Ann Reg Sci (2000) 34:315–341

The Annals of
Regional Science

Can regional policy affect firms' innovation potential in lagging regions?

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Received: March 1998 / Accepted: July 1999

Abstract. The initiation of innovation in lagging regions has become one of the most pressing issues in regional policy. Several studies have attempted to identify the factors that influence the creation and development of product innovation in firms located in lagging regions. The identification of these factors could assist regional decision-makers in promoting technological innovation in such regions.

The research question investigated in this study is whether the effectiveness of such regional policies is related to the degree of regional innovation potential and innovativness. This paper tries to deal with this central question by implementing an extended empirical model developed by the author. The Extended Model combines two prevailing probability models: LOGIT and Bayesian decision theory.

The data analyzed in the paper were collected from a field survey of a sample of 211 industrial firms located in the northern region of Israel. In the first stage of the analysis, the model was used to identify variables influencing product innovation; the second stage investigates changes in the probability of producing innovations in the defined region. The results of the analyses point to the effectiveness of a regional policy that could promote and support the creation of factors fostering technological innovation in selected industries in lagging regions.

1. Introduction

The possibility of setting the wheels of innovation in motion in lagging regions is a topic of interest to many researchers in the field of Regional Science. Various studies have tried to identify and define the factors that might influence the development of innovation in firms located in peripheral areas. These

The data used in this paper were collected for my Ph.D. thesis, which was written under the supervision of Professor Daniel Shefer and submitted to the Technion (Frenkel 1997). I would like to acknowledge the financial support received from the Israel Foundations Trustees and the office of the vice-president for research at the Technion.

factors might play a major role in public policy that aims at encouraging innovation in these regions.

The contribution of innovation to technological changes in regional economies is demonstrated most clearly in studies dealing with growth and economic development (Baumol et al. 1989; Jorgenson et al. 1988; Freeman et al. 1982; Nelson and Winter 1982; Suarez-Villa 1993; Davelaar 1991; Feldman 1994; Feldman and Kutay 1997; Davelaar and Nijkamp 1997; Frenkel and Shefer 1997). Industrial development has always been considered the driving force behind the economic growth of peripheral regions. In the Western world, industry tends to concentrate mainly in or on the outskirts of the larger cities and the metropolitan areas, where government authorities are easily accessible, where there is a large and varied labor force, and where the transportation and communications networks are developed. In comparison, the peripheries are characterized by inferior locations, hampering industrial development.

This study presents the outcome of an empirical study that employs for the first time the Extended Model, developed by Frenkel and Shefer (1997). The object is to assess the innovativeness and the innovation potential of different regions as a function of the presence of economic agglomerations and of the internal structure of the industries located in a region. The model is unique in that it is based on two basic models: the Logit model (a behavioral logistic model successfully used by other, similar studies to describe the diffusion processes), and Bayesian statistical decision-theory.

The second part of the paper will offer a literature review of the relationships between technological innovation and regional development and growth. The aim of the third part is to define the Extended Model and its advantages; the fourth part will describe the study's empirical framework. The fifth part will present the findings derived from an analysis of data accumulated from sampled firms located in the northern region of Israel. Finally, the conclusions are based on this analysis.

2. Technological innovation and regional development

What are the economic powers that compel a firm to be innovative? It is quite acceptable that the development of technological innovation is a basic need of the firm, deriving from the competitive environment in which the firm acts. New products and ideas are necessary to guarantee the survival of the firm; therefore, the firm must be innovative to maintain its life-cycle process. This rule is the basis on which Schumpeter developed his concept of dynamic entrepreneurial behavior, in which innovation plays a crucial role (Schumpeter 1934). This basic behavior is the motivation behind a regional policy that has the aim of promoting technological innovation.

New and or improved products will lead in the competition, particularly if there is greater demand for this product than for alternative products or substitutes. Competition based on a new product is therefore effective only to the extent that it increases the firm's sales and profits. In addition, innovative processes focusing on technological changes related to the production process of existing products and services are important factors affecting production efficiency, thereby improving competitiveness (Dosi 1988).

The growing role of technological innovation and the impact of its diffusion process on regional development and growth result from the inter-relationship of innovation, competitiveness, and economic growth (Freeman 1974, 1990; Freeman et al. 1982; Dosi 1984, 1989; Schmokler 1966; Rosenberg 1972, 1976, 1994; Jorgenson 1966; Grossman and Helpman 1990a,b, 1991a,b, 1994; Romer 1990, 1994; Bertuglia et al. 1995; Nijkamp and Poot 1996; Bertugalia et al. 1997). In recent years, there has been mounting interest in the role played by technological change as a driving force behind the wheels of economic growth (Davelaar 1991; Feldman 1994). Future economic growth will have to rely on extending existing and opening new markets (Freeman et al. 1982; Rothwell and Zegveld 1985). Hence, Schumpeter's theory, which views innovative enterprise as the driving force behind capitalistic economic growth, becomes increasingly relevant (Schumpeter 1934).

