number of observations by technological intensity and external R&D financing - R&D in manufacturing surveys, 1996-2004

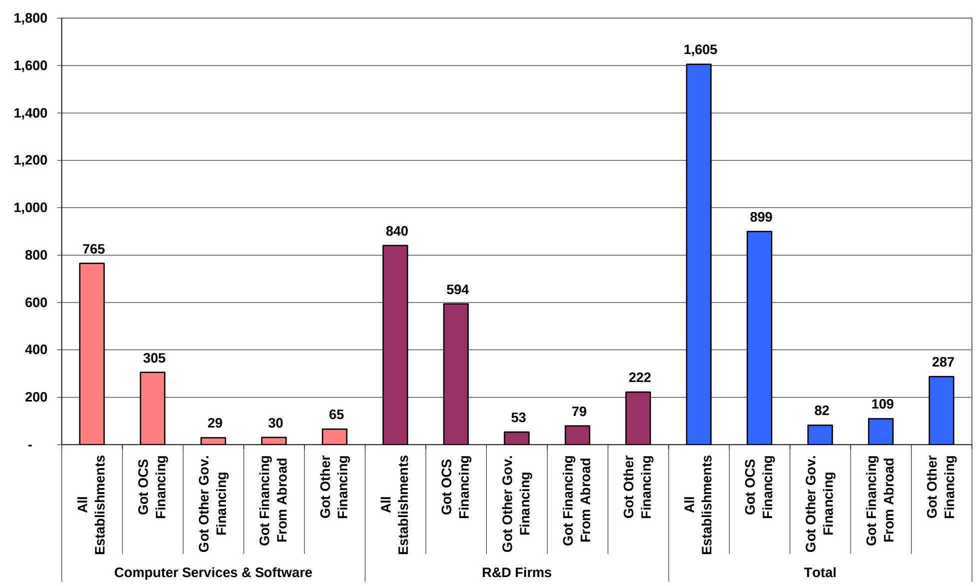


[21] See for example: 2007 Statistical Yearbook, chapter 26; national expenditures on civil R&D 1989-2006 (publication number 1321) and publications of the manufacturing industry surveys of various years. All published by the Central Bureau of Statistics.

The figure above shows that most of the establishments which received external financing in a given year – received it from the Office of the Chief Scientist in the Ministry of Industry, Trade and Labor. Scarcity of observations regarding other types of financing prevent the possibility of obtaining significant results from data analysis concerning their degree of impact over the economy.

The following figure presents similar data for the R&D surveys in the computer services, software and R&D branches. Here too, it is clear that the Office of the Chief Scientist supports most of the establishments which received support in a given year[22].

Figure 8: Number of observations by main branch and R&D financing from external sources - R&D surveys in the computer services, software and R&D branches, 1997-2005



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[22] We would like to note that "Other financing" includes activities which are not necessarily "external financing". In particular, it includes sums received for financing R&D from the parent company of the establishment and sums which were received from various investors (venture capital funds, private investors). Therefore, we believe that this type of financing cannot be addressed at face value and one, most certainly, cannot address all amounts specified in it as external financing of R&D activities.

3. Description of the Data

An analysis of the composition of R&D expenditures (materials, wages, equipment, etc.) revealed that there is no statistically significant difference between the structure of R&D expenditures of firms that received support from the Office of the Chief Scientist and firms that did not. That is to say, there are no facts that indicate that the structure of R&D expenditures in firms that received support from the Office of the Chief Scientist is biased towards any specific cost component. Furthermore, it was found that in the years 1996-1999, the Office of the Chief Scientist supported firms that were larger than average in the manufacturing industry. From year 2001 onwards, the difference is not statistically significant.

In light of the key role played by the Office of the Chief Scientist in supporting industrial R&D, several questions arise regarding the support patterns observed in the data. Does the OCS support certain establishments continually through time or does the assortment of establishments which receive support change each year? Furthermore, regarding establishments that do receive support in consecutive years, how does the level of support change through time?

The following table displays select data about the dynamics of R&D support granted by the Office of the Chief Scientist to the manufacturing industry:

Table 11:
The dynamics of R&D support by the Office of the Chief Scientist to the manufacturing industry, 1996-2004

Year	No. of Establishments that received funding from the OCS in relevant year	OCS funding continuity: 2 years	OCS funding continuity: 3 years	Establishments with positive change %	Establishments with negative change %	Positive change in OCS funding level for (weighted) average establishment %	Negative change in OCS funding level for (weighted) average establishment %
1996	103						
1997	132	46%		68%	32%	23%	-39%
1998	124	69%	39%	43%	57%	36%	-39%
1999	123	75%	53%	59%	41%	58%	-29%
2000	118	80%	60%	44%	49%	42%	-45%
2001	96	72%	59%	51%	49%	50%	-42%
2002	104	68%	48%	55%	45%	44%	-58%
2003	107	76%	57%	44%	56%	73%	-26%
2004[23]	93	74%	57%	29%	71%	50%	-32%

[23] The level of the grants in 2004 was only NIS 377 million, a decrease of approximately 30% from year 2003 and of approximately 40% in comparison to year 2004 .

The first column in the table displays the number of establishments that received funding from the Office of the Chief Scientist in the given years. The second column displays the percentage of these establishments that received funding from the OCS in the previous year as well. The following column displays the percentage of establishments which received funding from the OCS for two consecutive years. Thus, for example, in 1998, 124 manufacturing establishments received funding from the Office of the Chief Scientist. Among them, 69% received funding also in 1997 and 39% received funding both in year 1997 and in year 1996.

The fourth column displays the percentage of establishments whose level of support was increased in relation to the previous year and the fifth column displays the percentage of establishments whose level of support decreased in relation to the previous year. The percentages in these columns refer to the amount of establishments that received support from the OCS in the given year and in the preceding year. Thus, among the establishments that received support both in year 1998 and in year 1997 (constituting 69% of 124 establishments as aforementioned) – 43% received a higher level of support in 1998 than in 1997 and among 57% the level of support in 1998 was lower than in 1997.

The fifth and sixth columns display the rate of increase (fifth column) in the level of OCS support for establishments whose support increased in consecutive years; and the rate of decline (sixth column) in the level of OCS support for establishments whose support decreased in consecutive years.

The facts above show that the OCS support is granted for two consecutive years to approximately 70% of the establishments and for three consecutive years to approximately 50% of the establishments. That is to say, an establishment whose application was approved for the first time in a certain year, has an average expected probability of 70% to receive continued support in the following year and a 50% probability to receive support for three consecutive years.

Since this is the state of things de facto, it is recommended to consider enabling the OCS to commit in advance to multi-year financing schemes, thereby decreasing the level of uncertainty for establishments associated with the need to apply for support and wait for the approval each year. All the more so when 70% of them (on average) are expected in any case to receive support during at least two consecutive years. Nonetheless, it appears that an analysis of the level of firm heterogeneity in this context is in place. Furthermore, an analysis similar to the one presented above but at the single-project-level (data from the OCS), rather than at the firm level, as was conducted in this research, is called for.

From the firms viewpoint, the data on the probability of change in the level of support granted reflect a considerable degree of uncertainty. Among the establishments which are granted support for two consecutive years, 50% will receive a level of support approximately 50% higher than in the previous year and the other half will receive a level of support that is approximately 40% lower than that received in the previous year. The reasons for this high difference are not evident to us. We can only assume that some can be explained by the lifecycle stage of approved R&D projects, and some can be explained by budget limitations and the inability of the government support schemes to commit in advance to multi-year financing. Furthermore, it is possible that the state of financing observed in the data is optimal and that 50% of the establishments indeed require additional funding following one year and the other 50% require less.

These facts also support the conclusion that the OCS should be enabled to commit in advance to multi-year financing schemes. Thus sparing firms the uncertainty associated with the approval of applications on a yearly basis. It seems that in the case of high-risk processes such as R&D, where part of the rationale for government support is the reduction in business-related risk, it is important not to create a new uncertainty associated with required regulatory processes for the approval of support.

The following table displays similar data for the dynamics of the OCS's R&D support in the computer services, software and R&D branches. The trends and conclusions that emerge from the data are similar to those from the analysis above regarding the manufacturing industry branches.

Table 12:

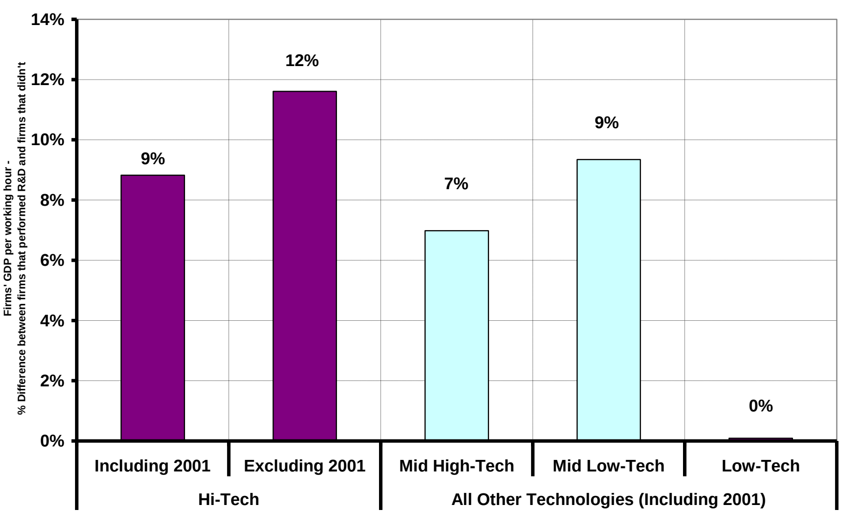
The dynamics of R&D support by the Office of the Chief Scientist to the computer services, software and R&D branches, 1997-2005

Year	No. of Establishments that received funding from the OCS in relevant year	OCS funding continuity: 2 years	OCS funding continuity: 3 years	Establishments with positive change %	Establishments with negative change %	Positive change in OCS funding level for (weighted) average establishment %	Negative change in OCS funding level for (weighted) average establishment %
1997	88						
1998	95	82%		56%	44%	66%	-36%
1999	99	77%	64%	42%	58%	47%	-36%
2000	101	86%	65%	52%	38%	83%	-35%
2001	77	59%	56%	55%	43%	53%	-36%
2002	111	73%	43%	32%	68%	75%	-30%
2003	121	75%	58%	41%	58%	45%	-29%
2004	114	69%	51%	28%	70%	41%	-43%
2005	88	59%	40%	36%	64%	46%	-42%

3.2.4. Initial indicators of R&D output in the manufacturing industry

This chapter presents several initial or basic indicators of R&D activity output and its impact on firms' GDP in the manufacturing industry. It is generally believed that R&D activity in firms increases productivity and GDP for given levels of capital and work inputs. The following figure compares firms' GDP per working hour (work productivity) between firms that engaged in R&D activities and firms that did not:

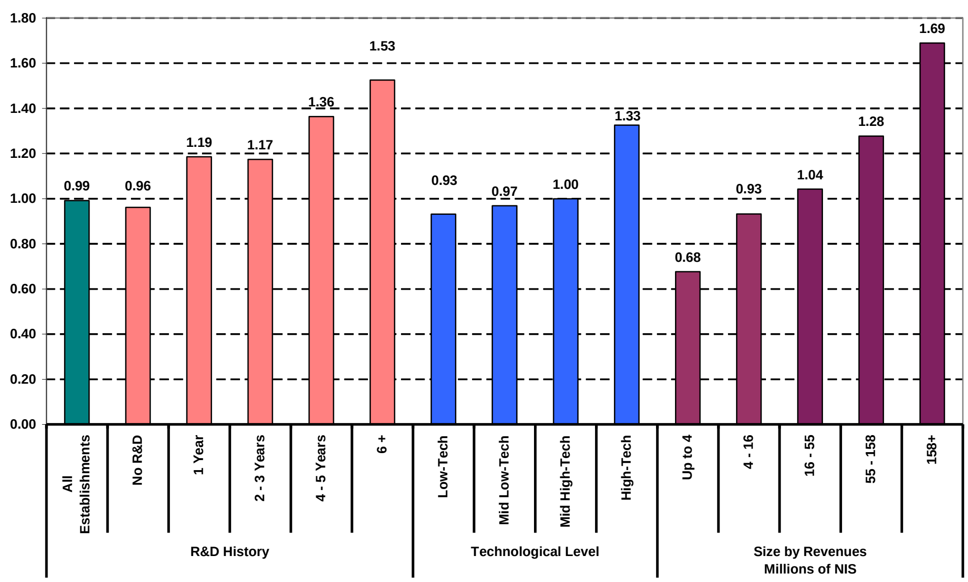
Figure 9: Firms' GDP per working hour by technological intensity - percentage difference between firms that performed R&D and firms that didn't, surveys of the manufacturing industry and R&D in the manufacturing industry, 1996-2003 on average



The figure above shows that GDP per working hour in the high technology branches of the manufacturing industry is approximately 9% higher (12% excluding year 2001) for firms that engaged in R&D activity than for firms that did not engage in such activities. In the medium–high technology and medium-low technology branches, the GDP per working hour was approximately 7% and 9% higher respectively for firms that engaged in R&D activities in comparison to those that did not. The result for the low-technology branches where firms' GDP is equal between firms that engaged in R&D activities and those that did not, is not consistent with the findings of other branches, but can plausibly be the result of the scarcity of observations of firms that engage in R&D activities in these branches.

With the aim of conducting a systematic comparison of firms' total productivity, a simple regression analysis was conducted where the coefficients of a Cobb-Douglas production function, which include only capital and work input, were estimated. Based on these results, the Sollow residuals, which represent Total Factor Productivity (TFP) were calculated. The following figure displays the TFP values by technological intensity, continuity in R&D engagement and firm size:

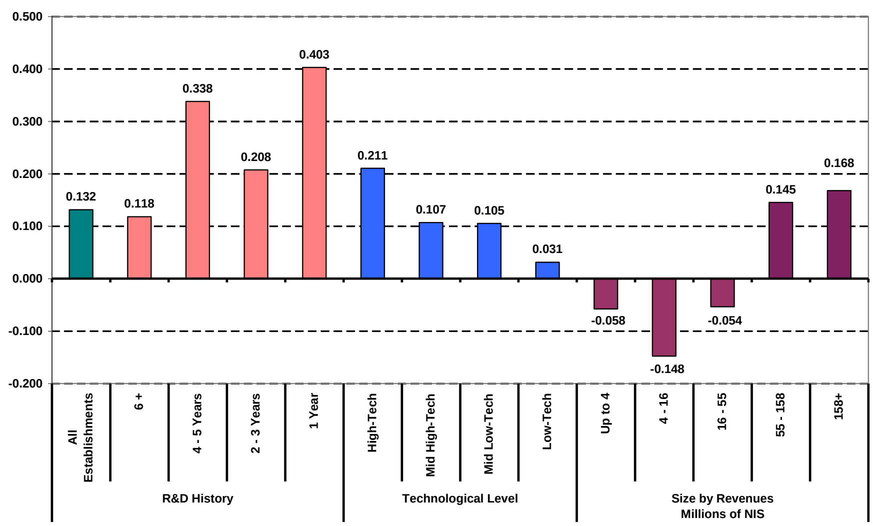
Figure 10: R&D output – Total Factor Productivity (TFP), 1996-2004 on average



It can be seen that as the number of consecutive years of R&D activity rise, so do the TFP values. Also, the level of TFP in high technology firms is higher than among firms from lower technological intensity groups. Additionally, a correlation between firm size and TFP can be observed, wherein larger firms display higher TFP values[24]. **It is important to emphasize that despite the evident trend in TFP averages, here too, a high degree of firm heterogeneity in TFP exists within the analyzed categories.**

The following diagram displays the correlation coefficients (Pearson) between the level of R&D expenditures and the TFP of firms within the categories presented above:

Figure 11: Correlation coefficients between R&D expenditures and TFP, 1996-2004 on average[25]



The figure above shows that the correlation between the level of R&D expenditures and TFP is higher in the high-technology industries and lower in the low-technology branches (although positive overall). For small firms the negative correlation obtained may be explained inter alia by the inherent risk of R&D activities, by small firms' higher R&D

[24] This does not suffices to determine causality. It is quite possible that the more efficient firms with higher productivity are the ones that survive, grow and strengthen and therefore ultimately comprise the group of larger firms in the industry.

