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The determinants of success of R&D projects: Evidence from American-Israeli research alliances

ODED BIZAN

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Oded Bizan

Analysis Group/*Economics*

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The determinants of success of R&D projects: Evidence from American-Israeli research alliances

Abstract

A basic premise of Israeli R&D support programs has been the principle of neutrality – all eligible projects are funded. With a binding budget constraint, however, the government has to select the projects it funds and thus to depart from neutrality. An optimal departure would favor those projects that have less of a chance to succeed without support. In this paper, I examine the performance of government supported collaborative research projects. I find that size and organizational form affect the probability of technical success and duration to commercialization in a way that suggests departing from neutrality by preferring less established firms.

Key words: R&D policy, Neutrality, Research alliance, BIRD Foundation

JEL: F2, L2

Oded Bizan
Anlysis Group/*Economics*
One Brattle Square
Fifth Floor
Cambridge, MA 02138
USA

obizan@analysisgroup.com

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Non-technical summary

A basic premise of Israeli R&D support programs has been the principle of neutrality (Trajtenberg, 2001). According to this principle, projects are not selected according to any discriminating criteria other than eligibility considerations such as technical feasibility. In particular, firms or projects are not discriminated by characteristics such as size or type of ownership.

In 1997, for the first time, the demand for government funds exceeded the budget allocated by the Israeli Government for this purpose. As a result, government agencies were forced to select the projects they fund, that is, to depart neutrality.

In order to design an efficient selection mechanism to depart from neutrality, one has to identify the factors that influence the performance of projects. This paper focuses on identifying the factors that affect project success in two key stages: (1) technical development, and (2) commercialization.

I use a unique data set to investigate the performance of 142 joint research projects conducted by American and Israeli high–technology firms in the years 1986-93, and supported financially by the BIRD foundation – the Israel-U.S **B**inational **I**ndustrial **R**esearch and **D**evelopment Foundation. Using this data, I first identify the determinants of technical success. Then, I identify the factors that influence the time it takes to commercialize technically successful projects.

I find that the probability of technical success increases when (1) duration of the project increases, (2) collaborating firms are related through ownership, and (3) firms possess complementary abilities. I also find that, technically successful projects takes less time to commercialize when (1) project budget increases, (2) revenue of the larger firm in the alliance increases, and (3) firms are related through ownership. These findings are consistent with the hypothesis that size influences project success and indicate a relationship between the organization of R&D and its effectiveness. Thus, these findings favor departing from neutrality by discriminating against larger, more established firms.

1. Introduction

A basic premise of Israeli R&D support programs has been the principle of neutrality (Trajtenberg, 2001). According to this principle, projects are not selected according to any discriminating criteria other than eligibility considerations such as technical feasibility. In particular, firms or projects are not discriminated by characteristics such as size or type of ownership.

In 1997, for the first time, the demand for government funds exceeded the budget allocated by the Israeli Government for this purpose. In the presence of a binding budget constraint, government agencies are forced to select the projects they fund. Any selection criterion imposed on the set of eligible projects represents a departure from neutrality. Since 1997, however, only ad hoc solutions have been given to this fundamental shift in market conditions. A permanent change in policy is pending.

A natural question that arises is what would be the most efficient way to depart from neutrality, or in other words, what would be the best criteria for project selection. This paper contributes to the discussion about the design of government R&D policy by studying the performance of government supported research projects. I develop, and test, two sets of hypotheses regarding the determinants of technical success and the timing of commercialization. The first set of hypotheses draws from the literature about the Schumpeterian hypothesis that relates size to performance. The second set of hypotheses, drawing from the literature on the boundaries of the firm, links organizational form to performance.

I employ a unique data set that includes detailed information about 142 joint research projects conducted by American and Israeli high–technology firms, and supported financially by the BIRD foundation – the Israel-U.S **B**inational **I**ndustrial **R**esearch and **D**evelopment Foundation. The BIRD foundation is a binational government agency that supports research alliances between American and Israeli firms in several high-technology industries, including electronics, software, medical equipment, communication, machinery and semiconductors. Typically, these projects involve a small Israeli firm with a technological edge and a larger American firm that is a potential user of the technology and that has well-developed marketing capabilities. BIRD provides each partner with financial support proportional to its share in the project's cost[1].

To test the hypotheses I estimate two models. The first model identifies the determinants of technical success, taking into account sample selection imposed by BIRD's project approval decisions. The second model identifies the determinants of duration to commercialization of technically successful projects, taking into account sample selection due to technical success and right truncation due to sampling procedures.

My results indicate that both size and organizational form affect the probability of technical success and duration to commercialization. I find that the probability of technical success increases when (1) duration of the project increases, (2) firms are related through ownership, and (3) firms possess complementary abilities. I also find that, given technical success, the time to commercialization decreases when (1) project budget increases, (2) revenue of the larger firm in the alliance increases, and (3) firms are related through ownership. These findings support the Schumpeterian hypothesis and indicate a relationship between the organization of R&D and its effectiveness. Thus, these findings favor departing from neutrality by discriminating against established firms.

The reminder of the paper is organized as follows. In section 2 I describe the BIRD foundation. I describe the data set employed in section 3. In section 4 I define three types of success and apply the definitions to the data set. In section 5 I develop hypotheses regarding the determinants of technical success and the timing of commercialization. In section 6 I analyze BIRD's project selection process that, potentially, shapes the structure the sample of research alliances. Independent variables, estimation procedures and estimation results are described in section 7. I conclude in section 8.

[1] Government support can, in principle, affect the partners' behavior. In the data, however, there is no variation in the form or scale of support given to projects. Hence, the effect of government support is not

2. The BIRD foundation

The BIRD Foundation was established in 1977 to stimulate mutually profitable cooperation between American and Israeli high-tech companies. It derives its income from a $110 million endowment, provided equally by the two governments, as well as from repayments from successful projects. BIRD cost-shares with each partner in Israeli company-U.S. company teams that seek to develop and commercialize any innovative (nondefence) technical product or process.

BIRD supports projects up to the point of commercial readiness. Its investment in such joint projects does not entitle it to equity or technology rights. Project awards are BIRD's main business. There are two types of awards: full scale and mini projects, depending on the total cost and duration of the proposed project.

Full-scale projects.

A full-scale project is currently defined as one in which the total cost to the two companies ranges from $200,000 to $2,500,000 over a one to three year period. Grants are either $1,250,000 or 50% of actual project costs, whichever is less.

BIRD's Board of Governors (BOG) meets semiannually to act on proposals for Full-scale projects. Members of the Board include US representatives from the National Institute of Standards and Technology (NIST), the Department of Treasury and the Department of State. Israel's Board members are the Director General and Chief Scientists of the Ministry of Industry and Trade, and the Director General of the Ministry of Finance. BOG actions are based primarily on confidential proposal reviews by the US NIST, Office of the Chief Scientist (OCS) of Israel's Ministry of Industry and Trade and by BIRD's staff.

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identified and will be ignored hereafter.

NIST’s review includes technical evaluation of the project. It includes assessment of the companies’ technical approach and capabilities and an overall rating of the technological aspects of the project.

OCS’ review includes both technical and commercial evaluations of the proposed project. It also includes an overall rating of the technological and commercial aspects of the project and an overall rating of the project’s contribution to the Israeli economy.

BIRD’s review includes evaluations of the commercial aspects of the project using information on the companies’ background, evaluations of their abilities to fulfill their roles according to the companies’ collaborative relationship, and their record of performance with BIRD.

Mini projects.

The executive director is empowered by the BOG to allocate up to 20% of annual conditional grant funds for the support of mini projects. Currently, the total recognized cost of such mini projects is $200,000 or less, and the maximum duration is approximately one year. Grants are either $100,000 or 50% of actual project costs, whichever is less. The same criteria regarding business and technical capabilities and commercial potential used for full-scale projects apply to mini projects. However, the executive director makes the decision without any formal outside review of the proposal.