The net effect of innovation may be expressed in the short-term by labor savings, and in the long-term by the expansion of the labor market. As a result, producers begin operating more efficiently, the relative competitiveness of the economic unit is improved, and product sales and marketing ability on local, national, and international markets are improved (Frenkel and Shefer 1997).

The contribution of innovation to regional economic change is often advocated in dealing with economic growth and development (see, among others, Freeman et al. 1982; Jorgenson et al. 1988; Schmookler 1966; Rosenberg 1972). Regional development in a location where discoveries and technological changes and inventions are created is generally accompanied by the sprouting of new economic activities, new markets, and new technological applications. Regions having a sound infrastructure of inventive capability become preferred locations for highly skilled labor, as well as a target for reinforcing the educational and cultural infrastructures by attracting higher-level populations from other regions. One of the most important goals in the long run is to reach a stage of consistent growth in a region's, and the country's, ability to innovate. A large, increasing stock of inventions, combined with high innovative capability, will ensure continuity in producing innovations and might also ensure a quick recovery in times of crisis (Suarez-Villa 1993). In these instances, technological substitutes might increase productivity and advance the opening of new markets (Berry 1991; Ayres 1990; Kamann and Nijkamp 1986; Kleinknecht 1986; Nijkamp 1986).

One of the main problems in innovation research originates in the difficulty of empirically measuring the rate of innovation. Different studies have tried to identify the connection between the level of investment in R&D and other variables (e.g., the income realized from new products, export orientation, growth in the number of employees, and the rise in sales). The firms, sectors, regions, and countries on the leading edge of technological knowledge show higher economic growth rates than do those that lag on this knowledge (Dosi 1988; Rosenberg 1985).

The prevalent view concerning the typical path followed by a new firm in the time-space dimension is that innovation begins in metropolitan regions, where the incubation of new products and processes takes place (Hoover and Vernon 1959; Davelaar and Nijkamp 1988). Empirical studies have usually confirmed the competitive edge enjoyed by firms located in large metropolitan areas (Thwaites 1982; Alderman 1985; Fischer 1989). These regions possess preferable conditions for technological changes. Here are located the headquarters of high-tech firms, as well as their R&D functions, information centers, etc. In contrast, peripheral zones are generally characterized by low innovation potential, expressed in the low percentage of firms engaging in innovation that are located there. This is mostly true with product innovation rather than process innovation.

Technological innovation has followed a noticeable trend of change in stages as expressed in the technological and economic characteristics of products and processes. During the firm's life cycle, it becomes increasingly difficult and expensive to innovate and substantially improve new products and services. When this point is reached, innovation efforts are directed more toward improving production techniques; i.e., process innovation (Dosi 1984; Davelaar 1991). A low regional economic capacity, while constituting a constraint on the innovation of new products, still allows for the diffusion of production processes (Alderman 1990). Firms adopt process innovation by purchasing it in the marketplace, similar to their purchase of other production inputs. By contrast, product innovation is protected, both structurally and conceptually, since it is a vehicle for the firm's gaining superiority over its competitors.

This study focuses on product innovation by defining innovative firms as those firms that have created product innovations during the past three years. Included in this definition are activities leading to the development and imitation of new products and the substantial improvement of existing products (development of the next generation of products). These activities emanate from in-house investments in R&D or from the purchase of know-how through outside R&D services. Firms that deal exclusively with developing or adopting innovative processes, or with adopting new products not requiring R&D investment, were not classified in the study as innovative firms.

Different types of regions might play a different role in the diffusion process of innovation, depending on their reciprocal relationship. Regions are thus complementary rather than competitive in nature. On the one hand, metropolitan areas supply the basis for the take-off of new sectors that are related to later technological systems. On the other, the later phase of the internal dynamics in some industrial branches is moved to other regions outside the metropolitan area (Kleinknecht and Poot 1991; Davelaar and Nijkamp 1989).

