The Contribution of Technology Firms' Collaborations, to the Firms' Innovativeness

TALI-NOY HINDI & AMNON FRENKEL

Faculty of Architecture and Town Planning, Technion – Israel Institute of Technology, Haifa 32000, Israel.

Email: tali@betaresearch.co.il

The study examines the effect of synergistic processes among high-technology firms on the innovation performance of the firms. More specifically, we aim to reveal how and to what extent the firm's collaborations with external companies or organizations affect the firm performance. Data collected among 195 high-tech firms on their internal R&D investments, including investment in collaborations with external firms and organizations and revenues generated from products developed, were analyzed using multivariate regression models. The finding revel that firms conducting external collaborations increase their revenue by 3.95 times compared with firms that do not interact.

Key words: Synergy, Hi-tech Firms, Collaborations, R&D

INTRODUCTION

Executives prefer to avoid collaborating process in technological R&D because of the risks and inputs it requires) Nickerson and zanger, 2004; Das, 2016). Yet, it can be assumed that with the strengthening of cooperative economic trends, such as the 'Circular economy' and the 'Sharing economy', the phenomenon of synergy will increase. Moreover, the most significant and strongest impact will occur with the consolidation of the IoT [Internet of THINGS] revolution[[1]](#footnote-1).

Various empirical studies were examined the nature of synergetic processes from the 1980s until today. In terms of synergistic processes, we refer to collaborations between firms and organizations in the development and upgrading of products and services. Beyond examining the scope of the phenomenon, there has been three phases in synergy research. At the first phase the research examined the motives led to synergetic processes, the inter-organizational mechanisms that enabled its existence and the conditions that enabled reduction of uncertainty and ambiguity between partners. on the second phase, studies have incorporated synergistic process characteristics into models that explain differences in the firm's innovation output, mostly patent outputs by focusing on a single variable. During the last decade a third phase arise, in which studies are estimating the impact of integrated synergetic variables on firm performance. However, the main empirical studies were based on secondary databases of firms which reported formal contracts for various types of cooperation involving at least two firms. Collaborations between firms and other types of organizations were not included in the databases. Therefore, these databases did not reflect the whole scope of the phenomenon but only its formal-contractual part and only the part that was published to the public. Furthermore, researchers expressed doubt about the reliability of the reports and the level of bias of the databases due to commercial considerations (level of exposure in the media), language bias (over-reporting to firms in English-speaking countries), and so on. In recent years, much of the research on synergetic processes and innovation has been based on the Community Innovation Surveys via EUROSTAT. Innovation surveys are conducted every two years and due to a change in methodology, they cannot be connected to a time series. As a result, there is a lack of initial and reliable database of synergetic processes of a formal and informal nature from different organizations in different industries, where the scope of synergetic processes between organizations is not directly estimated.

This study aims to reveal how and to what extent various degrees of interactions add value to firm performance. By conducting a comprehensive field survey of some 200 established high-tech firms, many data were collected about the collaborations they performed over four years and the impact these collaborations had on their revenue and innovation levels. The paper is structured as follows. The first Section provides a background to synergy processes and then provides an overview of the synergy research phases. The second Section describes the research methods. In Section 3 the findings are presented with reference to: the sample characteristics, description of the synergy phenomenon as reflected by the field survey, model estimation and the Impact of interactions' characteristics on firms' revenue***.*** The last section discusses and summarizes the findings.

Background to synergetic processes

High Innovation performance depends on internal and external variables to the firm. The internal components include competencies and absorptive capabilities, such as learning capabilities, information gathering and creating knew knowledge from integration of information (Von Tunzelmann and Wang, 2003, 2007). Whereas the external variables, also known as the 'local innovation milieu', include interactions with other players, such as: sharing infrastructure, creating collective capabilities to exploit economic opportunities, etc. (Camagni, 1995; Shefer and Frenkel, 1998, Fitjar & Rodriguez-Pose, 2015).

Interactions with other players on R&D processes contribute to the firm's innovation capability by raising the level of competencies of employees which are involved in these processes. These skills are used by employees in the creation of new knowledge, which comes from external firms, and enables the early identification and adoption of new technologies (Vinding, 2006). Scholars postulated that interactions help firms overcome deficiencies in information and scientific knowledge as well as resources and competencies (Becheikh et al., 2006; Kang and Lee, 2008; Back & Kohtamaki, 2015). Inter-organizational mechanisms reduce uncertainty and ambiguity between players (Nickerson and zanger, 2004; Mention, 2011; Das, 2016), carry on activities other than R&D, such as the development and/or acquisition of complementary assets (Teece 1986), the establishment of external collaborations and networking (Ahuja 2000) and external knowledge sourcing, possibly in an open mode (Chesbrough, 2003; Laursen and Salter, 2006; Sisodiya et al, 2013). Those activities are relevant to the demand and supply of external capital by the firm (Mina, Lahr, and Hughes 2013; Hall, et al., 2016).