3. Data

Between the years 1986 and 1993 170 full-scale projects were considered by BIRD's BOG of which 142 received support. All 170 projects are at the product development stage of the R&D program. The data was collected during the year 1998 at BIRD’s headquarters. Information about firms was verified and complemented using the CorpTech Directory of Technology Companies[2] and Hoover's Online[3]. The data includes four types of information.

(1) General information about the firms.

(2) General information about the project.

(3) Information about the contribution of each firm to the project.

(4) Progress reports.

The first two types of information are available for all 170 projects. Information about the contribution of each firm to the project is available for all 142 approved projects and only partially available for the 28 projects that were denied support. Progress reports, however, are not available for the rejected projects. Attempts to obtain consistent information about these projects were generally unsuccessful.

More details about the type of information available and descriptive statistics are given in the following subsections.

General information about the firms.

This group of variables includes information about the number of employees, revenues, ownership type, and date of establishment. This type of information is available for all 170 research alliances in the data set.

Table 1 contains descriptive statistics of this data. The picture arising from the table is that of a small, less established Israeli firm collaborating with a much larger American firm. On average, American firms are twice as old, have more than twelve times as much revenue, and seven times as many employees. Finally, in most cases Israeli firms are privately held whereas American firms are more often publicly traded.

[2] See www.corptech.com
[3] See www.hoovers.com

Information about the project.

Projects belong to one of the following industries: Electronics (16 projects), Software (40), Medical equipment (18), Communications (51), Machinery (16), Semiconductors (11), and Others (18).

By and large, information about the projects is available for all 170 research projects. More detailed information is available for 122 of the 142 approved projects. Project level descriptive statistics appear in Table 2. An average project continues for about 17 months with an average budget of more than $1 million. About a half of these projects involve firms that are related in some way (either through common ownership or one is a subsidiary of the other). These firms have very high expectations regarding their future returns – their expected internal rate of return is over 50% on average.

Firms' contribution to the project.

Data about firms' contribution includes information about the number of employees each firm assigned to the project, information about their education and experience, information about the activities each firm was responsible for in the project, and detailed information about the budget of each firm. This type of information is available for 122 of the 142 approved research projects.

On average, American firms spend 41% of a project's budget (S.E. equals 0.19) but the share ranges from 8% to 83%. Table 3 describes the human capital contributed to the project by American and Israeli firms. In general, an Israeli firm contributes more human capital to a project. On average, Israeli firms assign 9 employees to a project while American firms assign only 7. Moreover, Israeli firms assign twice as many employees with a Ph.D./M.D degree to the project, and almost 50% more engineers.

Table 4 describes the tasks each firm is responsible for in the project. A project is broken into five tasks[4].

(1) R&D including development of prototypes, and software modules.

(2) Product definition, specification and requirements, and protocol writing.

(3) Product and interface design, integration, alpha and beta-site tests, quality assurance, documentation and packaging.

(4) Manufacturing.

(5) Sales, services and customer support.

Each activity can be performed by the Israeli firm alone, by the American firm alone, by the two firms jointly, or the firms may split activity-related duties among them.

In all projects the Israeli firm is involved in R&D activity, but in 50% of the cases it is collaborating with the American partner. The Israeli partner, however, rarely handles product definition. In most cases it is done jointly, but in 32% of the cases solely the American firm does it. Product design is typically a joint activity; otherwise the Israeli firm does it. Manufacturing involves the Israeli firm in 85% of the projects but the American firm dominates sales activities. In 18% of the projects, responsibility for sales is split between the firms - each firm has exclusive rights to sell to a certain market[5].

Progress reports.

Progress reports refer to both technological and financial aspects of a project. They include information about payment and repayment schedules and sales reports as well as technical reports at significant milestones. This information is used mainly to evaluate aspects of success and to determine how firms share revenues.

[4] In some cases these tasks are irrelevant to a project. For example, manufacturing in the case of software projects is negligible.

4. The success of R&D projects

Determining whether an R&D project is successful is a subtle matter. First, such projects are often complex and involve several dependent phases. It could be then that one stage is successful while another is a failure. Second, it depends on who evaluates this success. For example, an outcome that would be considered a success in the eyes a supporting government agency would not necessarily be considered as such by a private firm (Arrow 1962). More generally, several forms of sample selection influence the definition of success and its probability.

The source of the data employed here is a government agency that supports collaborative research. This agency selects which projects to support in several ways. First, by targeting "collaborative research" all single-firm R&D projects are excluded. Second, firms have to be aware of this funding opportunity and be willing to consider it. The BIRD foundation is well known within the relevant industry sectors and it is thus safe to assume that all firms are aware of the funding opportunity it offers. Still, some firms are reluctant to have government involvement. The foundation, however, is also well known for its rapid and relatively informal procedures as well as for being uninvolved closely with the day-to-day operations of the firms it supports. Hence, it is also reasonable to assume that most firms would not be so reluctant to work with the BIRD foundation. A final concern has to do with the foundation's project selection procedures.

Unlike classical government intervention that seek to overcome the market failure that results from the gap between social value and private value, the BIRD foundation seeks to support the best projects it can, regardless of their social value. The declared mission of the BIRD foundation is to

"...stimulate, promote and support industrial R&D of mutual benefit to the US and Israel"

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[5] Often these segments are geographically based. A common example is that the American firm handles the American market while the Israeli firm handles the European market. In most cases the American firm also handles the Japanese and the Far East markets.

Definitions of success.

In light of the concerns raised above and the selection procedures imposed on the data I define three types of success as follows.

DEFINITION 1: An R&D project is said to be *technically successful* if the firm conducting the project achieved the goals it set for itself at the beginning of the project.

DEFINITION 2: An R&D project is said to be *commercially successful* (or *commercialized*) if the project generate some sales.

DEFINITION 3: An R&D project is said to be *financially successful* if the firm conducting the project made positive net profits of the project.

This paper is concerned with identifying the determinants of technical success and commercialization. Since the data contains no information on production costs it is impossible to evaluate financial success. Note that technical success would not be observed unless a project had already been approved, and that commercial success would not be achieved unless technical success had already been achieved. Figure 1 illustrates this point. The figure describes the timing and dependency of project-related decisions. Table 5 reports the sample probability of (1) approval given application was submitted, (2) technical success given approval, and (3) commercialization given technical success.

Probabilities of success.

First, note that probabilities of technical success given approval are close to 1, only 5.5% of the approved projects failed to achieve their technical goal. This high probability may be attributed to two factors: (1) BIRD's selection process, and (2) adverse selection on the firms' side. BIRD as a governmental agency as opposed to a private capital venture is expected to support more risky R&D projects, nevertheless, before approval projects are subject to inspection by NIST, OCS and BIRD itself. This selection process may be so good that firms who pass it are going to succeed almost surely. On the firm side either firms do not take chances in their R&D efforts and do not start a project unless its success is (almost) guarantied; or firms apply for BIRD's grant with their best projects (or both).

Second, it is interesting to compare the probabilities in Table 5 to those calculated by Mansfield et al. (1977) that also distinguished between three types of success. They calculated the probabilities of technical success, commercialization given success and financial success using data obtained from twenty major firms in the chemical, drug, electronics, and petroleum industries during the years 1968-1971. They calculated the sample probabilities to be 0.57, 0.65 and 0.74 respectively. The probability of commercialization given approval thus equals $0.57\times 0.65=0.3705$. Note that Mansfield et al. use a different, less demanding, definition of commercialization. The probability of financial success given approval equals $0.57\times0.65\times 0.74=0.2742$.