Would a directed policy enhance innovation potential in peripheral zones? This question keeps arising in view of the marked preference enjoyed by the metropolitan area in everything connected with innovativeness and innovation potential. The present study confronts the issue by offering an answer to this question through an examination of the influence of the various attributes on the innovativeness and innovation potential of firms in various regions. The results will assist in defining guidelines for a regional policy that will encourage, support, and enhance the innovation potential of these regions.

3. The extended model for predicting regional innovativeness

The Extended Model developed by Frenkel and Shefer (1997) is based on the integration of two known statistical models – the Logit model and Bayesian statistical decision-theory. The results obtained from the Extended Model might point to the innovativeness and innovation potential of various regions. The model is activated in two phases:

3.1. Phase I – Estimating the innovativeness of a region

The innovativeness of a region is manifested by the intensity of innovations developed by firms in that region. In this phase, an estimation is made of the probability that firms belonging to various industrial branches will develop a technological innovation as a function of the spatial location of these firms and their structural characteristics. This is, therefore, a conditional probability, which is defined in the Bayesian model as:

$$P(Z_i^k|Sj, \text{As}, \ldots, \text{Ge}) \tag{1}$$

where:

$P(Z_i^k)$ represents the probability that firm "i" in industrial branch "k" will adopt a strategic concept related to a binary choice between two alternatives;

$Z1$ symbolizes the decision to develop product innovations; or

$Z2$ symbolizes the decision not to develop new products, which would mean that the firm is not innovative.

In the model, the spatial-location alternatives of the firms will represent the various events to which benefits are attributed. Accordingly, three locational events will be examined by the model. These are defined by Sj as follows (where $j = 1, 2, 3$):

$S1$ – location of the plant in a central region (metropolitan);
$S2$ – location of the plant in an intermediate zone;
$S3$ – location of the plant in a peripheral zone.

Accordingly, the probability that firm "i" in industrial branch "k" will develop technological innovation, $P(Z_i^k)$ is conditioned by a previous occurrence (estimated by a-priori probabilities): $P(Sj)$, or the probability of its spatial location in region "j", and $P(\text{As}, \ldots, \text{Ge})$, its structural characteristics.

The firm's structural characteristics relate to its technological ability, which depends on the level of R&D activity in the company, the firm's size, its ownership type, the composition of the labor force employed, the firm's age, and the stage of the firm's product life-cycle.

In this phase of the Extended Model, the Logit model replaces the Bayesian model in calculating the conditional probabilities. Unlike the Bayesian technique, in which probabilities are derived by using the decision tree, the Logit is a binary-choice model that assumes that the individual (in this case, the firm) faces a choice between two alternatives and that the choice made depends on its characteristics (Pindyck and Rubinfeld 1981). It is possible to exhibit the probability estimation of the choice of an alternative in the model by the following equation:

$$P_i^k = F(Z_i^k) = F(\alpha + \beta 1 j + \beta 2\text{As}, \ldots, \beta n\text{Ge})$$
$$= \frac{1}{1 + \ell^{-Z_i^k}} = \frac{1}{1 + \ell^{-(\alpha + \beta 1 j + \beta 2\text{As}, \ldots, \beta n\text{Ge})}} \tag{2}$$

where:

P_i^k represents the conditional probability that firm "i" in industrial branch "k" will develop innovations, which is parallel to $P(Z_i^k)$ in the Bayesian model. In the equation, Sj and As, ..., Ge represent the spatial location and the firm's structural characteristics, factors that might explain the choice made by the firm. The conditional probability, therefore, indicates the chance that a firm belonging to a certain industrial branch, possessing a given set of characteristics, and placed in a given location, will engage in innovation.

The Extended Model integrates the advantages of the two basic models described above. Calculation of the conditional probabilities for developing innovation through the decision tree in the Bayesian model equals the results obtained from most of the simple causal models involving one-way causation. This simplistic calculation does not deduct the partial influence of the independent variables, and hence the result does not portray the real net influence of each variable. Accordingly, it is not possible, when applying the model, to identify the extent to which the distribution used for calculating probabilities is not random. In addition, the conditional probability derived from the Bayesian model does not indicate the level of importance and the contribution of each variable to the probability of developing an innovation. On the other hand, by using the Logit model for calculating the conditional probability in the Extended Model, one obtains information on the contribution of each of the explanatory variables given by the model along with its statistical significance. These statistical parameters improve the prediction ability of the model, which is expressed in the probability matrix calculated with the Extended Model.