Most of these studies were affected by the 2008-2009 economic crisis in Europe and as a result it focuses in the past several years on the costs and risks of external innovation activities and its impact on demand and supply of external capital by the firm (Mina, Lahr, and Hughes 2013; Hall, et al., 2016). Most of the empirical studies that engaged in measuring the synergetic value in Innovation activities, were based on four large databases, two of them cross-industry, SDC & MERIT-CATI; and the other two focused on biotechnology industry: RECAP & Bioscan. In total 42 studies were published based on the first of those two databases (Schilling, 2009). Moreover, various researchers used secondary databases of firms which reported formal contracts for various types of cooperation. They focused on the phenomenon of synergy and specifically examined trends and connections between the scope of the phenomenon and technological changes in specific industries.

In her comprehensive study, Schilling (2009) repeated several key studies based on the two large databases SDC & MERIT-CATI. The methods of processing and analysis were transferred from one database to another, and vice versa. Her conclusion from this study was that the two databases do not reflect the phenomenon and are only specimens.

The research body followed tried to assess the synergy phenomenon. For example, Srholec (2015) study which based on the fourth wave of the Innovation Survey of the European Union (CIS4), indicates that one-third of the products are classified as collaborative. As in the European survey, the Innovation Survey conducted by the Central Bureau of Statistics in Israel (2014) indicates that 30% of the firms that reported on technological innovation between 2010 and 2012 conducted different types of interactions. This survey is carried out using a similar methodology leaving out the non-formal processes and the processes that did not produce products. Therefore, it can be assumed that the scope of the phenomenon is underestimated.

Many of the studies focused on determinants of innovation output, mostly patent outputs. However, each study focused on a single variable, for example: institutional classification (firm, government, NGO, etc), partners mix (only firms, private-public collaboration, etc.), partner's role in chain of supply (supplier, customer), knowledge type (incremental vs. radical knowledge), etc. These studies found a correlation between partner's role in chain of supply and level of institutionalization. Differentiation was made between vertical interactions (customer and supplier interactions) and horizontal interactions (interactions outside the chain of supply such as with other organizations and institutions) (Parida et al, 2012, Lefebvre et al., 2015). This body of knowledge has found that innovation in processes is more common with suppliers, while innovation in products is more common with customers. It was also found that horizontal interactions contribute more to the firm's performance (Huang and Yu, 2011; Parida et al, 2012; Franco and Gussoni, 2013; Wang et al, 2015). More research was done indicate different effect to product innovation between private and public partners (Basit & Medase, 2019). In addition, it was found that knowledge type influences levels of interaction with partners: firms striving for radical innovation conduct the highest number of synergetic processes (Tether, 2002). Moreover, it was found that most of the interactions are persistence thus contribute to the innovative output (Freel, 2006; Nieto & Santamaria, 2007; Belderbos et al., 2015). Ad hoc interactions did not affect the output of innovation, except in association between a firm and a university or another research institution (Belderbos et al, 2015). The literature also indicates the influence of partner geographic location (local-oriented interactions vs. non-local interactions) with the firm's level of innovation (Sternberg and Arndt, 2001; Duyesters & Lokshin, 2011). This conclusion also emerges from EU innovation studies (Rothwell, Freeman et al., 1974; CIS 1, 1993; CIS 2, 1997; PACE 1, 1995).

Over the past decade, several studies estimated the contribution of integrated variables in the synergetic processes to the firm's performance, as reflected in innovation output and increased sales. These studies focused mainly on variance in innovation performance or variance in sales performance as a function of both partner role in chain of supply and persistence of interaction. However, the number of studies is still very limited and a key question about the impact of integrated variables of synergetic processes on firm performance remains open and has not yet been fully expressed in the literature (Parida et al., 2012; Ferrera et al, 2013; Franco and Gussoni, 2013; Wang et al., 2015; Belderbos et al, 2015).

Methodology

***Research hypothesis***

This study hypothesizes that synergistic processes between technological firms and/or other organizations, reflected in various features of interaction are of added value to the firm which may be reflected in an increase in revenue level and in the growth of innovation outputs (new products and processes). The hypothesis formulation is expressed in the conceptual model presented in Figure 1.



**Fig. 1: The hypothesized model: creating Innovative productions**

At the core of the model is a "black box" where inputs are transformed into outputs through interactions between different organizations. The process begins with the input of private and public investments in R&D done by the firm. The inputs are invested in creating reciprocal relationships between the innovation system components and all the components required for internal R&D. The innovation products that result from the process include products that are a direct result of the firm's sole internal investment, but also collaborative innovation products that are the result of interactions with other firms. The model has a feedback loop as some of the profits from innovation products come back into the system in the form of new investments[[2]](#footnote-2).

The Inputs in the model were measured through investments in infrastructure and R&D processes to promote internal R&D processes in the firm, and parallel investments in R&D to create collaborations with organizations and other firms. Interactions were measured directly using number of variables. For example: ad hoc or regular interaction, the time it lasts, the frequency level, the number of interrelated factors, the period of product life cycle in which the interaction is performed, etc.[[3]](#footnote-3). Outputs for assessing the level of innovation were estimated in the model by measuring the total of new products or processes that were created exclusively by the firm, or as a product of collaborations with other firms [collaborative products]. In addition, the firm's revenue from the sale of products and processes, new or improved, developed by internal R&D and external interactions.