The matching probabilities from Table 5 are 0.94 for technical success given approval and 0.79 for commercialization given technical success. Although it is impossible to identify financial success without information about production costs, it is possible to obtain an upper bound on the probability of financial success using revenue information. In some cases revenues were so low that it is safe to assume financial failure. Using this method, I find that the probability of financial success given commercialization cannot exceed 0.44. The probability of commercialization given approval is $0.94\times0.79=0.7426$ while the probability of financial success given approval cannot exceed $0.94\times0.79\times0.44=0.3309$.

Note that sample probabilities are considerably larger than those calculated by Mansfield et al. that may be explained by better selection or excess risk aversion. Moreover, note that as opposed to Mansfield et al., the probabilities decrease as R&D projects reach a more advanced phase. A possible explanation is that at the time (the late 1950's to early 1970's) markets were "hungry" for innovations, each successful phase of the R&D effort increased the probability of success in the next phase since the number of competitors was lower. To take things to the extreme, any new technology succeeds in a seller's market. Today's markets are more competitive and more selective. It is no longer enough to have a good technology; it also needs to be better than other technologies in a buyer's market.

5. Hypotheses

In this section I develop hypotheses regarding the factors that affect the success of collaborative R&D. The success of research alliances is influenced by either factors that influence innovation or by organizational factors. The literature on the factors that influence innovation – the so-called Schumpeterian hypothesis – will be used to develop hypotheses regarding the factors that influence the success of R&D. The literature on the organization of the firm will be used to identify factors that influence alliance success.

A summary of the hypotheses developed in the remaining of this section appears in Table 6. The table describes the expected effect of the four groups of variables described above on the technical success of research projects and on duration to commercialization.

The Schumpeterian hypothesis.

In this section I summarize the Schumpeterian hypothesis, linking firm and project size to innovative activity, and review some empirical tests of these relationships. I then use this literature to develop hypotheses regarding the factors that affect success.

Size may give an advantage to firms conducting R&D by increasing their incentive and ability to innovate. Larger firms, that have relatively more to lose, have a higher incentive to innovate in order to protect their market share or profits (Gilbert and Newbery, 1982; Katz and

Shapiro, 1987). Larger firms may also enjoy economies of scale in R&D (Cohen, Levin and Mowery, 1987). The source of these economies of scale may be better research facilities, better marketing infrastructure or a better ability to recruit high-skilled workers.

An argument against larger firms is that smaller firms may have greater incentive to innovate because their marginal benefit from innovation is larger (Reinganum, 1983). Also, larger firms are more bureaucratic and therefore take more time to make decisions that reduces their ability to innovate (Scherer and Ross, 1990).

Most of this literature refers explicitly to the size of the firm. Some of the arguments, however, may also be applied to the size of the project, especially those related to economies of scale. Larger projects are more important to firms. Oftentimes, large research projects influence the survival of a firm, both because they may open new market opportunities and because they enable the firm to raise more funds (or raise funds under better terms). Thus, as the size of the project increases firms tend to allocate better resources to the project; the best research facilities are used, the best workers are assigned to the project etc. This concentration of better resources is the source of economies of scale at the project level.

The following hypotheses summarize the discussion in this section.

HYPOTHESIS 1: The probability of success of R&D projects increases with firm size.

HYPOTHESIS 2: The probability of success of R&D projects increases with project size.

These hypotheses are stated in terms of the probability of success. A key factor to success in the modern high technology environment is “time to market”. The time of market introduction is often no less important than the ability to develop a good product. Since timing is an important aspect of success, especially commercial success as defined here, the above hypotheses could also be stated in term of duration to success.

HYPOTHESIS 3: Duration to commercialization decreases with firm size.

HYPOTHESIS 4: Duration to commercialization decreases with project size.

Organizational form hypotheses.

In this section I summarize the transaction cost literature linking organizational form and contractual arrangements to performance, and review some empirical tests of these relationships. I then use this literature to develop hypotheses regarding the factors that affect success.

While the determinants of organizational form have been studied extensively[6], its implications for performance have received less attention. The theoretical literature suggests that integration decisions matter for performance in the presence of incomplete contracts and ex post quasi-rents[7]. Under these conditions, contracting parties may behave inefficiently attempting to hold-up each other so as to obtain a larger share of the quasi-rents. Integration helps avoiding such opportunistic behavior and improves performance. Several studies provide evidence supporting such inference. For example, Lerner and Tsai (1999) analyze the impact of financial structure on the performance of alliance agreements in the biotechnology industry and find that contractual structure has significant impact on the success of these alliances. Muscarella and Vetsuypens (1990) find evidence for significant improvements in profitability following a leveraged buyout.

HYPOTHESIS 5: The probability of success of collaborative R&D projects increases with the degree of integration of the collaborating firms.

HYPOTHESIS 6: The probability of success of collaborative R&D projects increases with the degree of complementarity between collaborating firms.

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[6] See Hart (1995) for a review of the theory. Also see Bizan (2000) for a review of the empirical literature and an example utilizing the data set employed here.

As explained above, these hypotheses could also be stated in terms of duration to commercialization as follows.

HYPOTHESIS 7: Duration to commercialization decreases with the degree of integration of the collaborating firms.

HYPOTHESIS 8: Duration to commercialization decreases with the degree of complementarity between collaborating firms.

6. The approval decision

The goal of the analysis in this section is to correct subsequent success analysis for potential selection bias (Heckman 1976). Research projects are selected into the sample in several stages. First, firms self-select by choosing to approach the BIRD foundation. Not all pairs of firms are allowed to do that. BIRD's procedure book states that

> *"Any pair of companies, one from each country, may jointly apply for BIRD support, if between them they have the capability and infrastructure to define, develop, manufacture, sell and support and innovative product based on industrial R&D."*

It is required then that collaborators would belong to different countries and that collaboration will be "real".

Second, many pairs of firms that contact BIRD are discouraged to formally apply for funding for a variety of reasons. It is stated in BIRD's procedure book that

> *"After exploratory meetings, Israeli companies and US that fit the general criteria are invited to submit a brief Executive summary of the proposed project. After a swift review we advise the companies whether we encourage them to submit a full proposal in accordance with the guidelines published in the BIRD Procedure Handbook."*

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[7] Whinston (2000) observes that this is a common prediction of the "Transaction Cost theory" (Williamson, 1975, 1979 and 1985) and the "property rights theory" (Grossman and Hart, 1986; Hart and Moore, 1988).

Finally, not all the applications that were formally submitted get approved by BIRD's BOG. Between the years 1986 and 1993, 16.5% of the formal applications were rejected. In the remaining of this section I concentrate on the third source of sample selection, namely, BIRD's formal project approval. The first source simply set up the environment to be studied. The second source of selection poses a more serious problem. Because firms that fit into the BIRD model are never disallowed to apply for funding, some of the firms that were informally discouraged to apply simply delay their application until they improve various features of their project. Other pairs may discontinue exploring their joint idea as a result of BIRD's bad signal. In any event, informal rejection plays a small role in designing the sample.

Independent variables.

In preparation for each BOG meeting BIRD's employees[8] rank formal application according to a pre-designed form (see the appendix). The variable **BIRDRATE** measures the overall rating given to each project. This rating is normalized to lie within the interval [0,1], its average is 0.79 (S.E.=0.22).

Project's general characteristics are expected to influence BIRD's decision. The variable **BUDGET** represents the project's budget in millions of $US. The variable **DURATION** measures the project's duration in months. Firm's expectations are summarized in the variable **EXPIRR**. This variable measures the expected internal rate of return of the project based on a realistic scenario[9].

A third group of variables that is expected to influence the approval decision describes how well the two firms match over several dimensions. The first three variables describe how close in size are the two firms. The variable **MAT_AGE** measures closeness in age, the variable

[8] Three employees – BIRD's executive director, associate director and the project-specific program manger – independently fill in the form. The reported rate refers to the average of these three rates.
[9] In their funding application, the firms have to provide BIRD with worst, expected and best sales scenarios.