3.2. Phase II – Estimating the region's innovation potential

In the second phase, the conditional probabilities, derived as an output from the Logit model in the first phase, are used as inputs for estimating the innovation potential of different regions. The innovative potential is estimated by computing the joint probabilities and the posterior probabilities in the Extended Model while applying the Bayesian model. This technique is used, first, for computing the joint probabilities. As a second step, the posterior probability is computed by dividing the joint probability of a certain region by the sum of the joint probabilities of all regions examined. The posterior probability (as proven by the Bayesian theorem Bayes 1958) is portrayed in the following equation:

$$P(Sj, \text{As}, \ldots, \text{Ge}; |Z_i^k) = \frac{P(Z_i^k, Sj; \text{As}, \ldots, \text{Ge})}{P(Z_i^k)} \quad (3)$$

These probabilities demonstrate the ability of a region to attract innovative firms. The computation of the posterior probabilities allow us to estimate the probability that a firm that has the same kinds of characteristics mentioned above and that has decided to adopt a strategic attitude toward developing an innovation will prefer to locate in region "j". In other words, the posterior probabilities will facilitate a better assessment of the region's *future* chances of attracting *innovative firms*. This is in contrast to the results obtained by the

Logit model (in the first phase of the Extended Model), which referred to the chances that firms *currently* located in the region will *develop innovations*.

4. The framework of the empirical analysis

4.1. Sample of firms

The empirical analysis is based on data collected in a field survey that was carried out between July and December 1995. The sample, consisting of 211 randomly selected industrial firms, was large enough to support the statistical tests needed for the research. A carefully designed instrument was employed during a personal interview of senior managers in each of the firms in the sample.

There is ample evidence supporting the hypothesis that innovation activities are more prevalent among fastest-growing industries. Thus, it would be promising to investigate the phenomenon of innovation activities among firms belonging to this specific group – industries that most often provide the engine of economic growth (Suarez-Villa and Walrod, 1997). Accordingly the sample of industrial plants was randomly selected from several fast-growing industrial branches (FGI) with a high capacity for innovation: (1) radio and television equipment; (2) communications equipment; (3) electronics for science, medicine, and industry; (4) precision instruments; (5) optical and electro-optical instruments; (6) plastic products; (7) cutlery, tools, and accessories; (8) structural and metal products.

Fast-growing industries were defined according to their rate of growth in outputs, employment, and their export share of the respective industrial branches. Export performance reflects a firm's exploiting the opportunity to achieve economic growth, particularly in a small country like Israel, where the local market is small and limited. (For more details on the methodology of fast-growing industries, see Shefer et al. 1998.)

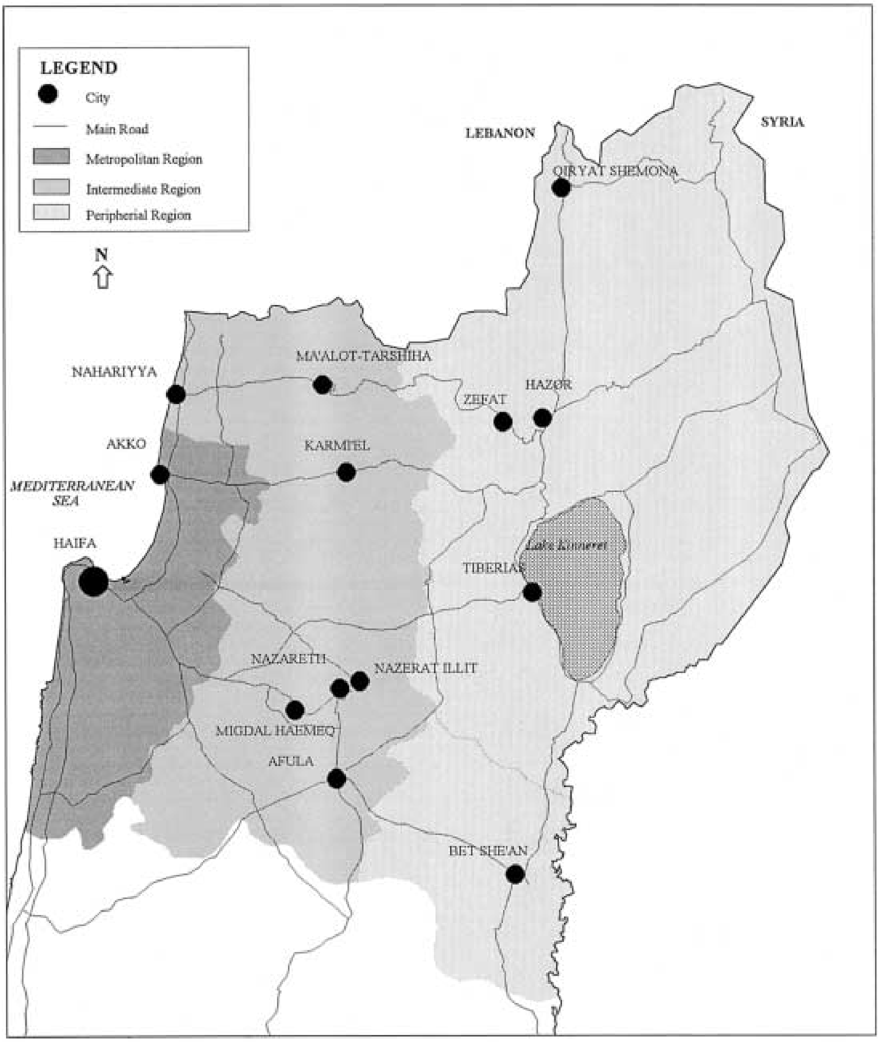
A classification of firms based on their affiliation with the fast-growing industries group and an identification of their spatial distribution point out the relevant plants located in each type of region identified in the study (core, intermediate, or peripheral). The sample represents about 72% of the total number of industrial plants in the FGI category located in the study area.