***Data Collection***

**Research region and population**

The study was carried out in Israel where the high-tech sector is highly developed[[4]](#footnote-4). In order to identify regional centers with concentration of high-tech firms that the field survey will focus on, the spatial distribution of the total of 5,780 established high-tech firms[[5]](#footnote-5) in the IVC database was examined toward their geographical location and their sector affiliation. The geographical mapping was done using the Point Density tool, which is part of the ArcMap 10.2.2 software spatial mapping tool. The tool calculates the size per unit area [density] according to the feature of the point in each cell environment (Silverman, 1986). The initial mapping revealed that the spread of high-tech firms in Israel is very extensive; However, the clusters are mostly concentrated in specific areas in the center of the country with three developed agglomerations of knowledge-intensive areas: Separate agglomerations, continuous agglomerations and Tel-Aviv agglomeration which presents concentric circular expansion [see figure 2 below]. At the end of the mapping process, three regions (clusters) were selected for conducting the online survey:

* Tel Aviv region, which represents the highest density point of 1,037 high-tech firms.
* Sharon region includes Herzliya, Kfar Saba and Ra'anana. This region represents the continuous agglomeration, includes 538 high-tech firms.
* Haifa region includes Haifa, Krayot and Yokne'am. This region represents the isolated agglomerations, including 323 high-tech firms. The unification between Haifa and Yokne'am is intended to increase the sampling frame, although their density is different.

The three sampling regions include 1,898 firms that constitute approximately one third (32%) of the total 5,780 established high-tech firms. Comparing the sectoral distribution of the firms in the three sample areas to all the high-tech companies, showed great similarity and indicated a good level of representativeness.



Figure 2: Spatial Density of Science-Based Firms in Israel - Geo Focus

**Web-based survey design**

The field survey was conducted between December 2014 and December 2015. The data collected by means of detailed web-based questionnaire that were sent to CEOs and senior managers in all 1,898 hi-tech firms in the three sampling areas. Firm managers were asked to provide data on their firms and their collaborations with other firms and / or organizations, in detail over the period 2010-2013. Each firm that reported that collaborated in R&D processes with a company and / or organization, external to the firm, was asked to provide detailed data on the interactions (up to three main interactions) performed in the four years prior to the survey. In addition, a data retrieval process was conducted via telephone questioning to those respondents who partially answered the questionnaire. Prior to embarking on the full field survey, a pilot was conducted that included a dedicated questionnaire used among high-tech firms in the Rosh Ha'Ayin area) excluded from the three sampling areas and used as an experimental area). Based on the pilot survey, questions in the designated questionnaire were sharpened.

The purpose of the questionnaire was to collect detailed data on the innovation inputs and outputs of the high-tech firms and their characteristics in the areas selected for the sample. The collected data enable analytical analysis of the relationships between the dependent variables, independent variables and moderating variables defined in the model. The questionnaire included questions relating to the following aspects:

* Firm characteristics: sector, sub-sector, number of employees, etc.
* Level of investment in R&D: Direct annual investment in R&D in the years 2010-2013. The figure is classified into two types of investment: (a) Direct annual investment in internal R&D; (b) Direct annual investment in promoting R&D external interactions.
* Data relating to external interactions: The types of collaborations their intensity and complexity (ad hoc or regular interaction, the time it lasts, the frequency level, The number of interconnected bodies, etc.). The firm in the sample was asked with what types of organizations it interacts with (competing firm, supplier, university/research institute, governmental entity and so on). The firm was also asked to elaborate in depth on the complexity of the interaction through closed questions, up to three of the most dominant collaborations it conducted during the period reviewed.
* Total new products or processes created by the firm exclusively or as a product of teaming up and collaborating with other firms/organization [collaborative products]; Also differentiate between supplemental innovation (i.e., improving existing products) or radical innovation (new product development) or process innovation.
* Revenue received from sales of products and processes, new or improved, developed through internal R&D and external interactions in the years 2010-2013.

Results

***Sample characteristics***

The survey yielded complete questionnaires from 195 high-tech firms, accounting for 10.3% of all firms in the three regions: 80 (8%) from Tel Aviv area, 51 (16%) from the Haifa area and 64 (10%) from the Sharon region.

In terms of the size, in both the sample and the total in the three sampling areas, most of the firms are small to medium-sized high-tech firms with an average size of 12.4 employees and a standard deviation of 22.6 employees. The distribution of this characteristic among the three regions was also found to be similar. In terms of firm's seniority, the sample was found to represent the population distribution well. Nearly half of the firms in both the total population and the sample are young firms established in the last four years (47% and 49% respectively). Another 40% of firms, both in the general population and in the sample, established in the first decade of the 2000s. This distribution was found to be similar across the three regions.