MAT_REV measures closeness in revenue and the variable **MAT_EMP** measures how close the firms are in terms of the number of their employees. All three variables are defined as the ratio of the absolute difference in age, revenue or number of employees to the sum. The variable **MAT_OWN** takes on the value 1 if the two firms have the same ownership type (i.e. both are private of both are publicly traded), and 0 otherwise.

The last group of variables that is expected to influence the approval decision describes the nature of collaboration. All variables in this group are dummy variables that take on the value 1 when, given their assets and capabilities, the firms complement each other in a certain task in the project, and the value 0 if the firms can substitute each other in that task. The variable **COMP_RSCH** refers to R&D activity, development of prototypes, and software modules. The variable **COMP_DEFN** refers to product definition, specification and requirements, and protocol writing. The variable **COMP_DSGN** refers to product and interface design, integration, alpha and beta-site tests, quality assurance, documentation and packaging. The variable **COMP_MANF** refers to manufacturing. Finally, the variable **COMP_SELL** refers to sales, services and customer support. The names and definitions of all independent variables are summarized in Table 7. Descriptive statistics appear in Table 8.

Estimation results and interpretation.

The approval equation is estimated using a PROBIT model. Estimation results are presented in Table 9. The table reports estimated coefficients and standard errors for each variable, also reported are marginal effects of significant variables. Overall, the approval decision is very well explained by the independent variables – pseudo R^2 equals 0.664. Estimation results indicate that the BIRD foundation tend to support firms that complement each other in R&D (COMP_RSCH) but can substitute each other in product design (COMP_DSGN). On average this means that the foundation favors projects in which the American firm is involved in the R&D stage. By contrast, the foundation tends to support projects in which both firms are involved in product design. Also, note that the extent to which collaborators are similar in terms of revenue in a project has a significant effect on the approval design (MAT_REV). Finally, the way BIRD perceives a project influences it's decision. The variable BIRDRATE is highly significant and has a large influence on the approval decision.

Excluding BIRD's rating from the approval equation, that is, concentrating on how applicant firms might forecast the decision ex ante results in a dramatic change. First, the overall performance of the model falls - pseudo R^2 equals 0.179. Second, some variables become statistically significant. Applicant firms expect the probability of approval to increase as differences in age increase (MAT_AGE). Applicants also expect the approval probability to increase with the degree of complementarity in manufacturing (COMP_MANF). On the other hand, the degree of complementarity in marketing and services (COMP_SELL) has a negative effect on the approval probability. Third, some variables become insignificant. The degree of complementarity in R&D (COMP_RSCH) is not significant. Forth, the magnitude and sign of the effect of some variables change. The effect of MAT_REV remains positive but is perceived as larger. By contrast, the effect of the degree of complementarity in product design (COMP_DSGN) flips sign. Finally, note that the log likelihood value associated with the model drops to –30.033. A simple likelihood ratio test emphasizes the importance of BIRDRATE for the approval decision.

7. The determinants of success

In this section I define and discuss measurement of the factors that potentially affect success. Then, I describe estimation of econometric models that seek to identify which of these factors have significant influence on different types of success. I then use the estimation results to test the hypotheses regarding the determinants of success.

Independent variables.

The set of independent variables is decomposed into five groups of variables. Variables in these groups are designed to measure (1) size of the project, (2) size of the firms, (3) degree of firms integration, (4) degree of inter-firm complementarity, and (5) control variables. Variable names and their definition are summarized in Table 7. Descriptive statistics appear in Table 8. A description of the construction of independent variables follows.

Size of the project.

This group includes the variables that describe the size of the project, and the size of the firms. The variables that describe the size of the project are **BUDGET**, and **DURATION**, as defined above.

Size of the firms.

A second group of variables describes the size of the firms engaged in the project. The variables **EMPUS** and **EMPIS** measure the size of the firms by looking at the number of employees of the American and Israeli firms respectively. The variables **REVUS** and **REVIS** look at the revenue of American and Israeli firms respectively as a measure of their size. The variables **PUBLICUS** and **PUBLICIS** indicate whether the firms are publicly traded or not.

Decomposing the alliance into different tasks knowing which firm is responsible for each task will enable testing task-specific Schumpeterian hypotheses.

Firms integration.

The variable **RELATED** is a dummy that measures the degree of integration of the two collaborating firms. The variable indicates whether the two firms have any kind of common ownership (either one firm is owned by the other or both are owned by a third firm). About 50%

of the projects involve related firms. In 42% of the projects one firm is the subsidiary of the other, while in 8% of the project a third firm owns the two collaborating firms.

Degree of complementarity.

The variables described in this section measure the firms' degree of collaboration within the project. The variable **COMP** counts the number of activities in which the two firms bring complementary skills to the project (see the discussion in the data section, and Table 4). The variable is normalized to lie between 0 and 1. The variable **TRAVEL** shows how much project-related money the two firms spent on travel. This variable is aimed to capture the importance of communication for the success of the project. On average, about 5% of a project's budget is spent on travel.

Control variables.

Finally, although BIRD does not discriminate among industries in its selection process, there may be differences across industries in their "natural" rate of success. Thus, I include industrial classification dummies in all subsequent success equations.

Technical success.

In this section I describe estimation of the econometric model, to identify which factors have significant influence on technical success. Most approved research alliances – 94.36% - succeeded in achieving technical success. This very high overall rate of success may be attributed to either BIRD's success in selecting projects or over-caution by applicants. Thus, obtaining unbiased estimates of the determinants of technical success will require accounting for sample selection. For this purpose I estimate the following selection model (see Van de ven and Pragg, 1981) using maximum likelihood.

$$
\begin{aligned}
S_i &= \Phi(X_i\beta) + \varepsilon_{1i} \\
B_i &= \Phi(Z_i\gamma) + \varepsilon_{2i}
\end{aligned}
\tag{1}
$$

Where S_i indicates whether project *i* has been technically successful, B_i indicates whether project *i* has been approved by BIRD, S_i is observed if and only if $B_i=1$, X_i and Z_i are vectors of independent variables, β and γ are the corresponding parameters, $\varepsilon_1 \sim N(0,1)$, $\varepsilon_2 \sim N(0,1)$ and $corr(\varepsilon_1,\varepsilon_2)=\rho$. The parameters to be estimated are β, γ and ρ.

Estimation results are reported in Table 11. The table reports estimated coefficients and robust standard errors[10] for each variable. In specification *I* I use the number of employees to measure firm size, while in specification *II* I use firms' revenue as a measure of size. The two measures of size are highly correlated for American firms (ρ(REVUS,EMPUS)=0.8855), and almost uncorrelated for Israeli firms (ρ(REVIS,EMPIS)=0.0302). I thus do not estimate a model that nests the two specifications.

Estimation results enable testing hypotheses 1, 2, 5 and 6 regarding the factors that influence technical success. Based on the two specifications I cannot reject the hypothesis that size of the project – measured as project duration – positively influences the probability of success at a .1 level of significance (Hypothesis 1).

The results concerning firm size are more ambiguous. While revenue does not influence the probability of success, the number of employees at the American firm has a positive influence as opposed to the number of employees at the Israeli firm. The net effect is positive but very small (0.00003). Whether or not a firm is publicly traded may also indicate its size. Hypothesis 2 suggests then that publicly traded firms will be more successful. Based on Table 11 I reject this hypothesis. While public trading of Israeli firms does not influence success, publicly traded American firms are less successful. A possible explanation is that for distorted incentives due to

[10] Allowing correlation between the error terms of projects approved in the same BOG meeting.

ownership type work against relatively small R&D projects. All in all, I find mixed evidence concerning the hypothesis that size of the firms affects the probability of success positively.