4.2. The study area

The study area for the current work was the northern region of Israel. In 1996, some 1.5M people, constituting about 26% of the population of Israel, resided in this region, which extends over an area of some 5,000 sq. km., or 23% of the total land area of the country. From 1989–1995, the population growth rate was very high, almost 12%, mainly owing to the large immigration flux to Israel from the former Soviet Union during this period.

The northern region of Israel is an area where all three types of zones identified above are represented (see Map 1):

a) The core zone – comprising the Haifa Metropolitan area.
b) The intermediate zones – comprising the areas that surround the core zone and that are within an acceptable commuting distance. Not too long ago,



Map 1. Major areal division of the Israeli northern region

this zone was considered peripheral, but the population growth that took place in the core zone in recent years "spilled over" into the intermediate areas and brought about a change in their rate of population growth and regional functionality; the northern intermediate areas consist of the central and western Galilee.

c) The peripheral zones – comprising the lagging areas of the northern region. These last areas are removed from metropolitan influence and are not within acceptable commuting distance. They exhibit most of the characteristics of a classic peripheral zone, including fewer employment opportunities and fewer social as well as commercial services. These areas include the Golan Heights, Eastern Galilee, and along the Jordan Valley,

Table 1. Distribution of sample, by location and percentage share of total

Zone type	Total firms in the region		Total firms in the sample		Sample % of total firms
	No	%	No	%	
Core (metropolitan)	85	28.8	66	31.3	77.6
Intermediate	142	48.1	82	38.9	57.7
Peripheral	68	23.1	63	29.9	92.6
Total	295	100.0	211	100.0	71.5

Note: All firms belong to the fast-growing industries group.

extending from Metula and Qiryat Shemona in the north to Bet She'an in the south-east.

The geographical distribution of the firms included in the sample is presented in Table 1. The sample consists of more than 70% of all firms in the industries selected that are located in the region, comprising more than 90% in the peripheral zone, almost 60% in the intermediate zone, and almost 80% in the metropolitan area. The distribution displays the clear dominance of the intermediate zone, with almost half of the firms located in this area.

4.3. The variables

In the model, the independent variables that explain the innovativeness and the innovation potential of the firms located in the various regions are categorized into basic variables and firms' attributes.

4.3.1. Basic variables

Location variable – divided into three sub-regions as defined above – metropolitan area, intermediate zone, and peripheral zone.

Branch affiliation – categorized into two types of industrial groups – (1) hi-tech industries (electronics, electro-optics, optics, and precision tools [sub branches 1–5 above]); and (2) traditional industries (plastics and metal products [sub branches 6–8 above]).

Analysis of the data demonstrated the different locational patterns of firms with respect to innovation when considering their industrial branch. The results suggest that it would be appropriate to examine the impact of the industrial branch on the rate of regional innovation, while categorizing firms into the two aforementioned basic industrial groups on the basis of their technological character.