In terms of industry affiliation, a quarter of the firms in the sample are from the life sciences industry, and about a fifth belong to the telecommunications (21%) and the internet (19%). The software and information technology industry constitute 15%, green energy (10%) and, below, various technologies and the conductor industry. The regional distribution indicated that each region is characterized by a mix of different industries. The dominant industry in the Tel Aviv area is the Internet industry (35%), the dominant industry in the Haifa area is life sciences (37.3%), and the dominant industries in the Sharon region are life sciences (26.6%) and the communications industry (25%).

In terms of investment in R&D over the four years examined, the total investments of the firms in the sample amounted to NIS 1.68 billion, with NIS 1.53 billion invested in internal R&D (accounting for 91% of total investment) and NIS 150.4 million on External R&D (only 9% of total investment). However, as will become clear in the next Model section, the impact of the collaborations was found to be very large due to the increase in investment coming from the external partner firms, an increase that greatly increases the return on investment. The average annual expenditure on total R&D (internal and external) between 2010-2013 was about NIS 2.2 million per hi-tech firm in the sample. This average is slightly higher in the Sharon region (about NIS 3.1 million) compared to the Tel Aviv area (NIS 1.8 million), and the Haifa area (NIS 1.6 million). However, these differences were not found to be statistically significant.

***The phenomenon of synergy***

The survey findings indicate that between the period 2010-2013, almost half of the firms in the sample (91 firms 47%) collaborate on R&D with other firms or organizations. In total, 270 collaborations reported (about three collaborations on average per firm). Based on detailed data reported on 135 collaborations, about a quarter were realized on the basis of some kind of social closeness between the collaborating organizations: previous workplace (15%), university (5%), previous business relationship (5%). It was interesting to note that very low rates of collaborations were based on family relations or mutual friends. On the other hand, the importance of social closeness becomes evident, as this is likely to intensify during the process of collaborations in which closeness is established. 60% of collaborations actually rely on some kind of social closeness: 40% report the existence of formal social closeness reflected in regular meetings, conferences and the like, 8% report on an informal social relationship, while 14% report that both types of relationships exist together.

In the period reviewed, the firms in the sample reported 1179 innovation outputs (new products and processes) resulting from internal R&D, which was called **exclusive products**; and 236 innovation outputs resulting from external R&D invested in collaborative processes which was called **collaborative products**. Although the share of innovation outputs that result from collaborations in all innovation outputs is relatively small, they are likely to be very significant outputs. The findings from the analysis presented in the next section shows that the impact of the collaborations on the firm's income is highly significant.

In order to examine whether and to what extent the phenomenon of synergy contributes to increasing innovation outputs, the differences in the amount of innovation outputs between firms that collaborate with those who do not collaborate with other organizations were examined. Firms that did not have any innovative outputs during the period for which the data were collected (2013-2010) were omitted from the analysis, as well as firms with extreme output (100 innovative outputs per firm), to moderate the results and express the most prevalent results. This analysis included 169 firms from the entire sample (The findings presented in Table 1).

Table 1: Cross Tabulation of Total Productivity by collaboration

|  |  |  |  |
| --- | --- | --- | --- |
| Collaborative/non-collaborative firm | Number of firms | Average innovative outputs per firm between 2010-2013 | S.D. |
| Non-collaborative firm | 92 | 5.20 | 4.94 |
| collaborative firm | 77 | 8.01 | 10.41 |
| Total | 169 | 6.47 | 8.01 |
| T-test | (t=-2.178, df=104, sig=0.032) |

Statistically significant differences exist between firms that collaborate (77 firms) and firms that do not collaborate (92 firms) in the amount of innovative outputs (mew products and processes). Collaborative firms increase their productivity by an average of 54%, which is reflected in an average addition of 2.8 innovation products compare to firms that do not collaborate. This addition of innovation activity is a significant added value for increasing firm performance.

The survey also revealed that out of 135 collaborations, 68 of them produced outputs that resulted in the creation of 205 new products and processes, of which 62% were new products and another 24% of existing products are significantly improved. The analysis shows that one-third of the 135 reported collaborations are one-time, lasting an average of 14 months, while two-thirds result from ongoing activity between organizations take an average of 30 months.

In terms of the geographical affiliation of the collaborations, those in which all partners operate in the same region (in each of the three sampled regions) were defined as local regional partnerships[[6]](#footnote-6). Collaborations that at least one of the partners located in Israel but outside of these areas have been defined as Israeli partnerships, while collaborations with at least one of the partners located abroad have been defined as international partnerships. The type of dominant collaboration in terms of geographical affiliation is the international partnership (about 50%). Presumably, due to Israel's limited market size, technology firms are trying to penetrate overseas markets and the need to raise capital.

***Model Estimation***

The relationship between the firm's investments in internal and external R&D and the revenue from the innovative output sales, as presented in the conceptual model (see Fig. 1 above) was examined by employing multivariate regression models. the firm's revenue from sales of new products and processes that it created in the innovation process served as dependent variable in the model. by controlling for the firm size, firm age and industry affiliation we aim to empirically test the impact of investment on R&D and collaboration on firm's revenue.