Whether or not firms are related influences technical success. I cannot reject hypothesis 5 that suggests that more integrated firms are more successful in their joint endeavor. This effect may be a result of better intra firm coordination, or a better match of firms' goals.

Hypothesis 6 suggests that the better the firms complement each other the greater their chance to succeed technically. Based on the results in Table 11, I cannot reject this hypothesis (at the 0.05 significance level in specification I and at the 0.1 significance level in specification II).

Although control variables are not reported in Table 11, it is worth noting that the only industry with a significantly different probability of technical success is the software industry. Software development projects were in general significantly less successful.

Note that the correlation coefficient ρ is very close to –1 suggesting that the unobserved factors, that increase the approval probability, decrease the probability of technical success. For example, BIRD may have an unobserved preference for projects in a certain field that is, on average, less successful.

Although the correlation coefficient is close to –1 estimates of the selection equation are not significantly different from those obtained by estimating the approval equation alone (Table 9).

Duration to commercialization.

In this section, I examine the determinants of duration to commercialization. The timing of commercialization is critical to success in highly competitive, rapidly changing markets. The variable **DTC** measures duration to commercialization in quarters of a year. Figure 2 describes the distribution of DTC given that commercialization actually occurred. The figure indicates that, by and large, commercialization occurs rapidly. A year and half after successful completion, 80% of the projects that succeeded to commercialize have already done so. By the end of the third year after the successful completion of a project over 96% of these projects are commercialized.

Of course, not all technically successful projects are commercialized. Table 10 and Figure 3 describe the duration to first sale given technical success. Table 10 and Figure 3 illustrate that the probability of commercialization decreases with time. The table and figure contain aggregate (over all projects) Kaplan-Meier hazard rates; that is, the aggregate fraction of projects in the risk groups (projects that technically succeeded but had not had sales yet) that made the first sale in that period. Period 0 is the period in which a project came to its end[11].

A classical problem with duration data is right truncation. The data set, and in particular information about commercialization, was constructed in August 1998. Some of the projects that had not commercialized by then could have succeeded later. In the data set, information about commercialization of 20 % of the projects that succeeded technically is truncated. The reported hazard rate is adjusted to right truncation by excluding truncated observations from the risk groups.

Standard error of the hazard rate is calculated as follows. Let H_t denote the hazard rate at period t and let R_t denote the size of the risk group at period t. Then, an approximation[12] for the standard error is the square root of $H_t(1-H_t)/R_t$.

In the context of estimation, ignoring the possibility that right truncated projects might succeed leads to estimation bias.

Another sample related problem is sample selection. Given technical success, collaborating firms face the challenge of commercialization. About 80% of the firm-pairs commercialize the outcome of their joint project by August 1998. By definition, failing to succeed technically leads to failure in commercialization. Thus, obtaining unbiased estimates of the determinants of commercialization requires accounting for sample selection.

[11] Payments are given to firms in three parts, at the beginning of an approved project, at the middle of the approved duration and at the end of it. It is then possible to know approximately when a project ends.
[12] It is an approximation because hazard rates in different periods of time are not independents.

As there are no time varying explanatory variables and since duration to commercialization is never negative, I address these potential sources of bias by estimating the following model of duration to commercialization.

$$\begin{aligned} \log(DTC_i) &= W_i\delta + u_i \\ S_i &= \Phi(X_i\beta) + \varepsilon_{1i} \end{aligned} \qquad (2)$$

Where DTC_i is observed if and only if $S_i>0$. In these cases, $DTC_i=DTC_i^*$ if $DTC_i^*\leq T_i$ (complete spell), and $DTC_i=T_i$ if $DTC_i>T_i$ (incomplete spell). T_i is the project specific point of truncation, that is, the time that passed from the end of project *i* to the end of the sample (August 1998). X_i and W_i are vectors of independent variables, β and δ are the corresponding parameters, $u\sim N(0,1)$, $\varepsilon_1\sim N(0,1)$ and $corr(u,\varepsilon_1)=\rho$. The parameters to be estimated are β, δ and ρ. The log-normality assumption I make in this model is justified by the non-monotonic hazard rate in Figure 3.

I estimate this model by Heckman's two-step procedure using the technical success equation as a selection equation. Estimation results are reported in Table 12. The table reports estimated coefficients and robust standard errors[13] for each variable. As in the technical success model, in specification *I* I use the number of employees to measure firm size, while in specification *II* I use firms' revenue as a measure of size. In specification *I*, I use specification I of the technical success model for the selection equation. Similarly, in specification *II*, I use specification *II* of the technical success model for the selection equation. In both cases, estimation results of the selection equation are not reported.

Based on the results in Table 12, I cannot reject the hypothesis that larger projects are faster to commercialize (hypothesis 3). On average, a 10% increase in project budget reduces time to commercialization by over 3 months.

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[13] Allowing correlation between the error terms of projects approved in the same BOG meeting.

The results concerning firm size are less definite. The negative effect of the number of employees at the American firm is consistent with hypothesis 4. However, the positive effect of the number of employees at the Israeli firm suggests rejecting the hypothesis. Furthermore, the two effects cancel each other. Revenue does better as a measure of size (specification II). Duration to commercialization decreases with the revenue of the American firm. On average, a 10% increase in the revenue of the American partner reduces duration to commercialization by almost 3 months.

Hypothesis 7, suggesting that integrated firms are faster to commercialize, cannot be rejected based on the results in Table 12. The hypothesis that the variable **RELATED** has no effect can be rejected at the 0.05 significance level. On average, related firms are about 5 months faster to commercialize.

Based on the estimated coefficient of the variable **COMP** it is possible to reject hypothesis 8. This outcome suggests that firms that can substitute for each other in more activities are faster to commercialize.

Note that the coefficient of the Mill's ratio is negative and significantly different from 0. This coefficient indicates the correlation between the residuals of the technical success (selection) equation and the duration to commercialization equation. Its negative sign implies that unobserved factors that increase the probability of technical success decrease the time it takes to commercialize.

Finally, it is worth noting that projects under the Medical Equipment category take much more time to commercialize. This is probably an institutional outcome; products in this market category have to be approved by the FDA before commercialization.

8. Conclusion

In this paper I employ data on American-Israeli research alliances to investigate the success of R&D projects. I develop, and test, two sets of hypotheses relating the size and organizational form of an alliance to technical success and the timing of commercialization.

I find that both size and organizational form affect the probability of technical success and duration to commercialization. Specifically, the probability of technical success increases when (1) duration of the project increases, (2) firms are related through ownership, and (3) firms possess complementary abilities. Given technical success, the time to commercialization decreases when (1) project budget increases, (2) revenue of the larger firm in the alliance increases, and (3) firms are related through ownership.

My findings support the Schumpeterian hypothesis linking size to performance, and are consistent with transaction cost theories that relate organizational form to performance. These findings add to the discussion about reforming government R&D by favoring departures from the principle neutrality such as discrimination against large firms. Moreover, these findings suggest other ways to depart from neutrality. For example, one can imagine a support schedule that depends on a firm's degree of specialization. Firms that lack crucial capabilities such as marketing chain would get a more extensive support than those that have a full line of capabilities.

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Appendix – Proposal evaluation

1. U.S. Company

a) Marketing capability and commitment (0-10)

b) "Newness" to Israel (-5–5)

Notes:

a) BIRD experience indicates that the single most important factor in determining the outcome of a project is the quality and commitment of the U.S. company. Its willingness to become involved in a project includes, among other factors, its own evaluation of the technology and its Israeli partner.

b) "Newness". Since an important function of BIRD – some say it is the most important function – is to attract new U.S. companies into projects, this factor should have significant numerical effect on the total score. Negative scores are ascribed to companies that seek repeat business with BIRD.