The similarity in behavior among the traditional industrial branches (plastics and metal products), on the one hand, and the difference between these industries and the hi-tech industries, on the other hand, lends justification to this grouping. Furthermore, numerous variations were found in the innovative properties characterizing these two industrial groups. This diver-

Table 2. Labor and R&D inputs, ANOVA between industrial groups (number of observations in parentheses)

Industrial groups	% Highly skilled labor	% R&D workers	% R&D expenditure	R&D Total expenditure (M$)
Electronics	25.9	24.6	24.0	2.22
	(86)	(85)	(82)	(82)
Plastics	6.9	3.2	3.0	0.15
	(77)	(79)	(68)	(69)
Metals	4.8	3.1	2.0	0.20
	(45)	(44)	(35)	(39)
F-Value	39.96	38.31	25.97	3.59
P	0.0000	0.0000	0.0000	0.028

gence is reflected in the high expenditure on R&D made by high-tech industries compared with those made by traditional industries. Table 2 shows the results of statistical analyses of several selected variables measuring the extent of R&D activity in firm: a significant difference is found to exist among the different industrial branches. When a similar analysis was conducted only between the plastics and metal industries, no statistical difference was observed.

4.3.2. Firms' attributes

This group includes variables representing the structural characteristics of the firms. The model examines their level of contribution to the innovative ability of the firms.

Internal R&D – Innovation is mainly conditioned by research and development activities that lead to the development of new products. The R&D variable in the model is a "dummy" variable representing the firms that conduct internal R&D activity (with or without additional external R&D services).

Composition of Labor Force – The firms surveyed were divided into two groups, according to the rate of highly skilled labor employed in the plants. Highly skilled labor would include, by definition, scientists, engineers, and academicians in the economics and management sciences. As there is a significant statistical difference in this composition between high-tech and traditional industries, the articulation was separately set for each of the industries examined. In the high-tech industry, firms characterized by a high rate of highly skilled labor are those in which 20% of the total labor force belong to this group. In the traditional industry group, the parallel rate is only 7%.

Age – The question dealt with by the research was whether new firms tend to be more innovative than older firms. In the model, seniority is a "dummy" variable that represents the young firms, those established from 1990 onwards.

Size – This variable allows us to test the scale effect on the innovativeness and the innovation potential of the firms. Here, too, the size variable is a "dummy" variable that represents large firms in the model. Also in this variable, a distinction was made between the two industry groups because of their variance: in the high-tech industry group, large firms are those with more than 50 employees; in the traditional industry group, firms with over 80 employees.

Table 3. LOGIT Model results – evaluation of the probability of developing new products (*t*-value in parentheses)

Independent variable	High-tech industries	Traditional industries
Constant	−2.907	−5.440
	(−2.31)*	(−4.81)*
Location in intermediate zone	−2.139	0.224
(yes) (1)	(−2.12)*	(0.30)
Location in peripheral zone	−1.985	1.929
(yes) (1)	(−1.91)**	(2.45)*
Internal R&D	3.181	4.029
(yes) (1)	(3.36)*	(4.97)*
Skilled labor force	2.983	1.701
(high) (1)	(2.79)*	(2.93)*
Age of firms	2.640	−0.840
(Young) (1)	(2.05)*	(−0.88)
Size of firms	1.986	1.359
(Large) (1)	(1.86)**	(2.20)*
N	82	122
Initial likelihood	−56.84	−84.56
Final likelihood	−25.77	−42.35
p^2	0.55	0.50
$\bar{p}^2$	0.48	0.48

* Significant at $p < 0.05$.
** Significant at $p < 0.10$.
(1) Dummy variable, reference group in parentheses.

The probability of reaching a decision to develop innovation refers in the study $P(Zi)$, as mentioned above (see page 5), to the probability that a firm will develop and/or improve new products.

5. Empirical results

5.1. The Logit model

The results of the Logit model tests are shown in Table 3. Results from running the models indicate that the location factor contributes to the innovation ability of firms. For high-tech industries, the move from the metropolitan area to the periphery has a statistically significant negative effect on the probability of developing innovative products. The parameter's value in the equation demonstrates that the level of the negative influence on the intermediate zone is even greater than that on the peripheral zone. This finding matches the tendency demonstrated in recent years for high-tech firms, especially in the field of electronics, that developed in the Haifa metropolitan area to relocate their production lines to intermediate zones. This relocation occurs together with a firm's progress in the growth and maturity phase. The subsidiaries are located in the intermediate zone because of the availability of land and reduced operational costs. These subsidiaries mainly mass-produce products developed by the firm in the metropolitan area. Naturally, their innovation focuses principally on the improvement of production processes and less on developing new products. On the other hand, the peripheral zone has not yet become a focal point of attraction for the subsidiaries of electronics firms, and the small number of high-tech firms located there for other reasons tend to consolidate both development and production activities under the same roof.