[25] The results are only for firms that engaged in R&D (positive R&D expenditures).

expenditures in relation to their output, and possibly also due to effects of organizational culture and knowledge of R&D process management, which naturally should be more rooted in large firms and less so in small ones. The results regarding the years of R&D execution show a higher correlation with TFP for firms that engaged in R&D for a period of 2-3 years than for firms that engaged for 6 years or more. This phenomenon is possibly linked to the decreasing marginal output of R&D and the relation between its rate of change, and the change in the learning rate of R&D process management. Nonetheless, it appears that simple coefficients, which show indicatively that R&D activities indeed impact productivity and GDP, are not the suitable instruments for a detailed analysis of the phenomenon.

4. Research results

This chapter describes the results of the research, obtained by applying the methodology presented above. The first subchapter presents the estimates of the impact that government support has on the level of R&D executed by firms in the manufacturing industry and the computer services, software and R&D branches. The following subchapter presents estimates of the returns to the economy that stem from industrial R&D activities by firm size and technological intensity - both private direct returns to the R&D performing firms and the returns to the economy in the form of R&D spillovers. Lastly, the final subchapter presents an integrated model based on the results from the previous parts, that enables the calculation of the returns to the economy directly stemming from government industrial R&D support.

4.1. The impact of government support on the levels of executed R&D

The examination of the impact of government support on R&D expenditures of firms in the manufacturing industry, computer services, software and R&D branches was conducted using the methodology specified in chapter 2.3. The additionality was estimated by creating for all firms (establishments) that received government support, a synthetic control group of firms that did not receive government R&D support, thus enabling the comparison between them.

The control group that was constructed included, for each firm (establishment) which received government support in a specific year, an identical establishment in terms of group size (see tables regarding segmentations according to group size below), technological intensity and additional observed characteristics that influence the probability of receiving governmental financing - yet was not granted government funding up to that year (including). Size groups in this context were determined in cooperation with the research steering committee, which expressed interest in a systematic examination of the research results regarding very large firms (above NIS 300 million) and small firms (less than NIS 50 million). The following table displays the quantity of firms (establishments) in the samples that were granted government funding. Its purpose is to present the reader with the quantity of observations in the various segmentations in which the analysis was conducted:

Table 13: Manufacturing establishments and computer services, software and R&D firms that were granted government funding, by source

Number of observations Establishments that were granted funding by source			
	Type of funding		
	All sources	Of which: OCS	Of which: international
By revenues range, 2003 NIS Millions			
Up to 50	461	418	74
50-300	129	123	23
Above 300	42	38	15
All establishments*	**632**	**579**	**112**
By technology intensity (manufacturing) or main branch (computer services, software and R&D)			
High	214	204	45
Medium high	60	55	10
Medium low	47	47	4
Low	17	14	0
Computer services and software	134	116	20
R&D firms	187	169	37
All establishments*	**659**	**605**	**116**
* Since some of the establishments do not have revenues data, the total number of establishments classified by size is smaller than the total number of establishments classified by technology			

The following figures display the distribution of funding received by the establishments from all external sources. Clearly, approximately half of the establishments did not receive government funding, and out of these, the control group may be chosen.

Table 14: Distribution of R&D external funding (government and other sources) – manufacturing industry branches

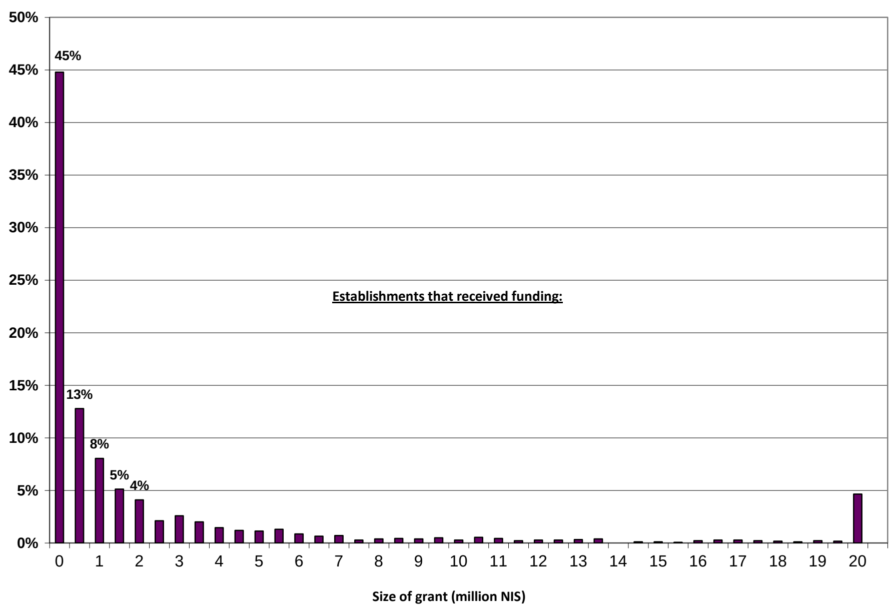
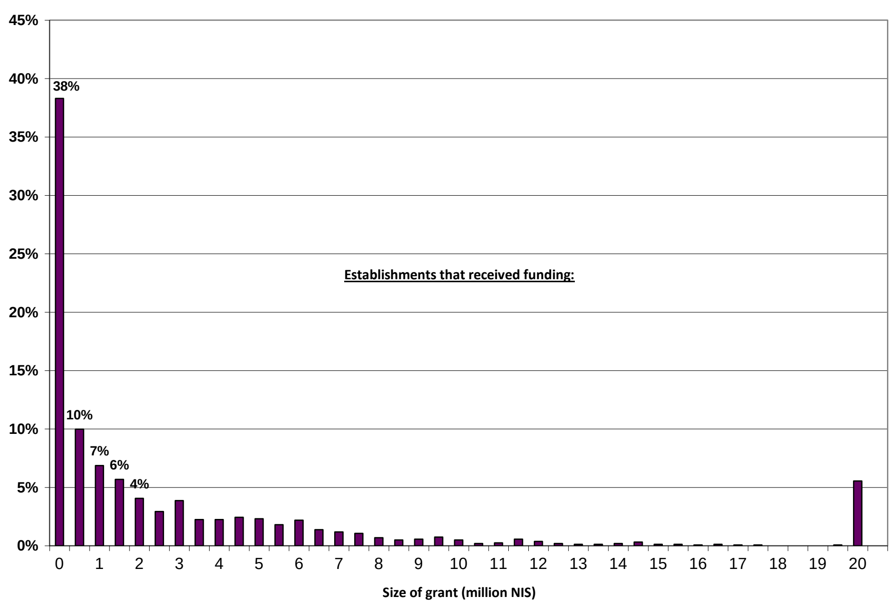


Table 15: Distribution of R&D external funding (government and other source) – computer services, software and R&D branches



The results of the probit regression which served to build the control group appear in appendixes 10 (manufacturing industry) and 11 (computer services, software and R&D branches). When creating the control groups for manufacturing establishments and computer services, software and R&D firms, the statistical closeness between the firms that performed R&D and their respective control firms was satisfactory. In the manufacturing industry branches the average absolute value of the difference in the probability of receiving government support among the firms that received government R&D support and their respective control firms (according to which the adjustment was made) was 0.008 and the median of the difference distribution was 0.0037. Therefore, the level of matching (measured by means of the probability's difference) is very satisfactory. In the computer services, software and R&D branches a matching of similar quality was obtained: The average difference was 0.0048 and the median was 0.0018.

Following the building of the control groups we now have pairs of establishments that are as similar as possible to each other (in particular, with regard to the selection process of government funding allocation) except for the fact that one of them received government funding and the other did not. Using this database, one can run a regression to examine the difference in R&D expenditures from private sources only (that is to say, net of government funding received) between the two types of establishments (those that got R&D support and those that didn't) and examine the impact of the level of government support received on these expenditures. We include in the regression (see appendixes 10 and 11) the levels of current R&D government funding and lagged one period, in order to enable the framework to encompass situations in which R&D projects span over two calendar years. The following table displays the increment to privately-funded R&D expenditures in the economy that are due to government grants and that would not have been incurred were it not for these grants - e.g. the additionality of R&D government grants:

Table 16: Additionality estimates – manufacturing industry branches, 2003 NIS in millions

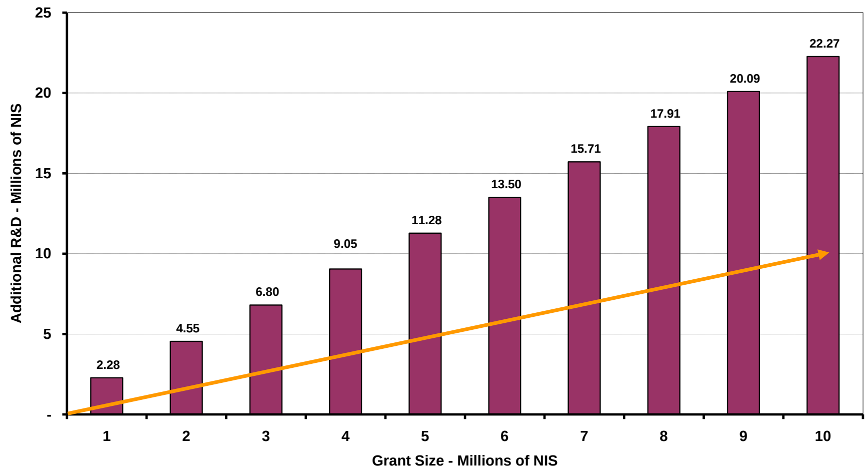
Gross government grant	Increment in establishments R&D expenditures (private sources)	Total new R&D that would not have been executed without the grant
1	1.28	2.28
2	2.55	4.55
3	3.80	6.80
4	5.05	9.05
5	6.28	11.28
6	7.50	13.50
7	8.71	15.71
8	9.91	17.91
9	11.09	20.09
10	12.27	22.27

The data therefore points at the existence of significant additionality among firms in the manufacturing industry. The results above show that a government grant of one NIS million created an increment in private R&D expenditures equal to NIS 1.28 million, and that altogether, the level of R&D in the economy increased by NIS 2.28 million. In terms of percentage increments, we find that the lower the grant is, the higher the additionality coefficient estimated[26]. Thus, for one NIS million, the additionality coefficient is 128% (1.28/1) and for NIS 10 million the additionality coefficient is approximately 122% (12.27/10). These estimates indicate that the government support system is successful in selecting projects that would not have been executed were it not for the government support.

The following figure displays graphically the data from the table above. The columns (Y-axis) represent the total R&D increment to the economy as a result of government R&D grants (X-axis). The diagonal is a 45^0 line. We shall restate that the R&D increments would not have been executed were it not for the government grants.

[26] It is convenient to think about these estimates as multipliers of the government R&D grants. Thus allowing to easily calculate the increment to private R&D for a given government grant(s) level. In this context, we use the term "additionality coefficient".

Figure 12:
Total R&D increment in the economy as a result of government grants (additionality) – manufacturing industry,
2003 NIS in millions



It is important to emphasize: The grants data are gross data. The R&D surveys do not monitor royalty payments at all. It is obvious, that firms' decision variable when determining its level of R&D expenditures is the net grant (net of royalties to be paid in the future or currently being paid on account of other projects). Therefore, the calculated levels of new R&D created as a result of government grants as shown above are **lower bound** estimates of the actual levels of additionality.

We find small differences in results obtained by firm size. For small firms (less than NIS 50 million) the additionality coefficient is positive and 30% lower than the average. For a grant of NIS 1 million the firm adds from its own resources approximately NIS 0.9 million. For medium firms (NIS 50-300 million), we found an additionality coefficient that is 2.5 larger than average. For a grant of NIS 1 million the firm adds from its own resources approximately NIS 3.2 million. For large firms (NIS 300+ million) an effect similar to the average is obtained: for a grant of NIS 1 million the firm adds from its own resources approximately NIS 1.2 million. The estimates obtained remain stable (robust) also within groups of technological intensity - excluding the low-technology segment where the amount of observations is insufficient.

The following table displays the additionality estimates for firms in the computer services, software and R&D branches:

Table 17: Additionality estimates - computer services, software and R&D branches, 2003 NIS in millions

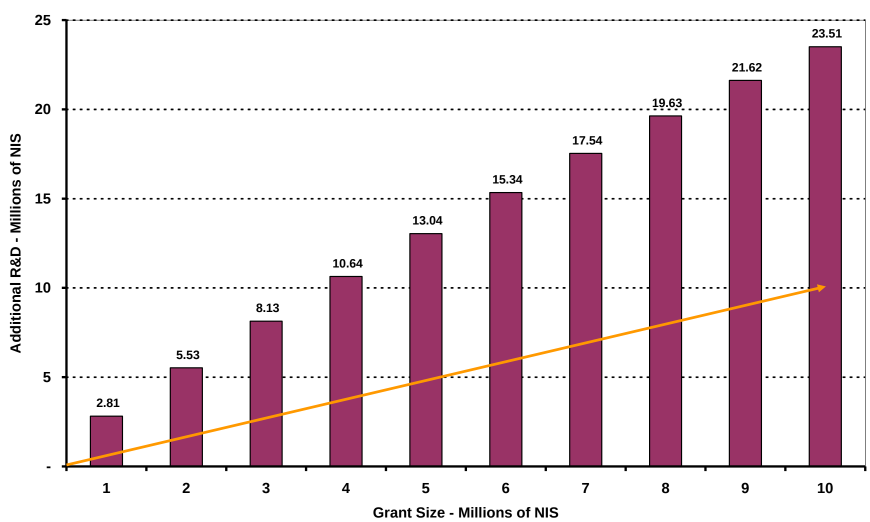
Gross government grant	Increment in establishments R&D expenditures (private sources)	Total new R&D that would not have been executed without the grant
0.5	0.92	1.42
1	1.81	2.81
2	3.53	5.53
3	5.13	8.13
4	6.64	10.64
5	8.04	13.04
6	9.34	15.34
7	10.54	17.54
8	11.63	19.63
9	12.62	21.62
10	13.51	23.51
15	16.40	31.40
20	16.71	36.71

Also, in the computer services, software and R&D branches the data indicate that government R&D support generates significant additionality in R&D activities. The estimates show that a government grant of NIS 1 million creates an increment in private R&D expenditures equal to NIS 1.81 million – a total increase of NIS 2.81 million in the R&D level of the economy. For NIS 1 million, the additionality coefficient is 181% (1.81/1) and for NIS 10 million the additionality coefficient is approximately 135% (13.51/10).

The fact that estimates that are positive, stable and of a similar order of magnitude are obtained both in the manufacturing industry and in the computer services, software and R&D branches, supports the conclusion that the existing government support system is effective and succeeds in choosing the projects that would not have been executed were it not for government support. In light of this, it is probable that also in branches for which no extensive past data is presently available (biotechnology, nanotechnology) one can expect a similar performance from the existing support mechanisms.