2. Israeli Company

a) Ability to fulfill its role (0-5)

b) Financial viability (-5-0)

Notes:

a) The smaller range of scores (0–5) compared to that for the U.S. company (0–10) reflects the fact that few Israeli companies fail to meet technical project objectives if these are properly defined and monitored.

b) A major cause of project failure is lack of financial viability on the part of small Israeli start-up companies in particular.

3. The project

a) Commercial prospects (0-10)

b) Relevance and compatibility with other company activities (0-5)

Notes:

The project is less important than the companies! Good companies can rescue less good projects; less good companies can ruin excellent opportunities.

a) The commercial prospects, based on sales forecasts as a function of percentage of companies' business and previous record, projected rate of internal return, maximum negative cash flow and how it is to be handled, prospects for BIRD's payback are all considered in estimating this parameter.

b) The degree of commitment that a project tends to receive is often a determining factor. The additional 0-5 points here reflect the need to emphasize this consideration.

4. The record

a) Record of performance in other BIRD projects (-5-0)

Notes:

a) If either or both of the partners had a previous BIRD project, their effectiveness therein is evaluated and translated into a score in the range –5-0

5. Intangibles

a) A summation of intangible factors (0-5)

Notes:

a) On the whole, BIRD's instincts about projects and partnerships have become reasonably well developed over 180 projects, about half of them successful. If there is no special reason to add points for intangibles, the extra score is zero; if somehow we become madly in love with the people and the project, we add points accordingly, up to a maximum of five.

Table 1
Firms in a research alliance: descriptive statistics (170 observations)

	Mean	S. D.	Min	Max
	American firms			
Age of firm (years)	15.19	19.47	0	113
Previous year's Revenue (US$M)	256.44	1168.41	0	12000
Number of Employees	1478.43	7834.92	3	75000
Is firm publicly traded?	0.44	0.49	0	1
	Israeli firms			
Age of firm (years)	7.90	8.09	0	37
Previous year's Revenue (US$M)	0.49	0.16	0.28	1
Number of Employees	324.18	1150.15	4	10000
Is firm publicly traded?	0.21	0.41	0	1
	$Log(X_{US}/X_{IS})$			
Age of firm (years)	0.49	1.39	-3.14	4.03
Previous year's Revenue (US$M)	4.01	1.92	-0.69	9.39
Number of Employees	0.81	2.59	-5.74	8.23
Is firm publicly traded?	0.23	0.62	-1	1

Note: I report statistics that correspond to $(X_{US}-X_{IS})$ instead of $Log(X_{US}/X_{IS})$ for the ownership dummy (last row of the table).

Table 2
Research projects: descriptive statistics (170 observations)

Variable	Obs	Mean	S. D.	Min	Max
Duration (in months)	170	17.182	6.407	5	36
Budget (in US$)	170	1,066,000	496,000	288,000	2,911,000
Labor	122	619,921	359,179	100,000	2,085,000
Materials	122	99,035	144,415	0	1,350,960
Travel	122	47,229	69,937	0	757,750
Subcontracts	122	94,936	131,812	0	684,500
Consultants	122	28,897	60,540	0	547,900
Expected IRR (%)	170	50.349	30.417	15	300
#Employees	122	16.41	12.39	3	135
#Ph.D's	122	1.17	1.84	0	13
#Engineers	122	7.45	4.65	0	21
Experience (in years)	122	17.62	5.31	5	32
Are firms Related?	170	0.517	0.501	0	1

Note: Spending on “Other” and an additional 5% overhead are not reported under Budget.

Table 3
Firms contribution to the project (122 observations)

	Mean	**S. D.**	**Min**	**Max**
American firms				
Number of employees	7.29	11.67	1	125
Number of Ph.D's/M.D.'s	0.39	0.79	0	5
Number of engineers	3.04	2.88	0	14
Experience of head of project (years)	15.86	5.72	5	30
Israeli firms				
Number of employees	9.12	4.36	2	30
Number of Ph.D's/M.D.'s	0.78	1.28	0	8
Number of engineers	4.44	3.22	0	16
Experience of head of project (years)	15.24	5.20	2	32
X_{US}-X_{IS}				
Number of employees	-0.44	0.87	-3.40	2.53
Number of Ph.D's/M.D.'s	-0.38	1.07	-4	2
Number of engineers	-1.33	3.89	-16	9
Experience of head of project (years)	0.39	0.55	1.61	2.02

Note: I report statistics that correspond to $Log(X_{US}/X_{IS})$ instead of (X_{US}-X_{IS}) for the experience of head of project variable (last row of the table).

Table 4
How do firms allocate tasks in a research project? (142 observations)

	Israeli Firm	American Firm	Together	Split
R&D	50.53	0	49.65	0
Product Definition	8.51	31.91	59.57	0
Product Design	35.29	8.09	56.62	0
Manufacturing	44.66	14.56	38.83	1.94
Sales and Service	0.71	67.86	13.57	17.86

Note: All numbers in the table are percentage numbers. For example, in 50.53% of the projects the Israeli firm performs R&D alone.

Table 5
Probabilities of success

	Obs	Pr(Approved│Applied)		Pr(Technical│Approved)		Pr(Commercialized│Technical)	
Electronics	16	0.9375	(15)	1.0000	(15)	0.8666	(13)
Software	40	0.7500	(30)	0.9000	(27)	0.7778	(21)
Medical	18	0.8888	(16)	0.9350	(15)	0.6000	(9)
Communications	51	0.8235	(42)	0.9524	(40)	0.9000	(36)
Machinery	16	0.8125	(13)	0.9231	(12)	0.6666	(8)
Semiconductors	11	0.8182	(9)	1.0000	(9)	0.8888	(8)
Other	18	0.9444	(17)	0.9412	(16)	0.7500	(12)
All sample	170	0.8353	(142)	0.9436	(134)	0.7985	(107)

Note: Number of projects that correspond to each probability appears in parentheses

Table 6
Summary of hypotheses

		Firm size	Project size	Integration	Complementarity
Technical success	**H1**	+			
	H2		+		
	H5			+	
	H6				+
Duration to Commercialization	**H3**	–			
	H4		–		
	H7			–	
	H8				–

Note: The table summarizes the predicted effect of four groups of variables on the occurrence of technical success and duration to commercialization according to hypotheses 1 through 8.

Table 7
Definition of variables

Variable	Definition
BIRDRATE	Average rate given to project by BIRD's executives, $\in[0,1]$
BUDGET	Project's budget, Millions of $US
DURATION	Duration of project, Months
EXPIRR	Expected internal rate of return, %
EMPUS	Number of employees in American firm
EMPIS	Number of employees in Israeli firm
REVUS	Revenue of US firm in the year before the project, Millions of $US
REVIS	Revenue of IS firm in the year before the project, Millions of $US
AGEUS	Age of the American firm, Years
AGEIS	Age of the Israeli firm, Years
PUBLICUS	=1 if American firm is publicly traded =0 otherwise
PUBLICIS	=1 if Israeli firm is publicly traded =0 otherwise
MAT_AGE	|AGEUS)-AGEIS|/[AGEUS+AGEIS]
MAT_REV	|REVUS-REVIS|/[REVUS+REVIS]
MAT_EMP	|EMPUS-EMPIS|/[EMPUS+EMPIS]
MAT_OWN	=1 if both private or both publicly traded =0 otherwise
RSCH_D	=1 if firms can substitute each other in R&D =0 if complements
DEFN_D	=1 if firms can substitute each other in product definition =0 if complements
DSGN_D	=1 if firms can substitute each other in product design =0 if complements
MANF_D	=1 if firms can substitute each other in manufacturing =0 if complements
SELL_D	=1 if firms can substitute each other in marketing and service =0 if complements
RELATED	=1 if firms owned by the same entity or one is a subsidiary of the other =0 otherwise
COMP	=0 if firms substitute each other in all five types of activity =.2 if firms complement each other in one type of activity =.4 if firms complement each other in two types of activity =.6 if firms complement each other in three types of activity =.8 if firms complement each other in four types of activity =1 if firms complement each other in all five types of activity
TRAVEL	Travel expenses by the two firms jointly, Millions of $US