Firms that did not report sales revenue or investment on R&D during the period reviewed were omitted from the model. In addition, firms with extreme sales revenues (over NIS 200 million) during the period for which the data were collected, were also omitted to moderate the results and express the most common results.

The specification of the proposed models is given in Eq. (1):

$$\left(1\right) IN\_{i}= β\_{0}+β\_{1}×ERD\_{i}+ β\_{2}×C\_{i}+\sum\_{e=1}^{t}β\_{e+2}×AC\_{ie}+\sum\_{n=1}^{q}β\_{n+t}×AF\_{in}+ε\_{i}$$

Where:

INi= Revenue of firm i from sales of new product or processes, calculated as the LN [LOG at base e] of firm i's average annual revenue over the 4-year survey period (2010-2013).

ERDi= R&D expenses (internal and external) of firm i

Ci= dummy variable indicates on interactions (1=firm that made at least one collaboration with other organization; 0= non-collaborative firm).

ACie= Characteristic e (e= 1…t) of collaboration which firm i has with other organizations (for example: type of collaboration, collaboration frequency, etc.) Each of the companies in the model that collaborated is represented in the model by one collaboration in which the highest R&D investment was made.

AFi= Control Variables- Characteristic n (n= 1…. q) of firm i (for example: firm size, firm age, sector, etc.).

Given that we did not have a data panel beyond the reported four years, the question of non-existence of time leg between R&D investment flows and the actual firm performance (generating revenue) in the model was raised. It is important to note that the literature has not yet been able to accurately estimate the existing time gap between R&D investment flow and actual firm performance (Hall & Mairesse, 1995; Harhoff, 1998). At the same time, findings from Mairesse's and Sassenou (1991) and Hall and Mairesse (1995) indicate the stability of R&D investments made by technology firms over time, in different countries (France, USA and Germany); The researchers also pointed to insensitivity in the results even when different time gaps were examined.

Based on these findings, it was decided to run in the model the R&D intensity measure, by calculating the annual average value over the four-year period surveyed. This technique has also been used in Wakelin's (2001) study of productivity growth and R&D spending among UK manufacturing companies. We further confirmed this decision by examining the four-year differences we had in the R&D investment data and revenue of the firms in the sample. The findings strengthened the decision to use the four-year average annual value calculation in the firms' R&D investment and revenue data in the model.

The results of the multivariate regression models are presented in Table 2. Transformation was performed for the variables: revenue from sales of new product or processes and R&D investment into LN values. In Model 1, these variables were used as the annual average of investments and revenues during the period reviewed (as explained above), In Model 2 these two variables were normalized by the firm size (number of employees) in order to determine whether the firm size has an effect on the results. All other explanatory variables were identical in both models and included the collaboration dummy variable, dummy variable for the sectoral affiliation of the firm, with a score of 1 for firms in the life sciences industry and 0 for all other industries, a continuous variable for firm's seniority, and a categorical variable for its location (in the 3 surveyed regions).

Table‑2: Multiple Regression Model Estimation Results for Evaluating the Contribution of Explanatory Variables to Products Sales

| Variables | **Model 1**Dependent Variable- Average annual firm revenue (LN)  | **Model 2**Dependent Variable- Average annual firm revenue (LN)-Per employee |
| --- | --- | --- |
| S. E | Estimate | S. E | Estimate |
| Average R&D investment (LN)  |  0.117\*\*\* | 0.543 |  |  |
|  Average R&D investment (LN)- per employee |  |  |  0.154\*\*\* | 0.540 |
| Dummy-Variable Interaction (1=at least one interaction, 0=no interactions) |  0.333\*\*\* | 1.046 |  0.348\*\*\* | 1.103 |
| Firm's age (years) |  0.029\*\*\* | 0.128 |  0.029\*\*\* | 0.096 |
| Firm's location (1=Tel Aviv, 0=other) | 0.370 | -0.190 | 0.381 | 0.180 |
| Firm's location (1=Haifa, 0=other) | 0.468 | -0.676 | 0.482 | -0.634 |
| Firm's sector (1=life science sector, 0=other) | 0.502 | 0.325 | 0.515 | 0.211 |
| Constant |  1.536\*\*\* | 5.234 |  1.757\*\*\* | 4.543 |
| Number of observations | 102 | 102 |
| Adjusted R2 | 0.422 | 0.282 |
| F | 13.295 | 7.622 |

 \*\* level of significant 0.05 \*\*\* level of significant 0.01

The results in both models indicate that the annual level of investment in R&D is positively and statistically significant in a high level with the dependent variable - Annual Average of Revenue. A statistically significant positive correlation is also found between collaboration dummy variable and firm revenue variable. Moreover, the estimate of the collaboration dummy-variable is much higher than that of the R&D investment variable, indicating highly significant impact that collaboration has on the firm's revenue. Of the control variables, only the firm's age variable is in significant positive relation with the firm's revenue variable. The geographical location and sector affiliation of the firm were not found to be statistically significant with the firm's revenue.