The following figure displays graphically the data from the table above. Here too, the columns (Y-axis) represent the total R&D increment to the economy as a result of government grants (X-axis). The diagonal is a 45^0 line.

Figure 13: Total R&D increment in the economy as a result of government grants (additionality) – computer services, software and R&D branches, 2003 NIS in millions



The results presented above are high in relation to those obtained in other research that examined the same issues. It shall be noted that in most other research the methodology of propensity scoring was not applied as it was here. Lach (2002) used data on Israeli manufacturing firms for years 1990-1995 in order to estimate whether the support of the OCS had a stimulating (i.e. additionality) or a displacing (i.e. crowding out) impact over the investments of firms in R&D[27]. His results show that the OCS support significantly stimulated the investments of small firms but had a negative impact on the expenditures of large firms – or that their impact on large firms was not statistically significant[28]. We would like to note that Lach (2002) used data regarding the first half of the 90's while the data in this report are for the years 1995 to 2004. We believe the difference between the results in Lach (2002) and those presented here can mostly be explained by the difference in the periods of analysis. Griliches and Regev (2001) estimated separately the impacts of subsidized and unsubsidized R&D expenditures on the production and productivity of manufacturing Israeli firms between years 1975-1994[29]. They found a significant impact of subsidizing on firms' productivity.

Czarnizki and Fier (2002) researched the impact of innovation grants on private innovation expenditures among firms from the German service sector[30]. They used cross-sectional firm-level data and a non-parametric scoring method similar to the one used here. Their findings show that the intensity of innovation (innovation expenditures in relation to firms' sales) is significantly higher among firms participating in the innovation promotion programs. On average, the innovation intensity in these firms is approximately 6% higher in comparison to the other firms. They conclude that government support for the promotion of innovation in the German service sector in the 90's created new private investments (positive additionality). Furthermore, they rule out

[27] Lach, S., 2002, **"**Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel**",** *The Journal of Industrial Economics*, December, Vol. L, No. 4, pp. 369-390.

[28] Several other researchers found that government support and firms' private R&D investments are substitutes: Busom (2000) and Wallensten (2000) are cited further on, as well as Klette, T. J. and Moen., 1998, "R&D Investment Responses to R&D Subsidies: A Theoretical Analysis and Microeconomic Study**",** mimeo, Oslo.

[29] Z. Griliches, H. Regev, "R&D, government support and productivity in industrial establishments in Israel, 1975-1994", *The Journal of Economics*, year 46, number 2, November 1999.

[30] Czarnitzki Dirk and Andreas Fier, 2002, "Do Innovation Subsidies Crowd out Private Investment? Evidence from the German Service Sector", *Applied Economics Quarterly,* 2002 (1), pp. 1 - 15.

the possibility of a complete crowding out of private investments by public support to innovation.

Duget (2003) researched the impact of R&D grants on firms' R&D expenditures from private sources in France between the years 1985 - 1997[31]. In order to determine whether supported firms would invest in R&D at an identical level were it not for the grants, he used matching methods similar to those applied in this research. He found that the probability of receiving funding is positively correlated to firms' size, their debt ratio and the importance of privately funded R&D. Furthermore, while controlling for support granted in the past, he finds out that, on average, public R&D funding is complimentary to private expenditures. That is to say, there is no significant crowding out of private investments by public funds.

In Finland, the researchers Toivanen and Niinien (1998) examined whether R&D grants complement or substitute private funding for innovative activities among firms[32]. They used data from years 1985-1993. Their findings indicate that R&D grants increase R&D in small firms by approximately 5% yet no change was detected in large firms.

Busom (2000) reports the impact of R&D grants on R&D expenditures of the recipients and the probability of a firm to participate in programs in order to receive R&D grants[33]. This was achieved using a cross-section sample of Spanish firms. The empirical model is comprised of a system of equations: a participation equation and an R&D effort equation. Also, public funding was controlled for. The main findings are that: (1) the probability of receiving funding was higher for smaller firms – in accordance with the

[31] Duget, Emmanuel, 2003, "Are R&D a Substitute or a Complement to Privately Funded R&D? Evidence from France using Propensity Score Methods for Non-Experimental Data, mimeo, cahiers de la MSE EUREQua no. 2003(75).
[32] Toivanen, O., Niininen, P., 1998, "Investment, R&D, subsidies and credit constraints.", Working Paper, *Department of Economics MIT and Helsinki School of Economics.*
[33] Busom, Isabel, 2000, "An Empirical Evaluation of the Effects of R&D Subsidies", *Economics of Innovation and New Technology,* 9(2), pp. 111 - 148.

goals of policymakers; (2) on average, public support brought about an increase in R&D expenditures, nonetheless for approximately 30% of the firms, the possibility of complete crowding out of privately funded R&D expenditures by government support, could not be ruled out.

Wallensten (2000) examined whether R&D grants to firms increase their privately funded R&D expenditures[34]. For this purpose, he used a database of small high-tech firms from the U.S. which participate in the Small Business Innovation Research (SBIR) program. He estimated a system of simultaneous equations with instrumental variables in order to control for the endogeneity of R&D grants. His findings show that R&D grants crowded out self-funded R&D expenditures at a rate of 1:1 (complete crowding out). Nonetheless, the firm sample used by him does not allow to draw general conclusions in this context.

To summarize this chapter, we can say that the level of additionality found in this research is high in comparison to known levels and is indicative of the success (apparently systematic) of the government support mechanisms in Israel. It should be emphasized that the above comparison of results was conducted between support systems that vary in their declared goals, in their operational aspects and in regard to the control and monitoring instruments applied within their implementation. These differences could explain a significant part of the relative success of the government support mechanisms in Israel in comparison to others in the world. The next question, which shall be analyzed in the chapter below, refers to the contribution of the additional R&D, created by government support, to total GDP within the manufacturing branches of the economy.

[34] Wallensten, Scott. J., 2000, "The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program", *The Rand Journal of Economics,* 31(1), pp. 82 - 100.

4.2. Estimating the returns to the economy from R&D activities

This chapter presents the results obtained from analyzing the impact of R&D investments on the GDP of manufacturing firms in Israel in the years 1996-2003. We begin by presenting general data about the firms included in the sample used and later we present the results obtained from estimating two production functions models. The first model uses R&D stock (Griliches model – see detailed description in appendix 6) and the second model uses the flow of R&D investments (Blundell and Bond model – see detailed description in appendix 7). Bellow we present data about the quantity of establishments in the merged file of the manufacturing industry surveys and the R&D in manufacturing surveys used to estimate the returns on R&D. The quantity of establishments is displayed by technological intensity, size and R&D activity of the establishments:

Table 18: Number of Establishments by revenue groups, technology intensity and R&D execution

Revenue range 2003 NIS in Million	Technology intensity				
	High	Medium high	Medium low	Low	All
All Establishments					
Up to 50	203	257	710	950	2,120
50-300	75	84	131	180	470
Above 300	34	20	18	25	97
Total	**312**	**361**	**859**	**1,155**	**2,687**
Establishments that did not execute R&D					
Up to 50	128	231	692	946	1,997
50-300	27	59	110	169	365
Above 300	6	10	10	21	47
Total	**161**	**300**	**812**	**1,136**	**2,409**
Establishments that executed R&D					
Up to 50	75	26	18	4	123
50-300	48	25	21	11	105
Above 300	28	10	8	4	50
Total	**151**	**61**	**47**	**19**	**278**

It may be seen that the quantity of establishments used in the estimation is high and enables for a satisfactory and stable analysis of the phenomena. We would like to note that a large portion of the establishments appeared in the data in more than one year, thus enabling to control for firm specific characteristics. Finally, it is clear, also from the table above that the quantity of observations on low technology establishment that engaged in R&D is very small and cannot serve as the basis of a systematic analysis. The R&D surveys in the computer services, software and R&D branches do not contain information regarding firms' GDP and therefore it was not possible to conduct an analysis similar to the one presented above in this regard.

4.2.1. Private returns on R&D investments

The following tables display estimates for the GDP increment related to an investment of an additional NIS 100 thousand in R&D[35]. These estimates include only the private returns. That is to say, the GDP increment of investing firms without taking into consideration any spillover effects on other firms. The GDP values are discounted over an infinite horizon. The outputs of the regressions on which the estimates are based are displayed in appendixes 8 and 9.

[35] The estimations were calculated in discounted GDP values. That is to say, the future increase in GDP is expressed in present value terms (shekels of year 2003).

Table 19: Marginal GDP increment as a result of an additional NIS 100 thousand of R&D investments - Griliches model

Thousands of 2003 NIS and number of establishments [36]

Technology intensity	GDP increment	Standard deviation	Number of establishments
High	97	158	150
Medium high	153	148	77
Medium low	340	271	60
Low	347	231	26
All	**175**	**215**	**313**

Table 20: Marginal GDP increment as a result of an additional NIS 100 thousand of R&D investments - Blundell and Bond model

Thousands of 2003 NIS and number of establishments[37]

Technology intensity	GDP increment	Standard deviation	Number of establishments
High	64	113	124
Medium high	123	116	58
Medium low	233	182	38
Low	286	209	7
All	**113**	**147**	**227**

The tables above show that the private returns on R&D investments are 13%-75% on average. These estimates are within the conventional range obtained in other research. The main difference between the models' results is with regard to high-technology firms: In the Griliches model a zero marginal return to R&D is obtained. In the Blundell and Bond model the return obtained is negative (an increment of NIS 64 thousand in GDP

[36] The number of establishments in the estimation is smaller than the number of establishments in the sample because in the estimation lagged variables such as instrumental variables are used.

[37] The quantity of establishments used in the estimation is smaller than the quantity of establishments in the sample since the estimation included use of **explanatory variables and lagged variables**, a fact that reduces the quantity of observations used de facto for estimating.

stemming from an investment of NIS 100 thousand in R&D). The zero return obtained in the Griliches model indicates that high-technology firms are very close to the optimum point of R&D investment. A possible explanation for the negative returns in the Blundell and Bond model is that the R&D support mechanism operates in a manner in which at **the margins**, projects which would not have been executed were it not for the government grants, yield low private returns. For firms from the medium-low technology branches private marginal returns are positive – a finding indicating that additional R&D investment on their part is economically justifiable. It is important to emphasize that the standard deviations of the estimates indicate that the firms' returns are widely distributed around the average return estimated – a finding in line with the high risk characteristic of R&D investments.

The GDP-R&D elasticities obtained are 0.10 in the Griliches model and 0.04 in the Blundell and Bond model. These estimates are within the conventional range of elasticity estimates in similar research.

Schankerman (1981) estimated GDP-R&D elasticities by economic branches in 1963[38]. The statistically significant estimates obtained span a range between 0.034 (electronic components) to 0.292 (aircraft). The estimated elasticity of 0.104 for the chemicals branch is very close to that obtained in Minasian (1969), 0.11, for firms that operated in the same branch during the 50's[39]. Hall and Mairesse (1995) obtained estimates for R&D elasticites of approximately 0.18 for French firms during the 80's[40]. This result is very close to that of Cuneo and Maresse (1984) for the 70's (0.203)[41]. On the other hand, the

[38] Schankerman, M., 1981, "The Effects of Double-Counting and Expensing on the Measured Returns to R&D", *Review of Economics and Statistics,* 63: 454-458.
[39] Minasian, J. R., 1969, "Research And Development, Production Functions, and Rates of Return", *American Economic Review,* 59(2), 80-86.
[40] Hall, B. H. and Mairesse, J., 1995, "Exploring the Relationship Between R&D and Productivity in French Manufacturing Firms", *Journal of Econometrics,* 65: 263-293.
[41] Cuneo, P. and Mairesse, J., 1984, "Productivity and R&D at the Firm Level in French Manufacturing", In Z. Griliches (eds), *R&D, Patents and Productivity,* Chicago: University of Chicago, pp. 375-392.

elasticity estimates in Griliches (1980) for 1963 is 0.07[42]. Bartelsman et al (1996) estimated elasticities of 0.05 and 0.10 for the periods 1985-1989 and 1989-1993 respectively[43].

Griliches and Mairesse (1984) researched 133 U.S. firms and found that the R&D elasticity **in relation to sales** was 0.05, and that for scientific firms the elasticity increased to 0.19, significantly higher than for the other firms[44]. This finding was confirmed by Sassenou (1988) who recorded a higher elasticity for Japanese scientific firms (0.16) in contrast to other types of Japanese firms (0.10)[45]. On the other hand, in Cuneo and Mairesse (1984) the R&D elasticity for French scientific firms (0.11) is low in comparison to other French firms[41]. A possible explanation for this, as Cincera (1998) pointed out, is that the scientific firms from Japan and the U.S. rely less on governmental funding for executing R&D[46]. Because governmental funding for R&D purposes is generally channelled to basic research, its economic results usually are not discernable in the short term performance of firms.

A comparison of the estimates in Griliches (1980) and Sassenosu (1988) show that the impact of R&D on productivity is quite similar among firms in Japan and the US[42 45]. Moreover, the value of 0.15 which was reported in Harhoff (1994) for German firms is

[42] Griliches, Z., 1980, "R&D and the Productivity Slowdown", *American Economic Review,* 70(2): 343-348.
[43] Bartelsman, E.J., van Leeuwen, G., Nieuwenhuijsen, H. and Zeelenberg, K., 1996, "R&D and Productivity Growth: Evidence from Firm-Level Data in the Netherlands", *Netherlands Official Statistics,* 11 (Autumn), 52-69.
[44] Griliches, Z. and Mairesse, J., 1984, "Productivity and R&D at the Firm Level", In Z. Griliches (ed), *R&D, Patents and Productivity,* Chicago: University of Chicago Press, pp. 339-374.
[45] Sassenou, M., 1988, "Recherche-Developpment et Productivite dans les Entreprises Japonaises: Une Etude Econometrique sur Donnes de Panel", These de Doctorat, Paris: Ecole des Hautes Etudes en Sciences Sociales.
[46] Cincera, M., 1998, "Technological and Economic Performances of International Firms", Ph.D. Thesis, Belgium: Universite Linre de Bruxelles.

similar to the results obtained for French firms[47]. On the other hand, its results are higher than those of the U.S., and to a certain extent higher than those of Japan

Cincera (1998) researched R&D elasticities of 625 firms in different countries between the years 1987 and 1994[46]. His estimations are similar to those of the U.S. (0.09) and Europe (0.10). Nonetheless, in the case of Japan, his estimations are significantly lower (0.02). Cuneo and Mairesse (1984) use the GDP and level of sales as explanatory variables[41]. The estimations they obtained are 0.11 and 0.18 when the explanatory variables are GDP and sales respectively.

Bloom Shankerman and Van Reenen (2007) used panel data of U.S. firms between 1981 and 2001 to estimate spillovers effects on firms' performance[48]. They reported an R&D elasticity estimate in relation to sales of 0.045.

Doraszelski and Jaumandreu (2008) estimate a production function that includes R&D flows as an explanatory variable[49]. This, for nine Spanish manufacturing branches using panel data (unbalanced) of more than 1,800 firms. Their theoretical framework includes the modeling of the dynamics in productivity, through which productivity itself, and its relation with firms' R&D flows are estimated. The inter-branch weighted average of R&D elasticity in relation to productivity is 0.012, identical to the flexibility of the chemicals branch.

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[47] Harhoff, D., 1994, "R&D and Prductivity in German Manufacturing Firms", *ZEW Discussion Paper No. 94-01,* Mannheim: Zentrum fur Europaische Wirtschaftsforshung.