Table 8
Descriptive statistics

Variable	Obs	Mean	S.D.	Min	Max
BIRDRATE	170	0.795	0.219	0.250	1
BUDGET	170	1.066	0.496	0.289	2.911
	142	1.072	0.485	0.289	2.761
	134	1.079	0.493	0.289	2.761
DURATION	170	17.182	6.407	5	36
	142	17.296	6.389	6	36
	134	17.306	6.295	6	36
EXPIRR	170	50.349	30.417	15	30
EMPUS	170	1,478.432	7,834.921	3	75,000
	142	1,713.787	8,533.687	3	75,000
	134	1,771.867	8,787.461	3	75,000
EMPIS	170	324.183	1,150.152	4	10,000
	142	242.344	936.818	4	10,000
	134	226.317	953.197	4	10,000
REVUS	170	256.440	1,168.41	0	12,000
	142	290.956	1,251.647	0	12,000
	134	240.227	1,174.906	0	12,000
REVIS	170	0.497	0.156	0.284	1
	142	0.505	0.161	0.284	1
	134	0.499	0.151	0.284	1
PUBLICUS	170	0.442	0.498	0	1
	142	0.519	0.502	0	1
	134	0.508	0.502	0	1
PUBLICIS	170	0.206	0.405	0	1
	142	0.197	0.399	0	1
	134	0.187	0.391	0	1
MAT_AGE	170	0.518	0.346	0	1
MAT_REV	170	0.897	0.180	0.045	1
MAT_EMP	170	0.676	0.273	0	0.999
MAT_OWN	170	0.541	0.499	0	1
COMP_RSCH	170	0.500	0.501	0	1
COMP_DEFN	170	0.582	0.495	0	1
COMP_DSGN	170	0.541	0.499	0	1
COMP_MANF	170	0.276	0.449	0	1
COMP_SELL	170	0.135	0.343	0	1
RELATED	170	0.518	0.501	0	1
	142	0.500	0.502	0	1
	134	0.515	0.502	0	1
COMP	170	0.659	0.311	0	1
	142	0.592	0.297	0	1
	134	0.601	0.298	0	1
TRAVEL	142	0.047	0.069	0	0.758

Table 9
BIRD's project approval decision (170 observations)

	I	II
BIRDRATE	11.292***	---
	(2.791) [0.005]	
BUDGET	0.715	0.471
	(0.859)	(0.490)
DURATION	0.048	-0.016
	(0.070)	(0.032)
EXPIRR	0.002	-0.004
	(0.012)	(0.0049)
MAT_AGE	0.396	-0.768 *
	(0.824)	(0.448) [-0.107]
MAT_REV	2.447*	2.169 **
	(1.332) [0.0011]	(1.148) [0.303]
MAT_EMP	1.681	1.090
	(1.390)	(0.462)
MAT_OWN	0.309	0.349
	(0.726)	(0.345)
COMP_RSCH	1.808**	0.329
	(0.898) [0.0029]	(0.645)
COMP_DEFN	0.899	-0.285
	(0.914)	(0.296)
COMP_DSGN	-2.654***	0.434 *
	(0.758) [-0.0175]	(0.237) [0.065]
COMP_MANF	1.064	0.710 *
	(0.748)	(0.420) [0.081]
COMP_SELL	-0.367	-1.375 **
	(0.778)	(0.696) [-0.351]
Constant	-10.632***	-0.159
	(2.813)	(0.975)
Pseudo R^2	0.664	0.179
Log Likelihood	-13.520	-30.033

Notes: - An * indicates a 0.1 significance level, an ** indicates a 0.05 significance level, an *** indicates a 0.01 significance level
- Robust standard errors are computed allowing for correlation within BOG meeting. R.S.E are reported in ()
- Marginal effects are computed for significant variables and are reported in []

Table 10
Hazard rates given technical success

Periods t	Risk Group R_t	Sold D_t	Hazard Rate (H_t)	S. E.
1	134	36	0.2145	0.00126
2	98	30	0.2444	0.00189
3	68	19	0.2231	0.00255
4	49	9	0.1467	0.00255
5	40	5	0.0998	0.0022
6	35	3	0.0684	0.0018
7	32	1	0.0249	0.0008
8	31	1	0.0257	0.00081
9	30	1	0.0266	0.00086
10	29	1	0.0275	0.000923
11	28	1	0.0285	0.000989
NOT	134	27	0.2015	-

Notes: - The table reports the hazard rate adjusted for right truncation by dropping truncated observations from the risk group.

Table 11
Technical success (142 observations)

	I		II	
	Coef.	**R.S.E.**	**Coef.**	**R.S.E.**
	Technical success equation (performance equation)			
BUDGET	0.0116	1.0222	-0.04857	1.0195
DURATION	0.3890*	0.2154	0.1680*	0.0991
EMPUS	0.00014***	0.00005	---	---
EMPIS	-0.0046***	0.0018	---	---
REVUS	---	---	0.00003	0.00015
REVIS	---	---	-1.9188	1.6319
PUBLICUS	-2.8196**	1.2728	-2.9365**	1.6238
PUBLICIS	2.0839	1.4177	-0.1562	0.4349
RELATED	1.6131*	0.8555	1.3306*	0.7494
COMP	2.5079**	1.1827	1.4674*	0.8177
Constant	-2.5581	2.1641	1.7804	1.6188
	Approval equation (selection equation)			
BIRDRATE	11.3775***	2.8282	11.3180***	2.8255
BUDGET	0.8778	0.8627	0.9026	0.8510
DURATION	0.0320	0.0670	0.0273	0.0634
EXPIRR	0.0054	0.0131	0.0046	0.0129
MAT_AGE	0.4497	0.9219	0.3871	0.8601
MAT_REV	2.5259*	1.3656	2.5106*	1.3869
MAT_EMP	1.4626	1.3244	1.5594	1.3309
MAT_OWN	0.4649	0.5799	0.5086	0.5733
COMP_RSCH	-1.8838*	1.0937	-1.8210*	1.0747
COMP_DEFN	-0.9711	0.9361	-1.0258	0.9043
COMP_DSGN	2.6681***	0.8498	2.6566***	0.8336
COMP_MANF	-0.4386	0.8271	-0.4312	0.8122
COMP_SELL	-0.4143	0.8983	-0.5011	0.8352
Constant	-10.7845***	3.0437	-10.6732***	3.0152
ρ	-0.9917	0.0430	-0.9962	0.0158
Log likelihood	-23.3302		-28.2545	

Notes: - An * indicates a 0.1 significance level, an ** indicates a 0.05 significance level, an *** indicates a 0.01 significance level
- Robust standard errors are computed allowing for correlation between projects approved in the same BOG meeting

Table 12
Duration to commercialization (134 observations)

	I		II	
	Coef.	**R.S.E.**	**Coef.**	**R.S.E.**
BUDGET	-0.6965**	0.3342	-0.4905*	0.2857
DURATION	-0.00348	0.0243	-0.00752	0.02637
EMPUS	-0.0000084*	0.0000051	---	---
EMPIS	0.000599**	0.000262	---	---
REVUS	---	---	-0.000162*	0.000107
REVIS	---	---	0.9451	0.8823
PUBLICUS	0.2469	0.2235	0.1307	0.2474
PUBLICIS	-0.0770	0.2865	0.0126	0.2891
RELATED	-0.3343**	0.1453	-0.3186**	0.1469
COMP	0.4055*	0.2276	0.5144*	0.2772
Mill's Ratio	-0.1875	0.1160*		
Constant	1.8546***	0.4397	1.3146**	0.6537
Log likelihood	-133.12		-132.77	