The results obtained show that investments in R&D and, moreover, the existence of collaborations clearly increase the firm's revenue from new products and processes. This can be seen as another indication of the firm's level of innovation. However, we did not have panel data that would allow us to unambiguously examine the direction of the positive relationship between investments in R&D and the firm's revenue from new products and processes. it was doubted whether firms with high revenue attract more collaborations rather than collaboration is the one that generates higher revenue as defined in the research hypothesis. In order to solve this endogeneity problem, we have taken the Instrumental Variable method (IV) which proved that industry classification can serve as instrumental variable that is not related to firm's revenue. To test the suitability of this variable to serve as an instrumental variable, we examined the relationship of the industrial affiliation dummy variable (affiliation with life sciences = 1, affiliation with other industries = 0), with the explanatory variable - the average level of investment in R&D, and with the dependent variable - the firm's revenue.

The results obtained indicate that the sectoral affiliation in the life sciences sector is in a positive and statistically significant correlation at a high level with the R&D investment variable, but it is not in significant statistical correlation with the firm revenue variable. Therefore, this variable can be used as an instrumental variable for estimating the R&D investment vector that will replace the original variable and solve the endogeneity problem. A similar finding was also obtained in Wakelin's study (2001) which showed that the intensity of investment in R&D is sensitive to the sectoral affiliation of the firm.

Using the instrumental variable that replaced the suspected endogenous variable and the dummy-variable for Interaction, in the regression model no. 3 (Table 4) indicate a statistically significant positive effect at a high level (p = 0.001) of the two explanatory variables on the dependent variable. Furthermore, the positive effect of the dummy-variable of interaction on the revenue is significantly higher than the effect of the predicted Average annual R&D investment variable (see the estimated values ​​of these two variables). That is, given the same R&D investment between two firms, the firm that interacted with other firms or organizations has achieved a much higher revenue than a firm that has no interaction in R&D processes.

Table-4: Linear Regression Model for Evaluating the Contribution of Interaction Explanatory Var. on Products Sales

|  |
| --- |
| **Model 3**- Average annual sale R2= 0.193ָָָAdjustedN=102 |
| Variable | Estimate | S. E |
| Dummy-variable- Interaction  | 1.601 | 0.387\*\*\* |
| Predicted variable - Average annual R&D investment | 0.659 | 0.241\*\* |
| Constant | 4.225 | 3.232 |

\*\* level of significant 0.05 \*\*\* level of significant 0.01

Estimating the effect of interaction on revenue is obtained from the following function which uses the estimator and multiply the revenue by 3.95 times (E=e 1.601-1= 3.95). Meaning, interacting firms increase the firm's revenue by 3.95 times compared to non-interacting firms (without reference to the number of interaction).

In addition, examining the effect of the interaction variable on the predicted variable - average annual R&D investment (multiplying the interaction variable with firm investment in R&D), enable to identify the aggregate impact that the interaction has regarding R&D investment. The results show a significant statistical relationship between the independent variables and the dependent variable - the firm's annual average revenue (Model 4 in Table 5).

Table‑5: Multiple Regression Model for Evaluating Contribution of Interaction on Products Sales and Interaction Activity

|  |
| --- |
| Model 4- Average annual revenue from salesAdjusted R2= 0.222ָָָN=102 |
| Variable | Estimate | S. E |
| Dummy-variable - Interaction  | 13.87 | 6.355\*\* |
| Predicted variable - Average annual R&D investment | 1.139 | 0.343\*\* |
| INTERACTION: between dummy-var. interaction & Predicted variable [Average annual R&D investment] | 0.919- | 0.475\*\* |
| constant | 2.200- | 4.605  |

\*\* level of significant 0.05 \*\*\* level of significant 0.01

The interesting finding obtained in Model 4 is that the effect of the interaction variable (with a negative effect) almost completely reduced the effect of the annual R&D investment variable on the firm's average annual revenue, while the effect of the dummy-variable interaction was greatly increased. This means that there is virtually no difference in marginal return as a result of increasing one percent of R&D spending, between firms that interact and firms that do not interact with other firms. The main impact is caused by the very existence of interaction.

The explanation that can be provided for this finding is that the additional investment in R&D with which the external partners brings with them are those that greatly increase the revenue to those firms that cooperate and not the investment of the firms in the sample (this investment was also found to be relatively lower than the total R&D investment). There are additional financial inputs from the external partner with whom interaction is made, beyond the direct investment of the interacting firm whose isolated influence only slightly increases the revenue. This is an exclusive contribution of the interaction.