[48] Bloom, N., Schankerman M. A., and Van Reenan, J., 2007, "Identifying Technological Spillovers and Product Market Rivalry"**,** *NBER Working Paper* No. W13060, Cambridge, Massachusetts: National Bureau of Economic Research.

[49] Doraszelski, U. and Jaumandreu, J., 2008, "R&D and Productivity: Estimating Production Functions When Productivity is Endogenous", *Harvard Institute of Economic Research,* Discussion Paper No. 2147.

4.2.2. Estimation of R&D spillover effects

We estimated the R&D spillover effects using the methodology described in section 2.2 above. Being unable to create reasonable proximity indexes between firms, we assumed that each firm's pool of potential spillovers included the R&D expenditures of all firms within the same group of technology intensity and size, besides, of course, the R&D expenditures of the relevant firm[50]. By delimiting the pools of potential spillovers by firm size it was possible to assess whether technological spillovers stem in different degrees from large or small firms.

The following tables display the GDP increment resulting from R&D spillovers estimated using the Griliches and Blundell and Bond models. The estimates represent the total GDP increment (sum) from all firms within the same technology intensity group, that result from an increment of NIS 100 thousand in the R&D expenditures of a single firm of medium-large size within the same technology group[51]. The findings show positive and statistically significant R&D spillovers effects within the Israeli manufacturing industry.

The following table displays the results obtained within the framework of the Griliches model for medium-large firms (NIS 50-300 million):

[50] Because of budget constraints, the research steering committee preferred to include the analysis of the R&D data in the computer services, software and R&D branches over the construction and use of technology proximity indexes based on patents, as was first proposed by us.

[51] In fact, the R&D increment accrues to the total R&D expenditures of the firms within the same technology intensity group. In this sense, there is no specific firm that increases its R&D expenditures.

Table 21: Estimates of R&D spillovers from medium-large firms (NIS 50-300 million) - Griliches model, given a NIS 100 thousand increment in the branch R&D level

In thousands of NIS

Technology intensity	Total GDP increment from spillovers	Number of establishments
High	157	150
Medium-high	224	86
Medium-low	290	69
Low	65	25

The following table displays the results obtained within the framework of the Blundell and Bond model:

Table 22:
Estimates of R&D spillovers from medium-large firms (NIS 50-300 million) - Blundell and Bond model, given a NIS 100 thousand increment in branch R&D level

In thousands of NIS

Technology intensity	Total GDP increment from spillovers	Number of establishments
High	224	147
Medium-high	411	84
Medium-low	459	65
Low	90	17

According to the estimates above, due to R&D spillovers, an increment of 100 thousand NIS in the R&D expenditures of a medium-large, high-technology firm bares an impact of 157-224 thousand NIS to the technological-branch GDP - above and beyond the impact on the firm's own GDP increment. This increment to total branch GDP represents the social value of R&D not taken into consideration by private firms when determining their R&D investment level based on their profit and loss accounts only, and its mere existence justifies the support given by the government to private R&D activities.

For medium-large firms the elasticity coefficients estimated using the Griliches and the Blundell models are 0.09 and 0.07 respectively. Both are statistically significant. The high similarity between the results from both models, given the different assumptions that underlie them, attests about the robustness of the estimates. It is clear from both tables that the spillover estimates from medium-large, low-technology firms are approximately half to one-quarter the value of those in other industry branches. This might be explained by the low number of observations and low levels of R&D expenditures in these branches. The following tables display the estimates for very large firms (NIS 300+ million):

Table 23: Estimates of R&D spillovers from very large firms (NIS 300+ million) - Griliches model, given a NIS 100 thousand increment in the branch R&D level

In thousands of NIS

Technology intensity	Total GDP increment from spillovers	Number of establishments
High	20	177
Medium-high	44	87
Medium-low	152	74
Low	178	32

Table 24: Estimates of R&D spillovers from very large firms (NIS 300+ million) - Blundell and Bond model, given a NIS 100 thousand increment in branch R&D level

In thousands of NIS

Technology intensity	Total GDP increment from spillovers	Number of establishments
High	17	146
Medium-high	44	84
Medium-low	85	63
Low	15	6

In conclusion - we have found positive and statistically significant spillover effects for medium-large and very large firms. For small firms, the coefficients estimated are negative but their levels of statistical significance are low. Therefore, we can determine that no evidence of significant technological spillovers from small firms was found in the data. The largest spillover coefficients (0.07 in the Griliches model and 0.09 in the Blundell & Bond model) were estimated for medium firms (NIS 50-300 million of annual sales). For very large firms (NIS 300 million and up) positive coefficients were estimated (0.03 in the Griliches model and 0.02 but with borderline statistical significance in the Blundell and Bond model).

The results above might be taken to justify the preference of R&D executed by medium/large firms over small firms, given that no spillovers (or even negative spillovers) stem from the latter. Nevertheless, this stance does not take into account that the government intervention in regard to R&D is justified in the presence of several market failures, R&D spillovers included but by no means the only one - as specified above. Other market failures include limited access to capital markets and the limited ability to receive credit for high-risk ventures in the presence of asymmetric information (between the suppliers and the recipients of financing)[52]. For small firms, these limitations are of paramount importance and many government programs (in Israel and abroad) provide relevant support to small and medium enterprises (SMEs). It is important to keep in mind that the focus of analysis in this work is that of the R&D impact on the Israeli economy through R&D spillovers. Other market failures are not explicitly modeled and therefore, the results above regarding the lack of spillovers from small firms are by themselves insufficient to form the basis of the mentioned stance.

[52] The economic meaning of asymmetric information was first formally analyzed in:
Akerlof, G.,1970, "The Market for Lemons: Quality Uncertainty and the Market mechanism", *Quarterly Journal of Economics*, 84 (3), 488-500.
The foundations of the theory about markets characterized by the existence of asymmetric information (including credit markets) was first presented in:
Stigler, George J., 1961, "The Economics of Information", *Journal of Political Economy*, 69 (3), 213-25.

Furthermore, one theory regarding the channels through which spillovers occur deals with the mobility of workers between firms as a central element of knowledge transfer in the economy. Workers who were exposed to knowledge in large and medium-sized firms move afterwards to other firms (and perhaps establish their own small firms) and make use of the knowledge acquired in the previous workplace. Therefore, it may be claimed that part of the spillover potential of the large and medium-sized firms depends, de facto, on the existence of small firms that absorb the knowledge acquired by workers in the research departments of the large firms.

The results obtained here are consistent with the findings of other research on the topic. In most research that focuses on estimating R&D spillovers - positive, statistically significant spillover estimates are found. Jaffe (1988) was the first to carry out this endeavor and found positive spillover effects among firms that are technologically proximate to each other in a sample of U.S. firms from the 70s[53]. Using a sample from the U.S. for the years 1987- 1994 and a similar approach, Cincera (1998) obtained estimates that were very similar to those of Jaffe[46].

Bernstein (1988) presented findings of an econometric analysis regarding the social and private returns to R&D within and between industries in Canada[54]. He identified that the social returns to investments in R&D are significantly higher than the private returns. His findings show that inter-industry spillovers are relatively small. On the other hand, intra-industry spillovers were found to be relatively high, especially in R&D intense industry branches. In a similar research, Bernstein & Nadiri (1989) found positive and significant intra-industry spillover effects in four U.S. branches[55].

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[53] Jaffe, A. B., 1988, "R&D Intensity and Productivity Growth", *Review of Economics and Statistics,* 70: pp. 431-437.

[54] Bernstein, J. I., 1988, "Costs of Production, Intra and Inter Industry R&D Spillovers: Canadian Evidence", *Canadian Journal of Economics,* 21(2), pp. 324-347

[55] Bernstein, J. I. and Nadiri, I. M., 1989, "Research and Development and Intra-Industry Spillovers: An Empirical Application of Dynamic Duality", *Review of Economic Studies, 56, pp. 249-269*.

Griliches (1992) summarized the results of econometric research on the rates of return to R&D in the U.S.: In absolute terms (percentile points), the social returns are higher than the private returns by approximately 18%-20%[56]. In relative terms, the gap between the private and social returns to R&D, due apparently to spillovers, equals to about 50% - 100% of the private return. The results obtained here show that similar differences in the rates of return are present in Israel too.

Based on U.S. and Japanese panel data, Branstetter (2001) provides estimations of the knowledge spillover effect on international and intra-national innovation and productivity at the firm level[57]. His results indicate that the spillover effects are of a local character. This result was strengthened by Cincera (1998) for the U.S.[46].

Bloom Shankerman and Van Reenen (2007) explicitly modeled two spillover effects: (1) a complementarity effect (positive) derived from spillovers of technological knowledge between firms that belong to the same technological sphere; and (2) a rivalry effect (negative) derived from increased competition between competing firms in the products' market[48]. They used panel data on U.S. firms for the years 1981-2001 and patent data to define the technological proximity between the firms. According to their findings, both effects are at work and the net social returns (after setting off both effects) are approximately 3.5 times higher than the net private returns. Excluding the rivalry effect of spillovers, they report an elasticity estimate of technological spillovers in relation to sales of 0.111. Including the rivalry effect of spillovers, the elasticity estimate of marketing spillovers (the rivalry effect) is equal to 0.009. The spillover estimates obtained here are similar to those reported in similar research.

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[56] Griliches, Z., 1992, "The Search for R&D Spillovers", *Scandinavian Journal of Economics,* 94, pp. 29-48.
[57] Branstetter, L. G., 2001, "Are Knowledge Spillovers International or Intranational in Scope? Microeconometric Evidence from the U.S. and Japan, *Journal of International Economics,* 53, pp. 53-79.

4.3. An integrated model for estimating the returns to the economy from government R&D support

This chapter presents an integrated model for estimating the returns to the economy that stem from government support to private R&D. As specified in the methodology chapter, the results of the previous chapters can be combined into one model, which enables to estimate the amount of new R&D created due to government support and its impact on the executing firms and on other firms, which benefit through knowledge spillovers.

The following table presents the results of the integrated model based on the Griliches model, assuming a government grant of NIS 5 million given to a medium-large firm (NIS 50-300 million):

Table 25:
Total returns to the economy due to R&D government support – Griliches model, medium-large firms (NIS 50-300 million), assuming a NIS 5 million government grant

In thousands of NIS and percentages

Technology intensity	Self effect	Spillover effect	Total GDP Increment to economy	Government money multiplier
High	10.9	17.7	28.6	473%
Medium-high	17.3	25.3	42.6	751%
Medium-low	38.4	32.8	71.2	1323%*
Low	39.1	7.3	46.4	828%*

* Low-technology branches – scarcity of observations

The results above show that a NIS 5 million grant to a medium-large firm creates a net effect on GDP (deducting the grant) of between 475% to 751% (the values for the medium-low and low technology branches appear to be relatively high, and we are concerned that this is due in a significant part due to scarcity of observations). However, the main finding is that for the high-technology branches were, as presented above, the vast majority of R&D expenditures are undertaken and that have been support recipients throughout the years, a multiplier of 4.7 to government money is obtained. In other words, even in branches in which the number of observations and the levels of R&D and government support are high - high and positive returns to R&D government support are obtained.

The following table displays the results of the integrated model based on the Blundell and Bond model, assuming a government grant of NIS 5 million given to a medium-large firm (NIS 50-300 million):

Table 26:
Total returns to the economy due to R&D government support – Blundell and Bond model, medium-large firms (NIS 50-300 million), assuming a NIS 5 million government grant

In thousands of NIS and percentages

Technology intensity	Self effect	Spillover effect	Total GDP Increment to economy	Government money multiplier
High	7.3	25.3	32.6	552%
Medium-high	13.8	46.4	60.3	1106%
Medium-low	26.3	51.7	78.0	1460%*
Low	32.3	10.1	42.4	748%*

* Low-technology branches – scarcity of observations

As can be seen, the R&D-return levels estimated using both models are within a reasonable range from each other. This is certainly the case regarding the high-technology branches. Therefore, we can ascertain with a high degree of confidence, that a "government money" multiplier of 5-6 fairly represents the returns to the economy that stem from R&D government support to medium-large firms.

The following two tables present the results of the integrated model assuming a government grant of NIS 5 million given to a very large firm (over NIS 300 million):

Table 27:
Total returns to the economy due to R&D government support – Griliches model, very large firms (NIS 300+ million), assuming a NIS 5 million government grant

In thousands of NIS and percentages

Technology intensity	Self effect	Spillover effect	Total GDP Increment to economy	Government money multiplier
High	10.9	2.2	13.2	163%
Medium-high	17.3	5.0	22.3	346%
Medium-low	38.4	17.2	55.6	1012%*
Low	39.1	20.1	59.2	1085%*

* Low-technology branches – scarcity of observations

Table 28:
Total returns to the economy due to R&D government support – Blundell and Bond model, very large firms (NIS 300+ million), assuming a NIS 5 million government grant

In thousands of NIS and percentages

Technology intensity	Self effect	Spillover effect	Total GDP Increment to economy	Government money multiplier
High	7.3	1.9	9.1	83%
Medium-high	13.8	5.0	18.8	276%
Medium-low	26.3	9.6	35.8	616%*
Low	32.3	1.7	33.9	579%*

* Low-technology branches – scarcity of observations

Regarding large firms too, high rates of returns on R&D government support are obtained - in the range of 83% to approximately 346% in the high and the medium-high technology branches. Therefore, we can reasonably determine a "government money" multiplier on the range of 1.5 - 2 to R&D support to very large firms.

Summarizing, we have found sound evidence of very high and positive returns to industrial R&D government support in years 1996-2003. Thus, a clear picture of the impact (in GDP terms) of many years of government policy in this context is obtained for the first time in Israel. In light of the findings, we believe that there is ample justification for the continuation of government activity in the area of R&D support to the private sector - at least at the levels that prevailed in the studied period and perhaps even at higher levels of funding.

It is important to state that the R&D rates of return presented here were calculated per gross Shekels of R&D funding, of which approximately several tens of percentage points on average are returned to the governments as royalties. Therefore, the figures presented here are lower bound multipliers of actual (net) returns.

4.3.1. Returns on R&D investments vis-à-vis investments on physical capital

The data used in this research enables us to calculate the ratios of the return on investments in R&D in relation to the return on investments in physical capital - at the economy level. By doing so, we use the calculation methodology applied also by Eckstein and Wasserteil (2006) with the objective of examining where should the economy's marginal Shekel be invested from a resources allocation viewpoint[58]. The table below presents the ratios of the return on R&D investments to the return on physical capital investments at the economy level and for returns measured in GDP terms - by technology intensity and based on the elasticity estimates obtained using both the Griliches and the Blundell and Bond models:

Table 29:
Ratios of the return on R&D investments to the return on physical capital investments at the economy level and for returns measured in GDP terms - by technology intensity based on elasticity estimates obtained using the Griliches and Blundell and Bond models

Technology intensity	Return ratio - Griliches model	Return ratio - Blundell and Bond model
High	0.96	0.87
Medium-high	5.83	7.64
Medium-low	18.56	33.95
Low	192.08	218.23

It is clear that the marginal return to R&D investments is similar to that resulting from investing in physical capital in the high-technology branches only. In the rest of the manufacturing industry, the return on R&D investments is six times and up to two hundred times higher than the return on capital investments. Here too, we would like to draw the reader's attention to the scarcity of observations in the low-technology branches. We believe that more reasonable return ratios would be of up to eight times in favor of investments in R&D. The facts show that from a resource allocation viewpoint – R&D investments are preferable in most cases over physical capital investments.

[58] Z.Ekstein, D. Wasserteil, 2006, "Productivity in the Israeli manufacturing sector: International comparison and estimates of the returns to capital and R&D investments ", E.G.P. Applied Economics Ltd., for the Office of the Chief Scientist in the Israeli Ministry of Industry, Trade and Labor.