The influence of the location factor on traditional industries is directly the opposite. For this group, the model reveals the advantages that the peripheral zone offers. These are manifested in the positive value of the parameter and in the level of its statistical significance. On the other hand, location in the intermediate zone was not found to have a statistically significant influence on the probability of developing innovation in this type of industry. The finding is also affected by the emphasis that many firms in the intermediate zone place on process innovation rather than on product innovation.

For the traditional industries, location in the periphery does not constitute a disadvantage in the ability of such firms to develop innovations. This is a result of the character of innovation in these industries, which requires much less human capital resources, technological complexity, and R&D resources compared to high-tech industries. In addition to the location factor, there is the fact that a considerable proportion of these plants is owned by kibbutzim, which are found in large numbers in the northern region of Israel. The relatively high innovative ability demonstrated by kibbutz firms is probably related to their production milieu as manifested in their human resources, whose average technological level surpasses that of the population in the peripheries. In addition, the economic structure of the kibbutz and the kibbutz movement has allowed the kibbutzim, at least in the past, uniquely to invest in R&D in the peripheral zones.

From the structural characteristics of firms as shown in Table 3, it is clearly evident that the ability to innovate is highly affected by a firm's internal R&D activity and by a high rate of skilled labor. Both industry groups demonstrated a greater positive effect of internal R&D activity on the probability of developing product innovation in firms. This finding emanates from the positive, statistically significant value of this parameter, whose weight is higher in the traditional industry group than in the high-tech industries.

Employment of highly skilled labor is found to be the second most important variable affecting the development of innovation in firms. Results indicate the statistically significant positive effect of this variable. In all plants where there was a high rate of highly skilled labor (over 20% in the high-tech industry group, and over 7% in the traditional industries), the chances of product innovation are better. This variable's impact on the probability of innovation in firms is secondary to the previous variable although it is certainly higher than any of the other structural characteristics tested. A comparison of the two industry groups seems to show that the effect of internal R&D on the ability to innovate in traditional industry is more significant than the effect of the highly skilled labor variable. This finding explains the ability of plants in this group to innovate in the peripheries, where the availability of highly skilled labor is low.

The age variable was also found to contribute to a willingness to develop new products in the high-tech industry group. In this group, the chances that younger plants (those established since 1990) will develop innovations are higher than are those of older plants. This finding is related to the first life-cycle phase, in which younger plants, mainly in the high-tech industry, engage in developing new products, whereas the emphasis in the maturity phase moves to mass production and, with it, to the improvement and development of production processes. In the traditional industry group, on the other hand, the seniority factor was not found to have an affect on the decision to develop innovations.

As expected, the scale effect on the probability of developing innovations was found to be positive for both industrial groups. It can be deduced, therefore, that the economies of scale prevalent in classic production theory exist in innovation activity, as well. The willingness to innovate in medium and large plants, those employing over 50 workers in the high-tech industry and over 80 workers in the traditional industries, is higher than in smaller plants. This is demonstrated by the statistically positive and significant value attributed to this variable. The scale effect on firms is statistically more significant in the traditional industries ($p < 0.05$) than in the high-tech industries ($p < 0.10$).

5.2. The Extended Model – evaluating the innovativeness of regions

The results obtained from the Logit model were installed in the Bayesian model in order to compute, in the first phase, the conditional probabilities of developing product innovation by firms in each of the regions selected. The firm's age variable was taken out of the equation when computing the conditional probabilities, as this variable cannot be affected by public policy; in any case, its level of contribution to explaining the binary choice was not found to be high. The computation of conditional probabilities, by using the parameter values of the logistic equation estimated above, was performed in stages. The first stage tested the probability of developing innovative products; this was conditioned by the location variables and followed by a gradual entry of all the remaining independent variables according to rate of importance: the existence of internal R&D, a high rate of highly skilled labor, and the size of the plant.

The conditional probabilities matrices obtained by computing the probabilities in the equations obtained from running phase I of the model (the Logit) are shown in Tables 4 and 5. These allow us to examine changes in the probability of developing an innovation at each stage and in each of the industry groups.

Findings indicate that there is a trend toward a reduction in the innovativeness of plants belonging to the high-tech industries (Table 4) when there is a move from the metropolitan area to either the intermediate or peripheral zone. A considerable increase in the probability of innovating was found in all regions among firms conducting internal R&D, as opposed to a marked decrease in this ability in firms that do not do so. The spatial differences in this regard are conspicuous, especially in firms that do not conduct internal R&D. *The probability that this kind of firm, located in the metropolitan area, will become innovative is 2.7 times higher than the parallel probability in the intermediate zone, and 5 times higher in the peripheries*. This result apparently relates to the production milieu in the metropolitan area, where there is a convenient and supportive infrastructure for innovative firms, much more so than in the production milieu found in the intermediate and peripheral zones.