***The Impact of interactions' characteristics on firms' revenue***

Examination of the aggregate impact of the collaboration components on firm's revenue was done by integrating the results obtained from Cluster Analysis into a multivariate regression model[[7]](#footnote-7). First to select the interactions' characteristics that are correlated to the firm's revenue, each of the 13 characteristics reported in the survey were examined in a multivariate regression model that included a dummy-var interaction and the predicted- firm investment in R&D. These tests revealed that there are 6 collaboration characteristics that contribute significantly to the firm's revenue, identifies as:

1. The partnership mix that describes the composition of the various partners - to do this, we borrowed a classification from the concept of Social Capital (SC), according to which the mix were associated with two categories: Bridging SC and Bridging SC. Non-competitors 'Firm-Firm Mix' were classified as Bonding SC, while the other mixes (competing firm, a consulting firm, an academy and so on) were classified as Bridging CS. The Bonding-Bridging social capital refers in the literature to groups in society and was recently used to estimate its contribution to economic diversity in regions (Cortinovis, 2016).
2. The Geography of Interaction - Each Interaction was classified into one of the three categories: (1) Local interaction- all its members are in one of the three regions of the sample (Haifa, Tel Aviv or Sharon Area) (2) National interaction- at least one of the partners is located outside the 3 sampled regions but within the State of Israel (3) International interaction- at least one of the partners located outside of Israel. The variables were entered into the cluster analysis as three separate dummy variables (local, national, international).
3. Knowledge Type – This variable was classified dichotomously into partnerships in which there was a striving to create (even partially) innovative and radical knowledge and to partnerships focused on the creation of supplementary knowledge.
4. Social connection - the categories of the variable include interactions in which there is a social connection of any kind versus interactions in which there is no social connection at all between the partners.
5. Level of trust between the partners - the variable was classified into two categories: category having no trust between partners, and category classified as having trust between partners. This metric is also an indication of the partner's level of reliability and may indicate a previous partner's experience or reputation as a trusted partner who has met his or her obligations over time.
6. Formal mechanisms to interactions - For each interaction, it is specified whether it includes coordination mechanisms (management or directorate or joint board members). The formal mechanism variable is divided into two categories: interactions that have formal mechanisms [of any kind, one or more mechanisms], and interactions that do not have formal mechanisms.

Running cluster analysis on the above collaborative features resulted in grouping them into three clusters at a good level of analysis. The dominant features as emerged from the analysis is the geography of interaction. Accordingly, the interactions were unequivocally grouped into three distinct groups (Table 6): Local cluster (15% of the firms), National cluster (27% of the firms) and International cluster (58% of the firms).

*Local cluster* - most firms in this cluster focus on generating supplemental knowledge, express trust in the partnership which based on social connections and formal mechanisms. Most of the firms relies on bridging social capital (71.4%), that is, the partners come from essentially different types of organizations.

*National cluster*- most firms in this cluster focus on generating supplemental knowledge, but about half do not trust the partnership. In more than half of the firms the partnerships are more prone to ad hoc needs and the social ties are looser and the partnerships exist between types of organizations that are essentially similar (Bonding social capital).

*International cluster*- more firms in this cluster focus on creating innovative-radical knowledge than the firms in the previous two clusters. The cluster is based on a high level of trust between most of the partners, characterized by formal mechanisms. Most of them, though less than the local cluster, but more than the national cluster, have social connections. The international cluster relies on bridging social capital, i.e., organizations of a different nature and essence differ from each other to form the collaboration.

Table‑6: Cluster Analysis

|  |  |  |  |
| --- | --- | --- | --- |
| Variable- scale | Local clusterN=7 | National clusterN=13 | International clusterN=28 |
| Knowledge type- supplemental innovation | 85.7% | 69.2% | 60.7% |
| Having trust | 85.7% | 53.8% | 75.0% |
| Partnership mix- Bridging SC | 71.4% | 53.8% | 71.4% |
| Having formal mechanisms to interactions | 57.1% | 53.8% | 67.9% |
| Social connection - having social con. | 71.4% | 53.8% | 60.7% |

The impact of interactions' characteristics was examined using a multivariate regression model in which the parameters of 102 firms were run, some cooperative and some non-cooperative. In the model the independent variable is LN Annual average of revenue. The explanatory variables are: (x1) LN predicted variables investment in R&D; (x2)dummy-var. local cluster (local cluster=1, other=0); (x3) dummy-var. National cluster (national cluster=1, other=0); (x4) dummy-var. international cluster (international cluster=1, other=0). The contribution of variables to the firm's revenue is the contribution in relation to the dummy variable – firms without cooperation (serves as a control group). The results indicate that all explanatory variables significantly and positively correlated with the independent variable (see table 7):

Table‑7: Multiple Regression Model Estimation the Contribution of Cluster Var. to LN Average Annual Products Sales

|  |
| --- |
| Model 5: LN Average annual sales Adjusted R2= 0.205ָָN=102 |
| variable | Estimate | S.E. |
| Predicted- LN Average annual investment in R&D | 0.640 | 0.244\*\*\* |
| Local cluster | 2.089 | 0.79\*\*\* |
| National cluster | 1.166 | 0.607\*\* |
| International cluster | 1.715 |  0.456\*\*\* |
| Constant | 4.483 | 3.279 |

\*\* level of significant 0.05 \*\*\* level of significant 0.01

The calculation of the multiplier of each cluster for the firm revenue in relation to non-cooperating firms is as follows:

The local cluster contribution is: 7.07, [E=e2.089-1= 7.07]

The national cluster contribution is: 2.2, [E=e1.166-1= 2.2]

The international contribution is: 4.5, [E=e1.715-1= 4.55]

These findings indicate a declining effect of the clusters on sales revenue: the local cluster has the highest impact (7.07), followed by the international cluster (4.5) and the lowest the national cluster (2.2). These results indicate that synergism characterized by high geographical proximity has a unique and empowering significance for the growth of the firm and the region. These interactions simultaneously constitute an anchor that characterizes the innovative environment and attracts additional firms and a growth engine of the regional innovation system.