Appendix 1: List of variables in the data bases

The source of the data used in the research was the Israeli Bureau of Statistics' surveys of the manufacturing industry and of R&D in the manufacturing industry and in the computer services, software and R&D branches. The existing variables in each survey are listed bellow by survey:

Variable	Survey
Year of survey	Manufacturing ,R&D
Industry code, 3-digits	Manufacturing ,R&D
Industry code, 2-digits	Manufacturing
Industry code, 1-digit	Manufacturing
CBS aggregated branches codes	Manufacturing
Gross output	Manufacturing
Value added = GDP	Manufacturing
Local sales	Manufacturing
Exports	Manufacturing ,R&D
Total income	Manufacturing ,R&D
Revenues and return on capital	Manufacturing
General inputs	Manufacturing
Consumption of main production inputs (purchases)	Manufacturing
Total inputs	Manufacturing
Wages (labor expenditures)	Manufacturing
Workers	Manufacturing ,R&D
Employees	Manufacturing
Work hours (man hours)	Manufacturing
Increase in product inventory	Manufacturing
Increase in materials inventory	Manufacturing
Expenditures on buildings and equipment rental	Manufacturing
Investments in fixed assets - buildings	Manufacturing
Investments in fixed assets - equipment	Manufacturing
Investments in fixed assets - vehicles	Manufacturing
Investments in fixed assets - furniture and office equipment	Manufacturing ,R&D
Investments in fixed assets - total	R&D
Investments in fixed assets - infrastructure	R&D
R&D - expenditures total	Manufacturing ,R&D
R&D - expenditures on wages (labor expenditures)	Manufacturing ,R&D
R&D - expenditures on materials	Manufacturing ,R&D
R&D - outsourcing expenditures	Manufacturing ,R&D
R&D - expenditures other	Manufacturing ,R&D
R&D - outsourcing expenditures: higher education institutions, local	R&D
R&D - outsourcing expenditures: higher education institutions, abroad	R&D
R&D - outsourcing expenditures: research institutions, local	R&D
R&D - outsourcing expenditures: other, local	R&D
R&D - outsourcing expenditures: other, abroad	R&D
R&D - depreciation expenditures	Manufacturing
R&D - expenditures on rent (buildings, equipment and storage)	Manufacturing
R&D - in-house expenditures, total	Manufacturing

Variable	Survey
R&D - in-house expenditures + external R&D financing	Manufacturing
R&D - financing from external sources, total	Manufacturing ,R&D
R&D - financing from external sources, Office of the Chief Scientist	R&D
R&D - financing from external sources, international funds	R&D
R&D - financing from external sources, government other	R&D
R&D - financing from external sources, other	R&D
R&D - workers, with academic education	R&D
R&D - workers, with technical training	R&D
R&D - workers, other	R&D
R&D - workers, total	R&D
R&D - full-time jobs	R&D
R&D - investments in fixed assets, total	R&D
R&D - investments in fixed assets, infrastructure	R&D
R&D - investments in fixed assets, machines and equipment	R&D
Ownership type (small business, private incorporated, partnership, etc.)	Manufacturing ,R&D
Sector (private, government, association)	Manufacturing ,R&D
Geographic location	Manufacturing
Napa number - Central Bureau of Statistics geographic region codes	Manufacturing
Weight in population	Manufacturing ,R&D

Notes:
*** Manufacturing = Manufacturing industry surveys; R&D = R&D in the manufacturing industry and in the computer services, software and R&D branches.**

Appendix 2: Price adjustments

a. Price indices used

The table bellow presents details about the price indices used to account and adjust for price changes in the monetary variables employed in the research. Some variables were adjusted using different indices depending on the variables' sources (manufacturing industry surveys, R&D in manufacturing surveys or R&D in the computer services, software and R&D branches). For instance, R&D investments in the manufacturing industry were adjusted using the index of price changes of investments in machinery and equipment in the manufacturing industry, while R&D investments in the computer services, software and R&D branches were adjusted using the index of price changes in machinery and equipment in the commerce and service branches. Some of the indices used here are also employed by the CBS and publicly available. For some variables we used indices especially computed in the framework of this research - bellow we describe in detail the computing procedure for these indices.

Variable	Survey	Price index used	Aggregation level
Inputs	Manufacturing	Inputs in manufacturing	2 digit
Outputs	Manufacturing	Outputs in manufacturing	2 digit
Added value = GDP	Manufacturing	Inputs & outputs in manufacturing	2 digit
Income	Manufacturing R&D in manufacturing	Outputs in manufacturing	2 digit
Income	R&D in 72, 73	Average index of outputs in manufacturing	Branches 72, 73
Investments in machinery and equipment	Manufacturing	Investments in machinery and equipment in manufacturing	Manufacturing
Investments in buildings	Manufacturing	Investments in buildings in manufacturing	Manufacturing
R&D expenditures on wages	Manufacturing R&D in manufacturing R&D in 72, 73	R&D expenditures on wages	Manufacturing or Branches 72, 73
R&D expenditures on materials	Manufacturing R&D in manufacturing	Inputs in manufacturing	2 digit
R&D expenditures on materials	R&D in 72, 73	R&D expenditures on wages	Branches 72, 73
R&D outsourcing expenditures	Manufacturing R&D in manufacturing	R&D outsourcing expenditures	1 digit
R&D outsourcing expenditures	R&D in 72, 73	R&D expenditures on wages	Branches 72, 73

Variable	Survey	Price index used	Aggregation level
R&D expenditures, other	Manufacturing R&D in manufacturing	R&D expenditures, others	1 digit
R&D expenditures, other	R&D in 72, 73	R&D expenditures on wages	Branches 72, 73
R&D expenditures, patents and external knowledge	R&D in manufacturing	R&D expenditures, others	1 digit
R&D expenditures, patents and external knowledge	R&D in 72, 73	R&D expenditures on wages	Branches 72, 73
R&D expenditures, depreciation	Manufacturing	Investments in machinery and equipments in manufacturing	Manufacturing
R&D expenditures, rent	Manufacturing	Investments in machinery and equipments in manufacturing	Manufacturing
R&D investments	R&D in manufacturing	Investments in machinery and equipments in manufacturing	Manufacturing
R&D investments	R&D in 72, 73	Investments in machinery and equipment in the commerce and services branches	Branches 72, 73
R&D funding, all types	R&D in manufacturing	R&D expenditures - composite index (weighted wage and materials expenditures)	1 digit
R&D funding, all types	R&D in 72, 73	R&D expenditures on wages	Branches 72, 73
Notes: **72 = Computer services and software branches; 73 = R&D firms branch**			

b. Price indices computed especially within the framework of the research

Price indices of output, inputs and added value (GDP) in the manufacturing industry

The prices of output, input and added value (GDP) were adjusted to 2003 prices using manufacturing output and input basic price indices. The indices were computed using the CBS's data on manufacturing input and output at current and fixed prices - at the 1 to 3 digit levels of branch aggregation.

Overall we computed six indices - an index for each variable (2 variables: input and output) at each branch aggregation level (3 levels). Below, we describe the computation procedure for one index at one aggregation level. The following data are for the aggregated branch number 1 of the manufacturing industry (it contains 9 aggregated 2-digit branches).

Branch	Year	Current NIS at basic prices		1995 NIS at basic prices	
		A	B	C	D
		Output	Input	Output	Input
1	**1995**	124,302,704	81,659,169	124,302,704	81,659,169
1	**1996**	140,976,440	92,367,211	131,261,236	86,992,602
1	**1997**	153,889,797	98,360,325	135,163,309	88,279,202
1	**1998**	168,626,288	106,488,977	142,468,463	92,908,265
1	**1999**	184,532,625	116,846,496	145,899,828	96,233,656
1	**2000**	207,019,286	131,868,970	161,392,585	104,052,855
1	**2001**	197,024,917	128,899,832	153,531,762	102,317,726
1	**2002**	204,018,090	136,365,374	148,840,420	100,650,155
1	**2003**	205,790,189	136,465,988	147,567,235	96,576,962

The first step is to divide columns A and B by columns C and D respectively in each year (row) so as to obtain the change in prices in each year relative to 1995 prices. The following values are obtained:

Branch	Year	Index of basic price changes relative to 1995 prices	
		E	F
		Output	Input
1	**1995**	**100%**	**100%**
1	**1996**	107%	106%
1	**1997**	114%	111%
1	**1998**	118%	115%
1	**1999**	126%	121%
1	**2000**	128%	127%
1	**2001**	128%	126%
1	**2002**	137%	135%
1	**2003**	139%	141%

In order to obtain price indices with the year 2003 as the base year, each value (row) in the table above (each branch in each year) should be divided by the value corresponding to year 2003, thus obtaining:

Branch	Year	Index of basic price changes relative to 2003 prices	
		G	H
		Output	Input
1	**1995**	72%	71%
1	**1996**	77%	75%
1	**1997**	82%	79%
1	**1998**	85%	81%
1	**1999**	91%	86%
1	**2000**	92%	90%
1	**2001**	92%	89%
1	**2002**	98%	96%
1	**2003**	**100%**	**100%**

The output and input data were adjusted using the relevant indices while the adjusted added value (GDP) data were computed by subtracting the adjusted input data from the adjusted output data.

As stated, price indices were computed for each aggregation level and ideally, the values at any given aggregation level should be adjusted using indices specific to the relevant level: Firm level data should be adjusted using 3-digit aggregation price indices, 2-digit branch data should be adjusted using 2-digit price indices, and so forth. In spite of that, we adjusted prices of firm-level data using 2-digit aggregation price indices. There are two reasons for this:

First, at several 3-digit branches there are no data that allow the computation of the indices for all years in the sample. This is because at this level of aggregation (3-digits) often the "branch" in the sample includes a very small number of establishments (firms) and sometime a single one. Because of this, when this small number of establishments (or a single establishment) does not appear in the sample in a given year, the whole 3-digit branch "disappears" from the data on that year - and so does the possibility of computing the 3-digit level price index for that specific branch. Establishments may not appear in the sample because of technical reasons as responding too late to the CBS requests for information, or because of other reasons more economic in nature - e.g. changes in ownership, going out of business, etc.

Second, because at different stages throughout the research we compute and show results at various levels of aggregation, mainly aggregation by technological intensity. We believe that the choice to use price indices at the 2-digit aggregation level is a reasonable one in terms of the tradeoff between accuracy and efficiency, given the workload that would have been involved in adjusting prices for each aggregation level addressed.

Adjusting income prices

The income data in the manufacturing industry were adjusted using the price indices of output in the manufacturing industry, at the 2-digit aggregation level. We did this since as far as we know, there is no defined methodology at the CBS for adjusting of income prices, and it is our belief that the output price data are the closest to the income data.

The income data in the computer services, software and R&D branches were adjusted using the price indices of output in the manufacturing industry, at the whole industry aggregation level. This was done because to the best of our knowledge there are no price data for these branches either for output or income.

Adjusting R&D expenditure prices

Current R&D expenditures of firms are comprised of wage expenditures - which account for about 70% of total R&D expenditures, expenditures on materials, outsourcing expenditures and other types of expenditures. In regard to the manufacturing industry data, and in consultation with CBS personnel, we computed separate price indices for each type of expenditure: The price adjusted R&D expenditures on each year are defined as the sum of all separately adjusted types of R&D expenditures. As for the computing services, software and R&D branches, all types of expenditures were adjusted using a wage price index computed by us.

As well, we computed a composite price index of all types of R&D expenditures in the manufacturing industry at the 1-digit aggregation level, weighted by the share of each type of R&D expenditures in total R&D expenditures. Below, we present a detailed description of the indices.

Price index of R&D expenditures on wages

Following is the definition of the index that serves to match R&D wages to 2003 terms:

$$PI_t^W = \frac{\dfrac{\sum_i R\&DExpenditureOnWages_{i,t}}{\sum_i R\&DFullTimeJobs_{i,t}}}{\dfrac{\sum_i R\&DExpenditureOnWages_{i,2003}}{\sum_i R\&DFullTimeJobs_{i,2003}}}$$

where:

t = year

i = establishment.

We tried computing indices at the 2 and 3 digit aggregation levels, but because of scarcity of observations in the more traditional industries in the R&D surveys, we had to settle for the computation of the index at the aggregation level of the whole manufacturing industry or the computer services, software and R&D branches together.

In the manufacturing industry survey of 1996 there was no reporting of R&D full-time jobs. We overcame this by means of extrapolating backwards the 1997 full-time jobs figures using the average change in R&D workers throughout the whole period. We tested whether it was reasonable to use the extrapolated figures and obtained satisfactory results: (1) The jobs-workers ratio is relatively stable throughout the sample period; (2) the correlation between the annual percentage change of workers and jobs is 0.43 - high for percentage-change-type figures; (3) the correlation between the annual workers and jobs data is 0.97. It should be noted that out of 186 establishments that appear in the sample in 1996, only 47 continue to appear in 1997. Because of this, the average job wage for 1996 was computed using 76 observations out of 186.

Price index of R&D expenditures on materials

The adjustment of R&D material prices in the manufacturing industry is done using the price indices of inputs in the manufacturing industry at the 1-digit aggregation level (3 branches):

$$PI_{t,j}^{Mat} \quad \text{(t = year; j = 1, 2, 3)}$$

In chapter "Price indices of output, inputs and added value (GDP) in the manufacturing industry" above it is explained how to compute the price indices of materials using the data on inputs at basic prices in the manufacturing industry. We use the 1-digit aggregation level because of scarcity of observations in the more traditional industries in the R&D surveys at the 2 or 3 digit levels.

Price index of R&D other expenditures

We computed a weighted composite index of the R&D wage and materials price indices in the manufacturing industries, weighted by their share in total expenditures:

$$PI_{t,j}^{Other} = \alpha_t \cdot PI_t^W + \beta_t \cdot PI_{t,j}^{Mat}$$

where:

$$\alpha_t = \frac{\sum_i RDExpendOnWages_{i,t}}{\sum_i RDExpendOnWages_{i,t} + \sum_i RDExpendOnMater_{i,t}} \quad \text{and } \beta_t = 1 - \alpha_t$$

t = year.
j = aggregate branch at the 1-digit level (3 branches).
i = establishment.

The computation of the above weighted index is based on the assumption that "other" R&D expenditures are comprised of a combination of expenditures on wages and materials.

We use the 1-digit aggregation level because of scarcity of observations in the more traditional industries in the R&D surveys at the 2 or 3 digit levels.

Price index of R&D outsourcing expenditures

We computed a weighted composite index of the R&D wage, materials and other price indices in the manufacturing industries, weighted by their share in total expenditures:

$$PI_{t,j}^{Out} = \alpha'_t \cdot PI_t^W + \beta'_t \cdot PI_{t,j}^{Mat} + \gamma'_t \cdot PI_{t,j}^{Other}$$
$$= PI_{t,j}^{Out} = \alpha'_t \cdot PI_t^W + \beta'_t \cdot PI_{t,j}^{Mat} + \gamma'_t \cdot \left[\alpha_t \cdot PI_t^W + \beta_t \cdot PI_{t,j}^{Mat}\right]$$

where:

$$\alpha'_t = \frac{\sum_i RDExpendOnWages_{t,i}}{\sum_i RDExpendOnWages_{t,i} + \sum_i RDExpendOnMater_{t,i} + \sum_i RDExpendOnOther_{t,i}},$$

$$\beta'_t = \frac{\sum_i RDExpendOnMater_{t,i}}{\sum_i RDExpendOnWages_{t,i} + \sum_i RDExpendOnMater_{t,i} + \sum_i RDExpendOnOther_{t,i}}$$

and $\gamma'_t = 1 - \alpha'_t - \beta'_t$

t = year.

j = aggregate branch at the 1-digit level (3 branches).

i = establishment.