Notes:
- Control variables (industrial classification) are not reported.
- The selection equations are not reported. Mill's ratios are calculated using the technical success equations in Table 11.
- An * indicates a 0.1 significance level, an ** indicates a 0.05 significance level
- Robust standard errors are computed allowing for correlation between projects approved in the same BOG meeting

Figure 1
The Decision Tree

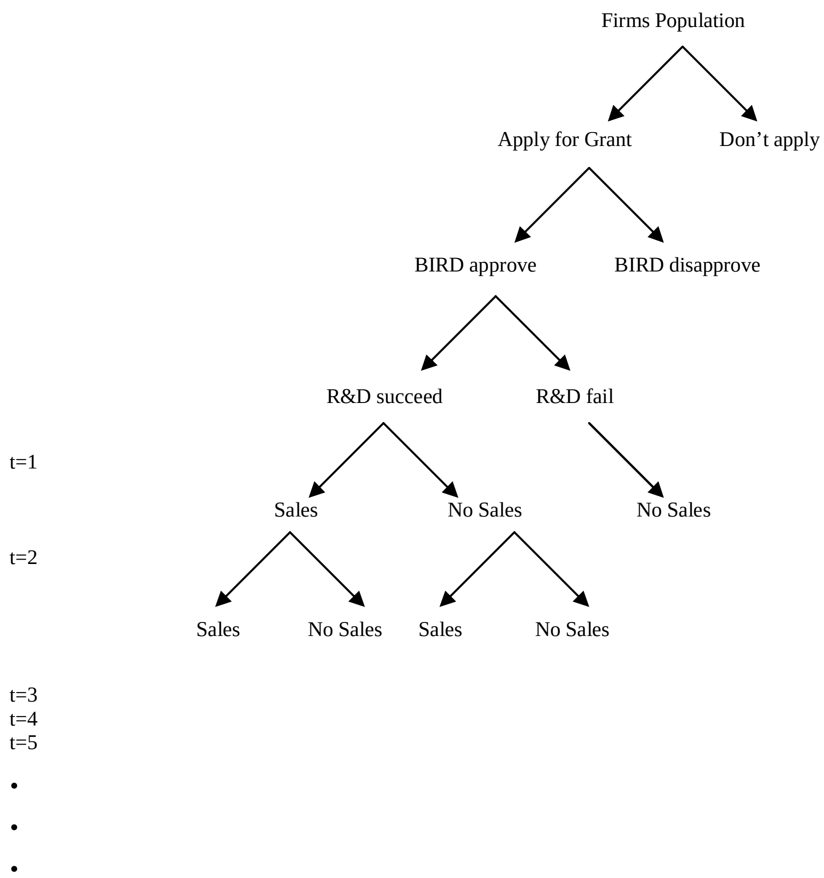


Figure 2
Distribution of duration to commercialization given commercialization

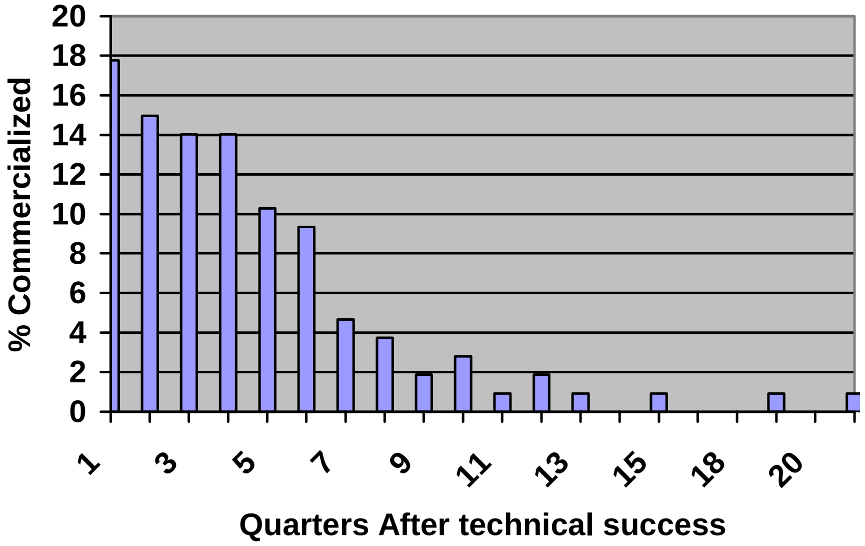
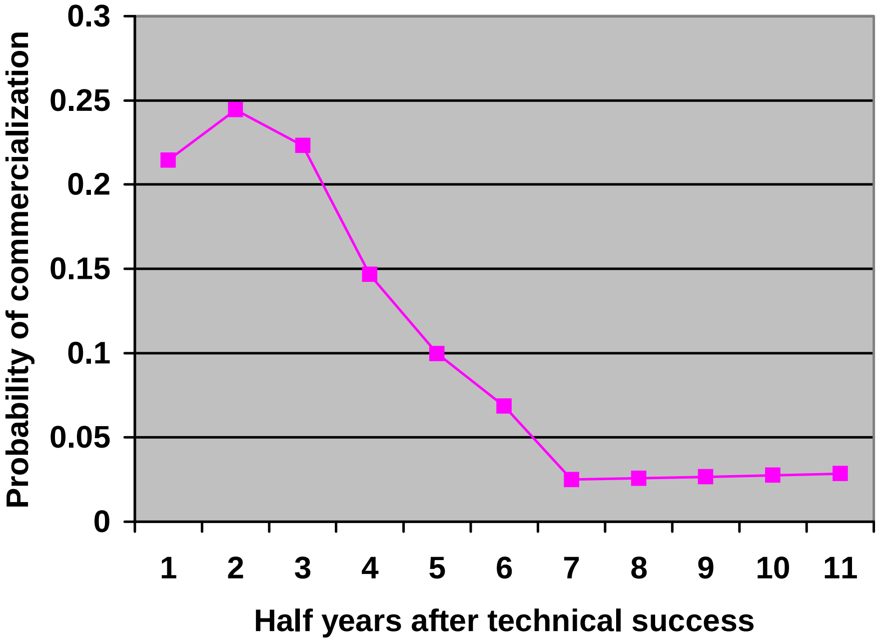


Figure 3
Adjusted hazard rate given technical success



Working and Position Papers

1) Lach, S., “Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel”, Science, Technology and the Economy Program (STE) – Working Papers Series, March 2001.

2) Trajtenberg, M., “R&D Policy in Israel: An Overview and Reassessment”, Science, Technology and the Economy Program (STE) – Working Papers Series, March 2001.

3) Lichtenberg, F. R., “Sources of U.S. Longevity Increase, 1960-1997”, Science, Technology and the Economy Program (STE) - Working Papers Series, November 2000.

4) Peled, D., “Defense R&D and Economic Growth in Israel: A Research Agenda”, Science, Technology and the Economy Program (STE) - Working Papers Series, March 2001.

5) Trajtenberg, M., “Innovation in Israel 1968-1997: A Comparative Analysis using Patent Data”, Science, Technology and the Economy Program (STE) - Working Papers Series, 2001.

6) Silipo, D.B. and Weiss, A., “Cooperation and Competition in R&D with Uncertainty & Spillovers”, Science, Technology and the Economy Program (STE) - Working Papers Series, August 2001.

7) Lach, S. and Sauer, R.M., “R&D, Subsidies and Productivity”, Science, Technology and the Economy Program (STE) - Working Papers Series, September 2001.

8) Bizan, O., “The Determinants of Success of R&D Projects: Evidence from American-Israeli Research Alliances”, Science, Technology and the Economy Program (STE) - Working Papers Series, September 2001.