**Discussion And Conclusions**

Most investors examine firms according to key criterion - firm value, which means the economic value of the firm's equity. This is true for most industries with one exception - the technology firms. By definition, high-tech firms are not born profitable. In their early years, they are expected to develop cutting-edge technology, which mainly involves heavy expenses. Some of them, in their early stages of their life cycle, start generating revenue from the product they have developed. However, due to their structure and the financing of venture capital funds, they are not intentional to reach profitability at early stages. Thus, in the case of technology firms, which are completely unprofitable, basic financial indexes, such as relative share price to earnings (P\E) are irrelevant and belong to the 'old economy'.

In practice, in order to estimate the value of a technology firm that is in its initial stages, the future profitability potential will be overweight. As a result, in recent years, we have witnessed the extreme phenomenon of firms known as 'unicorns' - private firms that have reached $ 1 billion or more. The problem that arises is a focus on growth at all costs, which encourages a high rate of cash burning without examining the way money is used and the value it generates - for example, in the sales measurement (McKinsey & Firm, July 2016; Bort, 2017; Ravon, 2017).

Today, in an environment characterized by macro risks, investors are taking cautious approach and go back to solid measures indicate real growth. Various investors believe that soon we will see a correction in the market with technology firms' valuations. Firms will have to cut back on investments and increase sales efficiency, even at a slower rate of growth. The rapid growth that is the product of large capital investment will be replaced by smart growth stemming from sales growth (Waters and Hook, 2016; Trigg, 2016).

These two aspects, capital investment and sales volume of the firm, were at the heart of the economic model of this study as complementary aspects of growth. Capital investment as a leader in rapid growth of firms and sales volume as a smart growth leader by establishing firm profitability.

In the model examined in this study, firms that did not present sales data were excluded. In other words, the model applies only to firms that have been established and have undergone the initial development phase. The results of the study indicated that high-tech SMEs allocate an average of only 10% of their investment budget to collaborate with external firms or other organizations. However, they receive a very high return on investment expressed in their redemption increase, on average, 3.95 times compared to firms that do not invest in interactions. This finding indicates a significant advantage in entering interactions. The main impact is caused by the very existence of collaboration. The additional investment flow in R&D that the firms with whom cooperation is being carried out is the ones that greatly increase the revenue to this firm that cooperate and not the firm's investment alone.

Moreover, the model findings indicate that the local cluster has the highest impact on sales revenue. Firms in the local cluster that cooperate generate 7.07 times more revenue than non-cooperating firms (higher than firms in the national and international clusters). It is an indication of geographical proximity impact on firm growth and innovativeness.

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1. The Internet of Things (IoT) is a network of physical devices, vehicles, home appliances, and other items combined with electronics, software, hardware, and sensors that create connectivity that allows these objects to exchange data. The purpose of connectivity is to enable physical devices to provide smart service to consumers. A service that studies the user's consumption characteristics from various databases and adapts itself to these characteristics. [↑](#footnote-ref-1)
2. The feedback loop could not be examined in the work frame as we did not have a sufficient data panel for this, but it should be noted in the theoretical model [↑](#footnote-ref-2)
3. The literature suggests, but has not been empirically proven, that there is a balance between external firm interaction and internal R&D processes due to e.g. moving employees from one firm to the other at the end of the joint venture. These employees have rich experience and knowledge and their contribution to the internal R&D is great. To examine this, a systematic study based on in-depth qualitative methods of several case studies is required, a framework which was not included in this study. [↑](#footnote-ref-3)
4. Internal R&D expenditure in the Israeli business sector in 2014 was 3.7% of GDP, the highest rate among OECD countries (CBS 2016). Total R&D expenditure in 2014 in high technology industries is NIS 10 billion, constitutes the bulk (82%) of total expenditure in the manufacturing sector. [↑](#footnote-ref-4)
5. Since the purpose of the study was to test firms that are in the maturity stage and already have products on the market to test the impact of interactions on scope of outputs and revenue, we did not included firms that are in the seed stage. [↑](#footnote-ref-5)
6. Among the local partnerships, the partnerships were reviewed in depth to disqualify multiple partnerships reported by various partners to prevent double counting. [↑](#footnote-ref-6)
7. The analysis included only companies that reported having collaborated with other companies and organizations. For each firm, a leading collaboration is selected (if more than one collaboration is reported) in order to avoid duplication of firm revenue data. [↑](#footnote-ref-7)