The computation of the above weighted index is based on the assumption that outsourcing R&D expenditures are comprised of a combination of expenditures on wages, materials and other R&D expenditures.

We use the 1-digit aggregation level because of scarcity of observations in the more traditional industries in the R&D surveys at the 2 or 3 digit levels.

Composite price index of all types of R&D expenditures in the manufacturing industry

Below, we define a weighted composite price index of all types of R&D expenditures in the manufacturing industry. The weights of the index are the shares of each type of R&D expenditure in total R&D expenditures:

$$PI_{t,j}^{All} = \alpha''_t \cdot PI_t^W + \beta''_t \cdot PI_{t,j}^{Mat} + \gamma''_t \cdot PI_{t,j}^{Other} + \delta''_t \cdot PI_{t,j}^{Out}$$

where:

t = year.

j = aggregate branch at the 1-digit level (3 branches).

i = establishment.

$$\alpha''_t = \frac{\sum_i RDExpendOnWages_{t,i}}{\sum_i RDExpendOnWages_{t,i} + \sum_i RDExpendOnMater_{t,i} + \sum_i RDExpendOnOther_{t,i} + \sum_i RDExpendOnOut_{t,i}}$$

$$\beta''_t = \frac{\sum_i RDExpendOnMater_{t,i}}{\sum_i RDExpendOnWages_{t,i} + \sum_i RDExpendOnMater_{t,i} + \sum_i RDExpendOnOther_{t,i} + \sum_i RDExpendOnOut_{t,i}}$$

$$\gamma''_t = \frac{\sum_i RDExpendOnOther_{t,i}}{\sum_i RDExpendOnWages_{t,i} + \sum_i RDExpendOnMater_{t,i} + \sum_i RDExpendOnOther_{t,i} + \sum_i RDExpendOnOut_{t,i}}$$

and $\delta''_t = 1 - \alpha''_t - \beta''_t - \gamma'_t$

Relation between the composite price index of all R&D expenditures and the price indices of other and outsourcing R&D expenditures

The composite price index of all R&D expenditures, the price index of outsourcing R&D expenditures and the price index of other R&D expenditures are equal under the assumptions above - that is:

$$PI_{t,j}^{Other} = PI_{t,j}^{Out} = PI_{t,j}^{All}$$

The following algebraic proof shows that the identity between the price indices of outsourcing and other R&D expenditures holds under the above assumptions. The proof for the composite index is similar:

$$PI_{t,j}^{Out} = \alpha'_t \cdot PI_{t,j}^{W} + \beta'_t \cdot PI_{t,j}^{Mat} + \gamma'_t \cdot PI_{t,j}^{Other}$$

$$= \alpha'_t \cdot PI_{t,j}^{W} + \beta'_t \cdot PI_{t,j}^{Mat} + \gamma'_t \cdot \left[\alpha_t \cdot PI_{t,j}^{W} + \beta_t \cdot PI_{t,j}^{Mat}\right]$$

$$\underbrace{\left[\alpha'_t + \gamma'_t\, \alpha_t\right]}_{\alpha_t} \cdot PI_{t,j}^{W} + \underbrace{\left[\beta'_t + \gamma'_t\, \beta_t\right]}_{\beta_t} \cdot PI_{t,j}^{Mat} = PI_{t,j}^{Other}$$

$$\Updownarrow$$

$$\alpha_t = \alpha'_t + \gamma'_t\, \alpha_t$$

$$\Updownarrow$$

$$1 = \frac{\alpha'_t}{\alpha_t} + \gamma'_t$$

$$\Updownarrow$$

$$1 = \frac{\dfrac{\sum_i RDExpendOnWages_{t,i}}{\sum_i RDExpendOnWages_{t,i} + \sum_i RDExpendOnMater_{t,i} + \sum_i RDExpendOnOther_{t,i}}}{\dfrac{\sum_i RDExpendOnWages_{t,i}}{\sum_i RDExpendOnWages_{t,i} + \sum_i RDExpendOnMater_{t,i}}} + \gamma'_t$$

$$\Updownarrow$$

$$1 = \frac{\sum_i RDExpendOnWages_{t,i} + \sum_i RDExpendOnMater_{t,i}}{\sum_i RDExpendOnWages_{t,i} + \sum_i RDExpendOnMater_{t,i} + \sum_i RDExpendOnOther_{t,i}} + \gamma'_t$$

$$1 = \alpha'_t + \beta'_t + \gamma'_t = 1$$

And the same applies for $\beta_t = \beta'_t + \gamma'_t\, \beta$

Appendix 3: Building capital series

Below, we describe the methodology for the computation of the (physical) capital and R&D capital stock series that are used throughout the research. The methodology is the same for both types of capital, besides that investments in fixed assets are accumulated to form physical capital, while R&D expenditures are summed through time to form the R&D capital series. Naturally, the rate of capital depreciation assumed for each type of capital is different.

The capital and R&D capital stocks of each establishment, at each point in time are defined as:

$$
\begin{aligned}
S_t &= (1-\delta)S_{t-1} + I_{t-1} \\
&= (1-\delta)^2 S_{t-2} + (1-\delta)I_{t-2} + I_{t-1} \\
&= (1-\delta)^{t-1} S_1 + \sum_{j=1}^{t-1}(1-\delta)^{j-1} I_{t-j}
\end{aligned}
$$

where:

S_t = Capital or R&D capital stock at year t and in fixed prices.

S_1 = Capital or R&D capital stock in the first year of the sample and in fixed prices.

I_t = Investments in fixed capital or expenditures and investments in R&D on year t and in fixed prices (henceforth: investments).

δ = Depreciation rate of either capital or R&D capital.

Note that:

$$S_1 = (1-\delta)S_0 + I_0 \sum_{j=0}^{\infty}(1-\delta)^j I_{0-j}$$

In order to estimate S_1 which is unknown, we assume a constant growth rate of investments, g:

$$I_0 = (1+g)I_{0-1} = (1+g)^j I_{0-j}$$

And so it is possible to express the investments at any given point in time as a function of initial investments, I_0:

$$I_{0-j} = (1+g)^{-j} I_0$$

And then,

$$S_1 = (1-\delta)S_0 + I_0 = \sum_{j=0}^{\infty}\left[\frac{1-\delta}{1+g}\right]^j I_0 = \frac{1+g}{g+\delta} I_0 = \frac{1}{g+\delta} I_1$$

The growth rate of investments g was estimated using the following linear OCS regression:

$$Log(I_t) = \alpha_0 + d_{1997} + d_{1998} + ... + d_{2002} + d_{2003},$$

where $d_{1997},..., d_{2003}$ are year dummy variables.

And then the average rate of growth each year t is given by:

$$\frac{I_t}{I_{t-1}} = \frac{e^{\alpha_0 + d_t}}{e^{\alpha_0 + d_{t-1}}} = \frac{e^{d_t}}{e^{d_{t-1}}}$$

And by averaging across years within technology intensity categories we obtained the following growth rates of investments:

Technology intensity	Investments - manufacturing industry surveys	R&D expenditures & investments - R&D in the manufacturing industry surveys
High	12.037%	5.098%
Medium high	5.316%	-4.949%*
Medium low	-1.809%	0.885%
Low	4.486%	52.039%*
*** Unreasonable estimates. For this reason, in the case of the medium high-tech we use an estimate of 3% - which is between the estimates in the high and medium low-tech groups. In the case of low-tech, we use the same estimate as in medium-low-tech.**		

In the manufacturing industry surveys the average for the whole industry is 4.7%. This figure is consistent with data from the Bank of Israel which indicate that between 1973 and 2003 the average growth rate of investments in the manufacturing industry was approximately 4.5%.

We also attempted at calculating simple growth rates at the establishment level, at the 1 and 2 digit aggregation levels and within groups of technology intensity. Unfortunately, the investments data volatility does not allow for his type of computations at those low levels of aggregation. The method we used (described above) enabled us to obtain reasonable estimates that incorporate the high variance in the data and allow the classification by technology categories.

The estimation of capital stocks according to the methodology described above necessitates continuous investments data beginning on the first year in which establishments appear in the data and up to the last. Both in the manufacturing industry surveys and in the R&D in the manufacturing industry surveys there are establishments that do not fulfill this criterion - that is, establishments that "disappear" from the data one or more consecutive years and then "reappear" later on in the sample.

In order to compute the capital stocks of these establishments for the years after they "reappear" in the sample, we estimated their investments in the years that these are missing from the data using the following algorithm:

Starting from the first year t that the establishment "disappears" from the sample:

$$I_t^m = I_{t-1} + \left[\frac{(I_{t-1+k+1} - I_{t-1})}{(t-1+k+1)-(t-1)}\right] = I_{t-1} + \left[\frac{(I_{t-1+k} - I_{t-1})}{k+1}\right]$$

where:

I_t^m = Estimate of the establishment investments on the years that it "disappears" from the data.

t = The first year when the establishment "disappears" from the sample.

k = Total number of years that the establishment "disappears".

And the computation is repeated for all years that the establishment "disappears" from the data where t and k are updated on each new computation. That is, after estimating the investments for the first year that an establishment disappeared, the second year that the establishment does not appear in the data becomes the first one. Accordingly k decreases by 1 each time that a missing investment data point is "filled in" with an investments estimate.

We reiterate that the investments estimated are used only to estimate the capital stocks of establishments after they disappear from the sample. After using the investments estimates for this purpose we delete them from the files.

The described methodology may be applied for building both physical capital stocks and R&D capital stocks. Naturally, for each type of stock the type of investments and expenditures required differ. As well, each type of stock requires different assumptions about the number of years through which the stock depreciates (i.e. the depreciation rate). The following table shows for each type of capital stock (physical capital or R&D capital) the respective types of investments or expenditures that comprise them and the respective depreciation rates assumed:

Investments and expenditures used for the computation of capital stocks		
Capital stock Manufacturing industry surveys data	**R&D capital stock Manufacturing industry surveys data**	**R&D capital stock R&D in Manufacturing industry surveys data**
Investments in equipment Investments in machinery	R&D expenditures on wages R&D expenditures on materials R&D outsourcing expenditures R&D other expenditures R&D expenditures on depreciation R&D expenditures on rent	R&D expenditures on wages R&D expenditures on materials R&D outsourcing expenditures R&D other expenditures R&D expenditures on patents R&D investments
Assumptions about depreciation years		
10 $\Rightarrow$ depreciation rate =1/10	7 $\Rightarrow$ depreciation rate =1/7	7 $\Rightarrow$ depreciation rate =1/7

Appendix 4: Issue of double counting R&D activity

The estimation of production functions that include R&D expenses or R&D capital stock as an explanatory variable may give way to the problem of "double counting" the R&D activity impact on the explained variable. This double counting may stem from two sources: First when workers (an explanatory variable) data include both general workers in the firm and also R&D workers. In this case, the R&D impact on the explained variable will stem once from the R&D workers (included in the count of total workers) and a second time from the R&D expenditures explanatory variable. The second instance when double counting might occur is when firms' investments data, with which the physical capital stock is created (an explanatory variable), and the R&D expenditures, and thus the R&D capital stock, include both R&D physical investments.

By definition, the relevant explanatory variables used in this research might induce the type of double counting of the R&D impacts described. Specifically, regarding the manufacturing industry survey data, it is not possible to separate the relevant variables' components as required, and so there is no way of avoiding the double counting problem. It is therefore recommended that in upcoming surveys, data on R&D workers and investments is collected separately from overall data on workers and investments. Nevertheless, results from tests we conducted allow us to confidently conclude that the double counting impact in the data used here is negligible. This is because in the manufacturing industry, both the physical investments in R&D and the number of R&D workers are very low relative to total investments and workers.

Appendix 5: Merging the data from the manufacturing industry surveys and the R&D in manufacturing surveys

The estimation of the R&D spillover effects was done through the estimation of various production functions (see chapter 2.2 above). The data used for the estimation includes data from the manufacturing industry surveys and the R&D in manufacturing surveys of establishments that could be identified in both sets of data in years 1996 - 2003.

The surveys of R&D in the manufacturing industry include mainly data about R&D expenditures and funding, while the surveys of the manufacturing industry include a broader set of economic variables, for example, added value (GDP), investments and R&D expenditures as well. But the R&D data from the manufacturing industry surveys are often less accurate or missing. Because of this reason and because R&D is the focus of this research, the estimation if the spillover effects was conducted using the manufacturing industry surveys with R&D data updated from the R&D surveys in the manufacturing industry.

First, the data from the R&D in manufacturing surveys was merged into the manufacturing industry surveys data using the identification variable "new establishment number" (CBS establishment identification code for surveys from 1995 onwards) and year. The R&D data from the manufacturing survey were then updated using the R&D data from the R&D in manufacturing survey in the following manner:

- On instances where both data sources had non-missing R&D expenditures values: R&D expenditures from the manufacturing surveys were updated with the data from the R&D in manufacturing surveys.
- On instances where there were non-missing R&D expenditures values only from the R&D in manufacturing surveys: These values were updated into the manufacturing surveys data.
- On instances where there were non-missing R&D expenditures values only from the manufacturing surveys (a minority of instances): These values were used.

- Establishments that appeared in the R&D in manufacturing surveys data but not in the manufacturing surveys data: Were deleted from the sample because they lacked data on added value (GDP) and physical capital - respectively the explained and explanatory variables in the models estimated.

After adjusting the units of measurement (thousands, millions, etc.) and prices of all R&D expenditures components (wages, materials, outsourcing, other), separately for each component, each establishment's R&D expenditures and investments were summed up into a total R&D expenditures variable in fixed prices. The following table presents in detail which price index was used to adjust each R&D expenditure component to 2003 prices:

Type of R&D expenditures	Survey	Price index used for adjusting prices[59]
Wage	- R&D in manufacturing - Manufacturing	Price index of R&D expenditures on wage. Computed in the framework of this research.
Materials	- R&D in manufacturing - Manufacturing	Price index of manufacturing inputs at the 2-digit aggregation level.
Outsourcing	- R&D in manufacturing - Manufacturing	Composite weighted index of R&D expenditures on wages and materials at the 1-digit aggregation level. Computed in the framework of this research.
Other	- R&D in manufacturing - Manufacturing	Composite weighted index of R&D expenditures on wages and materials at the 1-digit aggregation level. Computed in the framework of this research.
Investments	- R&D in manufacturing	Price index of equipment in the manufacturing industry.
Patents	- R&D in manufacturing	Composite weighted index of R&D expenditures on wages and materials at the 1-digit aggregation level. Computed in the framework of this research.
Depreciation	- Manufacturing	Price index of machinery and equipment in the manufacturing industry.
Rent (linked to R&D)	- Manufacturing	Price index of machinery and equipment in the manufacturing industry.

On instances where the establishments' industry code did not match at the 2-digit level between both data sources, the code kept was that from the R&D in manufacturing surveys.

[59] See appendix 2 above for further details regarding the price indices and their computation.

Appendix 6: Griliches model

The model

We assume a production function of the following form:

$$(1) \qquad va_{it} = \alpha + \beta^{l} \cdot l_{it} + \beta^{k} \cdot k_{it} + \beta^{rds} \cdot rds_{it} + \beta^{rdso} \cdot rdso_{it} + \varepsilon_{it}$$

where:

i = establishment; t = year; va = log of value added (GDP); l = log of the number of workers; k = log of (physical) capital stock; rds = log of own R&D capital stock; $rdso$ = log of other establishments' R&D capital stock; α , β^{l} , β^{k} β^{rdso} , β^{rds} ,are the variables coefficients respectively; ε = random error.

The physical and R&D capital stocks evolves as follows[60]:

$$S_{it} = (1-\delta) \cdot S_{it-1} + I_{it-1}$$

where:

S = level of physical or R&D capital stock; I = level of investments in fixed assets in the case of physical capital or R&D expenditures and investments in the case of R&D capital stock; δ = rate of capital depreciation.

For any firm m , other firms' R&D capital stock $RDSO$, is the sum of all firms own R&D capital sock RDS, besides the given firm's own:

[60] See appendix 3 for details about the computation of the physical and R&D capital stocks.

$$RDSO_{mt} = \sum_{j \neq m}^{i} RDS_{jt}$$

Econometric estimation

We estimated equation (1) above using as instrumental variables for the log of workers the lagged log of workers and the lagged log of added value (GDP), and including dummy variables for the year and for the 2-digit industrial branch and the size (by level of income) of the establishments. Also, the others R&D capital stock, $RDSO$, was computed separately within technology intensity categories (low-tech, medium low-tech, medium high-tech, high-tech) and size groups by income (NIS million: up to 50, 50-300, over 300)[61].

[61] See appendix 8 that contains the estimated equation and results.

Appendix 7: Blundell and Bond model[62]

We assume a production function of the following form:

$$(1) \qquad va_{it} = \alpha + \beta^l \cdot l_{it} + \beta^k \cdot k_{it} + \omega_{it} + \varepsilon_{it}$$

where:

i = establishment; t = year; va = log of value added (GDP); l = log of the number of workers; k = log of (physical) capital stock; α , β^l , β^k are the variables coefficients respectively; ε = random error.

The physical capital stock evolves as follows[63]:

$$K_{it} = (1-\delta) \cdot K_{it-1} + I_{it-1}$$

where:

K = level of physical capital stock; I = level of investments in fixed assets; δ = rate of capital depreciation.

ω represents the productivity of the production process (or knowledge) and we assume the it evolves through time as a function of each firm's own R&D and the stock of other firms' R&D, as a controlled first-order Markov process:

[62] This appendix is based on:
Blundell, R. and Bond, S., 2000, "GMM Estimation with Persistent Panel Data: An Application to Production Functions", *Econometric Reviews,* 19(3), 321-340.

[63] See appendix 3 for details about the computation of the physical and R&D capital stocks.

(2) $$\omega_{it} = \rho \cdot \omega_{it-1} + \beta^{rd} \cdot rd_{it-1} + \beta^{rdso} \cdot rdo_{it-1} + \xi_{it}$$

where:

rd = log of own R&D; rdo = log of other firms R&D; β^{rd} β^{rdo}, are the variables coefficients respectively; ξ = random error.

For any firm m, other firms' R&D, RDO, is the sum of all firms own R&D, RD, besides the given firm's own:

$$RDO_{mt} = \sum_{j \neq k}^{i} RD_{jt}$$

In order to estimate the production function in a semi-difference fashion we'll write equation (1) in lags and multiply by ρ, to get:

(3) $$\rho \cdot va_{it-1} = \rho \cdot \alpha + \rho \cdot \beta^{l} \cdot l_{it-1} + \rho \cdot \beta^{k} \cdot k_{it-1} + \rho \cdot \omega_{it-1} + \rho \cdot \varepsilon_{it-1}$$

Subtracting equation (3) from equation (1) results in the following differences equation:

(4)
$$va_{t} - \rho \cdot va_{it-1} = \alpha \cdot (1-\rho) + \beta^{l} \cdot (l_{it} - \rho \cdot l_{it-1}) + \beta^{k}(k_{it} - \rho \cdot k_{it-1}) + [\omega_{it} - \rho \cdot \omega_{it-1}] + [\varepsilon_{it} - \rho \cdot \varepsilon_{it-1}]$$

We'll insert the productivity equation (2) in the differences equation (4):

$$va_{t} - \rho \cdot va_{it-1} = \alpha \cdot (1-\rho) + \beta^{l} \cdot (l_{it} - \rho \cdot l_{it-1}) + \beta^{k}(k_{it} - \rho \cdot k_{it-1}) + [(\rho \cdot \omega_{it-1} + \beta^{rd} \cdot rd_{it-1} + \beta^{rdo} \cdot rdo_{it-1} + \xi_{it}) - \rho \cdot \omega_{it-1}] + [\varepsilon_{it} - \rho \cdot \varepsilon_{it-1}]$$
$$\Downarrow$$
$$va_{t} - \rho \cdot va_{it-1} = \alpha \cdot (1-\rho) + \beta^{l} \cdot (l_{it} - \rho \cdot l_{it-1}) + \beta^{k}(k_{it} - \rho \cdot k_{it-1}) + \beta^{rd} \cdot rd_{it-1} + \beta^{rdo} \cdot rdo_{it-1} + [\varepsilon_{it} - \rho \cdot \varepsilon_{it-1} + \xi_{it}]$$

$$\Downarrow$$

(5) $$va_t - \rho \cdot va_{it-1} = \alpha' + \beta^l \cdot \left(l_{it} - \rho \cdot l_{it-1}\right) + \beta^k \left(k_{it} - \rho \cdot k_{it-1}\right) + \beta^{rd} \cdot rd_{it-1} + \beta^{rdo} \cdot rdo_{it-1} + \varepsilon_{it}'$$

where:

$$\alpha \cdot (1 - \rho) = \alpha'$$

$$\varepsilon_{it} - \rho \cdot \varepsilon_{it-1} + \xi_{it} = \varepsilon_{it}'$$

Econometric estimation

We estimated equation (5) above using a series of positive ρ values such that $0 \le \rho \le 1$. For each value we keep the fitness of match index and choose the value that results in the best fitness of the model to the data. This procedure is known as "grid search" in the research literature. We did this using as instrumental variables for the log of workers the lagged log of workers, and including dummy variables for the year and for the 2-digit industrial branch and the size (by level of income) of the establishments. Also, the others R&D, RDO, was computed separately within technology intensity categories (low-tech, medium-low-tech, medium-high-tech, high-tech) and size groups by income (NIS million: up to 50, 50-300, over 300)[64].

[64] See appendix 9 that contains the estimated equation and results.

Appendix 8: Estimation output - Griliches production function

IV - 2SLS regression for the estimation of the R&D direct and spillover impact on the manufacturing industry added value (GDP)[65]:

$$va_{it} = \alpha + \beta^{l} \cdot l_{it} + \beta^{k} \cdot k_{it} + \beta^{rds} \cdot rds_{it} + \sum^{Size} \beta_j^{rdso} \cdot rdso_{jt} + \sum^{Branch2D} D_j^b \cdot b_{ji} + \sum^{Year} D_j^y \cdot y_j + \sum^{Size} D_j^s \cdot s_{ji} + \varepsilon_{it}$$

where:

i = establishment; t = year; va = log of value added (GDP); l = log of the number of workers; k = log of (physical) capital stock; rds = log of own R&D capital stock; $rdso$ = log of other establishments R&D capital stock; b = 2-digit industry branch dummy variable; y = year dummy variable; s = group size dummy variable; α , β^l , β^k β^{rdso} , β^{rds},, D_j^b , D_j^y , D_j^s are the variables coefficients respectively; ε = random error.

```
IV (2SLS) regression with robust standard errors       Number of obs =      998
                                                       F( 27,    265) =        .
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.9001
Number of clusters (mifal) = 266                       Root MSE      =  .44226

------------------------------------------------------------------------------
             |               Robust
va           |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
l            |   .6016598   .0533572    11.28   0.000     .4966017    .7067178
k            |   .1306973   .0305832     4.27   0.000     .0704804    .1909143
rds          |   .1099015   .0229163     4.80   0.000     .0647804    .1550227
rdso1        |   .0285477   .0286004     1.00   0.319    -.0277652    .0848606
rdso2        |   .0908256    .043996     2.06   0.040     .0041994    .1774519
rdso3        |   .0365122   .0105062     3.48   0.001      .015826    .0571985
b13          |  -.3768956   .3713137    -1.02   0.311    -1.107996    .3542049
```

[65] Appendix 6 above contains the algebraic foundations of the model.

```
b14          |  -.3671303   .1417476   -2.59   0.010    -.6462251   -.0880354
b16          |  -.4286321   .1029035   -4.17   0.000    -.6312446   -.2260196
b17          |  -.6895376   .1174345   -5.87   0.000    -.9207609   -.4583143
b18          |  (dropped)
b19          |  (dropped)
b20          |  (dropped)
b21          |  (dropped)
b22          |  (dropped)
b23          |  -1.063871   .2449736   -4.34   0.000    -1.546213   -.5815286
b25          |  -.8093411   .1896938   -4.27   0.000     -1.18284   -.4358423
b26          |  -.6032874   .2308775   -2.61   0.009    -1.057875   -.1486997
b27          |  -.6125493   .2707157   -2.26   0.024    -1.145577   -.0795219
b28          |  -.7884579   .2051164   -3.84   0.000    -1.192323   -.3845926
b29          |  -1.117444   .2362598   -4.73   0.000     -1.58263   -.6522592
b31          |   -.998414   .2332472   -4.28   0.000    -1.457667   -.5391606
b32          |  -1.169633   .3149889   -3.71   0.000    -1.789832   -.5494332
b33          |  -.9532259   .2895505   -3.29   0.001    -1.523338   -.3831136
b34          |  -1.030145   .2843944   -3.62   0.000    -1.590105   -.4701844
b35          |  -1.059793   .2667175   -3.97   0.000    -1.584948   -.5346376
b36          |  -.5641501   .0981385   -5.75   0.000    -.7573805   -.3709197
b38          |  (dropped)
b39          |  -.6070887   .2273277   -2.67   0.008    -1.054687   -.1594904
y98          |   .0049346   .0419549    0.12   0.906    -.0776727     .087542
y99          |  -.0203016   .0411148   -0.49   0.622    -.1012548    .0606516
y00          |   .0256786   .0357654    0.72   0.473    -.0447418    .0960991
y01          |  (dropped)
y02          |  -.0197307   .0355004   -0.56   0.579    -.0896294    .0501679
y03          |   .0487966   .0385319    1.27   0.206    -.0270711    .1246643
s2           |   .4996494   .0643279    7.77   0.000     .3729905    .6263083
s3           |   1.136003   .1383605    8.21   0.000      .863577    1.408429
_cons        |   5.101782     .30729   16.60   0.000     4.496741    5.706822
------------------------------------------------------------------------------
Instrumented:  l
Instruments:   k rds rdso1 rdso2 rdso3 b13 b14 b16 b17
               b18 b19 b20 b21 b22 b23 b25 b26 b27 b28 b29 b31 b32 b33 b34 b35
               b36 b38 b39 y98 y99 y00 y01 y02 y03 s2 s3 l_lag1 va_lag1
------------------------------------------------------------------------------
```

l_lag1 = log of the number of workers lagged one period.

va_lag1 = log of value added (GDP) lagged one period.

Appendix 9: Estimation output - Blundell and Bond 1998 production function

IV - 2SLS regression for the estimation of the R&D direct and spillover impact on the manufacturing industry added value (GDP) [66]:

$$\underbrace{va_t - \rho\cdot va_{it-1}}_{Diff\_va} = \alpha' + \beta^l \cdot \underbrace{\left(l_{it}-\rho\cdot l_{it-1}\right)}_{Diff\_l} + \beta^k \underbrace{\left(k_{it}-\rho\cdot k_{it-1}\right)}_{Diff\_k} + \beta^{rd}\cdot \underbrace{rd_{it-1}}_{rd\_lag1} + \sum^{Size} \beta_j^{rdo}\cdot \underbrace{rdo_{jt-1}}_{rdo\_lag1} + \sum^{Branch2D} D_j^b \cdot b_{ji} + \sum^{Year} D_j^y\cdot y_j + \sum^{Size} D_j^s \cdot s_{ji} + \varepsilon_{it}'$$

where:

$\rho = 0.55$;

i = establishment; t = year; va = log of value added (GDP); l = log of the number of workers; k = log of (physical) capital stock; rd = log of own R&D; rdo = log of other firms R&D; b = 2-digit industry branch dummy variable; y = year dummy variable; s = group size dummy variable; α' , β^l , β^k, β^{rd} β^{rdo},, D_j^b , D_j^y , D_j^s are the variables coefficients respectively; ε = random error.

```
IV (2SLS) regression with robust standard errors       Number of obs =      761
                                                       F( 27,    221) =        .
                                                       Prob > F      =   0.0000
                                                       R-squared     =   0.7666
Number of clusters (mifal) = 222                       Root MSE      =   .34492

------------------------------------------------------------------------------
             |               Robust
       ytemp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      Diff_l |   .4805314   .0843042     5.70   0.000     .3143885    .6466744
      Diff_k |   .1642525   .0431147     3.81   0.000     .0792839     .249221
     rd_lag1 |   .0412477   .0129555     3.18   0.002     .0157155    .0667798
   rdo1_lag1 |  -.0001002   .0172746    -0.01   0.995    -.0341442    .0339439
```

[66] Appendix 7 above contains the algebraic foundations of the model.

rdo2_lag1	.0764935	.0253188	3.02	0.003	.0265964	.1263907
rdo3_lag1	.020391	.0130288	1.57	0.119	-.0052856	.0460675
b13	.0030594	.1812945	0.02	0.987	-.3542279	.3603468
b14	.1164557	.1070491	1.09	0.278	-.0945119	.3274233
b16	(dropped)					
b17	.0383957	.0469991	0.82	0.415	-.0542281	.1310195
b18	(dropped)					
b19	(dropped)					
b20	(dropped)					
b21	(dropped)					
b22	(dropped)					
b23	-.2546243	.13553	-1.88	0.062	-.5217209	.0124722
b25	-.129799	.1132666	-1.15	0.253	-.3530198	.0934219
b26	-.0317037	.1385656	-0.23	0.819	-.3047826	.2413753
b27	-.0889538	.1222506	-0.73	0.468	-.3298799	.1519723
b28	-.1111956	.1070155	-1.04	0.300	-.322097	.0997059
b29	-.241093	.156209	-1.54	0.124	-.548943	.0667569
b31	-.1981464	.1408957	-1.41	0.161	-.4758175	.0795246
b32	-.3481272	.1819705	-1.91	0.057	-.7067467	.0104923
b33	-.133047	.1803655	-0.74	0.462	-.4885035	.2224094
b34	-.2961759	.1687053	-1.76	0.081	-.6286529	.0363012
b35	-.2301761	.1567301	-1.47	0.143	-.5390529	.0787008
b36	.0185213	.0607782	0.30	0.761	-.1012577	.1383003
b38	(dropped)					
b39	-.015522	.1173655	-0.13	0.895	-.2468208	.2157769
y98	(dropped)					
y99	-.1670079	.0506869	-3.29	0.001	-.2668995	-.0671164
y00	-.0624549	.0485849	-1.29	0.200	-.158204	.0332942
y01	-.0904504	.046682	-1.94	0.054	-.1824492	.0015483
y02	-.1175396	.0505102	-2.33	0.021	-.2170828	-.0179964
y03	-.0708036	.048862	-1.45	0.149	-.1670987	.0254915
s2	.2668737	.0492914	5.41	0.000	.1697324	.364015
s3	.5720761	.1116605	5.12	0.000	.3520204	.7921318
_cons	1.426196	.317933	4.49	0.000	.7996279	2.052765

```
------------------------------------------------------------------------------
Instrumented:  diff_L
Instruments:   diff_k rd_lag1 rdo1_lag1 rds2_lag1 rdo3_lag1 b13 b14 b16 b17
               b18 b19 b20 b21 b22 b23 b25 b26 b27 b28 b29 b31 b32 b33 b34 b35
               b36 b38 b39 y98 y99 y00 y01 y02 y03 s2 s3 l_lag1
------------------------------------------------------------------------------
```

l_lag1 = log of the number of workers lagged one period.

Appendix 10: Estimation output - additionality in the manufacturing industry

Probit regression for the estimation of the probability to obtain government R&D support:

$$SubDum_{it} = \alpha + \beta \cdot RDWksSh_{it} + \gamma \cdot RDAcadSh_{it} + \delta \cdot ExpIncSh_{it} + \sum^{Size} D_j^s \cdot s_{ji} + \sum^{Year} D_j^y \cdot y_j + \sum^{\substack{Technology \\ Intensity}} D_j^{tech} \cdot tech_{ji} + \varepsilon_{it}$$

where:

i = establishment; t = year; $SubDum$ = dummy variable for receiving exterior support or not; $RDWksSh$ = ratio of R&D workers to total workers; $RDAcadSh$ = ratio of R&D workers with academic education to total R&D workers; $ExpIncSh$ = ratio of exports to income; y = year dummy variable; s = group size dummy variable; $tech$ = technology intensity group dummy variable; α , β , γ , δ , D_j^s , D_j^y , D_j^{tech} are the variables coefficients respectively; ε = random error.

```
Probit Estimates                          Number of obs =   1,594
                                          LR chi2(16)  =    222.74
                                          Prob > chi2  =    -
Log likelihood =     -976.56              Pseudo R2 =       0.10
```

Funding Dummy	Coef.	Std. Err.	z	P>z
RDWksSh	1.219	0.157	7.760	0.000
RDAcadSh	0.353	0.154	2.290	0.022
ExportsSh	0.377	0.111	3.400	0.001
s2	0.051	0.078	0.660	0.511
s3	0.303	0.091	3.330	0.001
y97	0.080	0.142	0.570	0.570
y98	-0.124	0.140	-0.890	0.374
y99	-0.241	0.138	-1.750	0.081
y00	-0.214	0.144	-1.490	0.137
y01	-0.398	0.159	-2.500	0.013
y02	-0.576	0.141	-4.100	0.000
y03	-0.554	0.141	-3.940	0.000
y04	-0.560	0.143	-3.910	0.000
t62	-0.137	0.087	-1.580	0.115
t63	-0.387	0.102	-3.790	0.000
t64	-0.316	0.186	-1.690	0.090
_cons	-0.328	0.169	-1.940	0.053

OLS Regression for the estimation of R&D additionality:

$$\Delta RDNet_{it} = \alpha + \beta \cdot Sub_{it} + \gamma \cdot Sub_{it}^{2} + \sum^{\substack{Technology\\Intensity}} D_j^{tech} \cdot tech_{ji} + \sum^{Size} D_j^{s} \cdot s_{ji} + \sum^{Year} D_j^{y} \cdot y_j + \varepsilon_{it}$$

where:

i = establishment; t = year; $\Delta RDNet$ = the difference in net R&D expenditures (net of total external R&D funding) between establishments that received external funding and establishments that didn't; Sub = the level of external R&D funding; $tech$ = technology intensity group dummy variable; s = group size dummy variable; y = year dummy variable; α , β , γ , D_j^{tech} , D_j^{s} , D_j^{y} are the variables coefficients respectively; ε = random error.

Source	SS	df	MS
Model	242020.3	22	11000.9227
Residual	302092.21	534	565.715749
Total	544112.51	556	978.619622

Number of obs	=	557
F(22, 534)	=	19.45
Prob > F	=	0.0000
R-squared	=	0.4448
Adj R-squared	=	0.4219
Root MSE	=	23.785

$\Delta RDNet$	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Sub	1.286111	.1587014	8.10	0.000	.9743556	1.597867
Sub Square	-.005927	.0009192	-6.45	0.000	-.0077326	-.0041214
t61_1	9.36702	9.178392	1.02	0.308	-8.663164	27.3972
t62_1	-1.36183	9.349137	-0.15	0.884	-19.72743	17.00377
t63_1	.8078673	9.676963	0.08	0.933	-18.20172	19.81745
IS2_1	9.910743	2.462447	4.02	0.000	5.073472	14.74801
IS3_1	33.02041	3.156276	10.46	0.000	26.82017	39.22065
y97_1	-9.792945	4.958679	-1.97	0.049	-19.53385	-.0520362
y98_1	.4264156	4.318272	0.10	0.921	-8.056469	8.9093
y99_1	.1210135	4.327485	0.03	0.978	-8.379969	8.621996
y00_1	-3.425203	4.336225	-0.79	0.430	-11.94335	5.092949

```
      y01_1 |  (dropped)
      y02_1 |   2.661021    4.65721     0.57   0.568    -6.487678    11.80972
      y03_1 |   .9527507   4.554746     0.21   0.834    -7.994667    9.900168
      y04_1 |    -.57917   4.561767    -0.13   0.899    -9.540379    8.382039
      y97_C |   1.112601   3.400276     0.33   0.744    -5.566956    7.792157
      y98_C |   2.717488   3.928934     0.69   0.489    -5.000574    10.43555
      y99_C |  -8.567895   3.959877    -2.16   0.031    -16.34674   -.7890496
      y00_C |  -5.380796   4.055803    -1.33   0.185    -13.34808    2.586489
      y01_C |  -2.384949   4.588357    -0.52   0.603    -11.39839    6.628494
      y02_C |  -10.37519   4.586595    -2.26   0.024    -19.38517   -1.365212
      y03_C |  -7.517422   4.603159    -1.63   0.103    -16.55994    1.525099
      y04_C |   -14.0513   5.857789    -2.40   0.017    -25.55843   -2.544161
      _cons |  -3.040317   9.883145    -0.31   0.758    -22.45493    16.37429
------------------------------------------------------------------------------
```

Appendix 11: Estimation output - additionality in the computer services, software and R&D branches

Probit regression for the estimation of the probability to obtain government R&D support:

$$SubDum_{it} = \alpha + \beta \cdot RDWksSh_{it} + \gamma \cdot RDAcadSh_{it} + \delta \cdot ExpIncSh_{it} + \sum^{Size} D_j^s \cdot s_{ji} + \sum^{Year} D_j^y \cdot y_j + \sum^{\substack{Technology \\ Intensity}} D_j^{tech} \cdot tech_{ji} + \varepsilon_{it}$$

where:

i = establishment; t = year; $SubDum$ = dummy variable for receiving exterior support or not; $RDWksSh$ = ratio of R&D workers to total workers; $RDAcadSh$ = ratio of R&D workers with academic education to total R&D workers; $ExpIncSh$ = ratio of exports to income; y = year dummy variable; s = group size dummy variable; $tech$ = technology intensity group dummy variable; α , β , γ , δ , D_j^s , D_j^y , D_j^{tech} are the variables coefficients respectively; ε = random error.

Probit Estimates			Number of obs =	1,185
			LR chi2(16) =	157.38
			Prob > chi2 =	-
Log likelihood =	-715.04		Pseudo R2 =	0.10

Funding Dummy	Coef.	Std. Err.	z	P>z
RDWksSh	0.009	0.020	0.440	0.657
RDAcadSh	0.312	0.174	1.790	0.074
ExportsSh	0.047	0.099	0.470	0.635
s2	-0.325	0.100	-3.260	0.001
s3	-0.559	0.164	-3.410	0.001
y98	0.056	0.238	0.230	0.816
y99	-0.191	0.222	-0.860	0.390
y00	-0.384	0.210	-1.830	0.068
y01	-0.725	0.211	-3.440	0.001
y02	-0.710	0.199	-3.570	0.000
y03	-0.525	0.196	-2.680	0.007
y04	-0.891	0.197	-4.520	0.000
y04	-0.767	0.200	-3.830	0.000
t73	0.706	0.082	8.650	0.000
_cons	0.351	0.224	1.570	0.117

OLS Regression for the estimation of R&D additionality:

$$\Delta RDNet_{it} = \alpha + \beta \cdot Sub_{it} + \beta^{lag} \cdot Sub_{it-1} + \gamma \cdot Sub_{it}^2 + \gamma^{lag} \cdot Sub_{it-1}^2 + \sum^{\substack{Technology\\ Intensity}} D_j^{tech} \cdot tech_{ji} + \sum^{Size} D_j^s \cdot s_{ji} + \sum^{Year} D_j^y \cdot y_j + \varepsilon_{it}$$

where:

i = establishment; t = year; $\Delta RDNet$ = the difference in net R&D expenditures (net of total external R&D funding) between establishments that received external funding and establishments that didn't; Sub = the level of external R&D funding; $tech$ = technology intensity group dummy variable; s = group size dummy variable; y = year dummy variable; α, β, γ, D_j^{tech}, D_j^s, D_j^y are the variables coefficients respectively; ε = random error.

Source	SS	df	MS
Model	24122.0641	22	1096.45746
Residual	95038.2324	425	223.61937
Total	119160.297	447	266.577845

Number of obs	= 448
F(22, 425)	= 4.90
Prob > F	= 0.0000
R-squared	= 0.2024
Adj R-squared	= 0.1611
Root MSE	= 14.954

$\Delta RDNet$	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Sub	1.436258	.3722428	3.86	0.000	.7045924	2.167924
Sub Lagged	.4298866	.216901	1.98	0.048	.0035543	.8562188
Sub Square	-.0495317	.0111691	-4.43	0.000	-.0714853	-.0275781
Sub Lagged Square	-.0020015	.0022334	-0.90	0.371	-.0063915	.0023884
t73_1	-3.804069	1.699426	-2.24	0.026	-7.144394	-.4637432
IS2_1	-4.630461	2.216552	-2.09	0.037	-8.987229	-.2736924
IS3_1	-17.30689	15.12497	-1.14	0.253	-47.03594	12.42216
y98_1	(dropped)					
y99_1	3.097123	5.052303	0.61	0.540	-6.833489	13.02773

```
     y00_1 |   1.712851   7.274461     0.24   0.814    -12.58555    16.01125
     y01_1 |   6.833367   8.861861     0.77   0.441    -10.58516     24.2519
     y02_1 |   11.74851   8.879945     1.32   0.187    -5.705563    29.20259
     y03_1 |   -.663806   8.150179    -0.08   0.935    -16.68348    15.35587
     y04_1 |   14.57901   9.177077     1.59   0.113    -3.459098    32.61712
     y05_1 |   8.732523   8.912198     0.98   0.328    -8.784949    26.24999
     y98_C |   12.87049   4.636311     2.78   0.006     3.757532    21.98344
     y99_C |   10.23107   6.022661     1.70   0.090     -1.60684    22.06898
     y00_C |   6.872644   7.830344     0.88   0.381    -8.518378    22.26367
     y01_C |  -4.217588   9.579843    -0.44   0.660    -23.04736    14.61218
     y02_C |  -7.847598   9.394697    -0.84   0.404    -26.31345    10.61826
     y03_C |   .5474884   8.779314     0.06   0.950    -16.70879    17.80377
     y04_C |  -8.660198   9.729005    -0.89   0.374    -27.78315    10.46276
     y05_C |   1.560935   9.371985     0.17   0.868    -16.86028    19.98215
     _cons |  -9.376603   3.314423    -2.83   0.005    -15.89131     -2.8619
------------------------------------------------------------------------------
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Appendix 12: List of industrial branches by technology intensity

Industry	Code
High technology industries	
Office & computing equipment	30
Electronic components	32
Aircraft	355
Electronic communication equipment	33
Equipment for control & supervision	34
Pharmaceutical products	245
Medium-high technology industries	
Chemicals & refining petroleum (excl. pharmaceutical products)	24+23-(245)
Machinery & equipment	29
Electrical equipment & electrical motors	31
Transport equipment	35-(353+355+358)
Transport equipment n.e.c	358
Medium-low technology industries	
Mining & quarrying	10, 11, 12, 13
Rubber & plastic products	25
Non-metallic mineral products	26
Non-ferrous & precious metals	271, 273
Iron & steel foundries	270, 272, 274
Metal products	28
Ships & boats	353
Jewellery & silversmiths’	38
Articles n.e.c	39
Low technology industries	
Food products, beverages & tobacco	14, 15, 16
Textiles, wearing apparel & leather	17, 18, 19
Paper, printing & paper products	21, 22
Wood & furniture	20, 36

Appendix 13: Surveys of manufacturing and surveys of R&D in manufacturing and in the computer services, software and R&D branches - discussion

1. In the survey of R&D in manufacturing the number of observations (establishments) that belong to the low-technology group is very low. This imposes very significant limitations of analysis within this category.

2. The distributions of value added (GDP) and R&D expenditures are characterized by a very high degree of heterogeneity and a long tail to the right side of the distribution (positive high values). The inclusion of distributional characteristics in official statistics publications should be considered, so as to enable a more informed use of these.

3. The variable "other funding" in the R&D surveys includes data on investments (from venture capital funds and parent firms) that is not R&D funding, but rather reflect investment activities. In fact these data are not available in official publications, but are necessary to conduct the type of additionality analysis presented here.

4. Patent data - we recommend the CBS to collect the technological classification of establishments patent applications or grants. This will enable the definition and construction of technology closeness indices between firms. Establishments that filled applications for patents or were granted patents should be asked to fill in the technological class of the patents applied for or granted. Establishments that did not apply for patents could choose from the list of class technologies, from the USPTO for example, the technology class that better encompasses most of their technologies.

5. In the R&D surveys data it should be made possible to subtract the R&D workers, wages and investments from general workers, wages and investments data. Thus, the problem of double counting the R&D impact could be avoided. In the manufacturing surveys this cannot be done. Because the main data source for productivity analyses is the manufacturing survey and because the R&D surveys data cannot be completely merged into it - this gives rise to a problem that cannot be solved easily. The correction may be done only to a portion of the firms included in the survey (see appendix above).

6. Following what is said above - there is a need to create a uniform identification code for establishments in the survey of manufacturing and R&D for data merging purposes. The variable exists only from year 2003 onwards.

7. Questions regarding R&D activity are different in the manufacturing surveys and in the R&D surveys: In the R&D surveys the establishments are asked about R&D expenditures on wages, on materials, on outsourcing, other R&D expenditures, expenditures on patents purchases and R&D investments. In the manufacturing surveys establishments are asked about R&D expenditures on wages, on materials, on outsourcing, other R&D expenditures, expenditures on R&D depreciation & expenditures on R&D related rent. We recommend harmonizing the definitions between the publications.

8. In the R&D surveys there is no reference or treatment of R&D royalties paid by firms to the government when R&D projects produce sales. It is unclear how do the establishments deal with them when reporting their data - are these included inside "other" R&D expenditures? Within establishments' general expenditures? There is a

need to differentiate between gross and net R&D grants - i.e. before and after deducing royalties payments to the government).

9. Given the variety of international R&D funding programs we recommend adding to the R&D surveys a variable with the identity of the international programs.

10. We recommend to differentiate between industrial OCS R&D funding received through the "MAGNET" program (for generic R&D undertaken jointly by a consortium of firms) and R&D funding received through the "R&D fund" (the main OCS funding scheme).

11. It would be beneficial to include economic variables in the R&D surveys alike the ones from the manufacturing surveys - e.g. added value and output.

12. We recommend considering to harmonize definitions of the existing surveys with those of the European Union - i.e. the pan-European innovation surveys, CIS.