Employing a high rate of highly skilled labor in high-tech firms (over 20% of the labor force) contributes to the chances of innovating, although on a

Table 4. Conditional probabilities matrix – innovation in hi-tech industries

Location	Metropolitan region 0.86								Intermediate zone 0.68								Periphery zone 0.50							
Internal R&D	Yes 0.94				No 0.35				Yes 0.82				No 0.13				Yes 0.70				No 0.07			
Skilled Labor force	High 0.97		Low 0.84		High m.o		Low 0.25		High 0.92		Low 0.62		High m.o		Low 0.09		High 0.85		Low 0.45		High m.o		Low 0.05	
Size of Firms	Large 0.99	Small 0.97	Large 0.88	Small 0.73	Large m.o	Small 0.63	Large 0.29	Small 0.13	Large 0.96	Small 0.89	Large 0.66	Small 0.42	Large m.o	Small m.o	Large 0.10	Small m.o	Large 0.92	Small 0.82	Large 0.52	Small 0.29	Large m.o	Small m.o	Large 0.06	Small 0.02

m.o = Missing observation.

Table 5. Conditional probabilities matrix – innovation in traditional industries

Location	Internal R&D	Skilled Labor force	Size of Firms
Metropolitan region 0.27	Yes 0.55	High 0.69	Large 0.85
			Small 0.56
		Low 0.32	Large 0.50
			Small 0.19
	No 0.02	High 0.03	Large 0.09
			Small 0.02
		Low 0.01	Large 0.02
			Small 0.00
Intermediate zone 0.35	Yes 0.52	High 0.68	Large 0.85
			Small 0.57
		Low 0.31	Large 0.51
			Small 0.19
	No 0.02	High 0.03	Large 0.10
			Small 0.02
		Low 0.01	Large 0.02
			Small 0.00
Periphery zone 0.54	Yes 0.84	High 0.93	Large 0.97
			Small 0.90
		Low 0.73	Large 0.87
			Small 0.61
	No 0.08	High 0.16	Large 0.41
			Small 0.14
		Low 0.04	Large 0.11
			Small 0.03

m.o = Missing observation.

smaller scale. It was not possible to test this variable as an alternative variable to the internal R&D variable, as no firms in the model were found to employ a high rate of highly skilled labor without conducting internal R&D. Finally, the additional contribution made by the scale effect on the probability of innovating is relatively small, albeit consistent. In each of the regions selected, the probability of developing innovation rises among the large firms as opposed to the small firms, while all the remaining variables stay constant.

The final results of the conditional probability matrix in the high-tech industry group show that the probability of developing innovation in firms located in the metropolitan area ranges from 13%–99%. In the intermediate zone, the parallel range is 4%–96%; and in the peripheral zone, 2%–92%. The high level applies to firms with internal R&D, employing a high rate of highly skilled labor, and whose total number of employees is over 50. The low value refers to firms with the opposite characteristics.

The innovativeness of regions as derived from the results indicates that the highest level of sensitivity is in the peripheral zone, followed by the intermediate zone and then, much less, the metropolitan area. Hence, the existence of internal R&D in firms located in the metropolitan area assures a relatively high probability of innovating, even by small firms with a low rate of highly skilled labor (0.73). In the intermediate zone, however, the probability of innovating with the same composition of characteristics is reduced to 0.42, and in the peripheral zone to 0.29 (where under optimal conditions, the probability of innovating would be over 90%).

The conclusion to be derived from such findings is that a public policy that stimulates plants to move to peripheral zones encouraging, in particular firms whose character is found to have a considerable impact on the probability of innovating, will increase the rate of innovation in the region. Results show that the composition of certain structural characteristics in a firm makes it possible to develop high innovativness in high-tech industries located in the periphery, as well, and thereby to affect economic growth in these regions. The probability of developing innovation by firms with internal R&D and employing a high rate of highly skilled labor exceeds 85%, even if located in the periphery or in the intermediate zone. A similar chance exists in the metropolitan area, even for firms with a low rate of highly skilled labor.

Findings in the traditional industry group show an opposite trend (Table 5). The probability of innovating rises when there is a move from the metropolitan area to the intermediate zone, and from there to the periphery. The high innovativeness of the peripheral zone in this group of industries is expressed by the high probability of developing innovation, which is indicated at 0.97 in firms having the total composition of characteristics found to contribute to innovativeness, as opposed to the parallel probability of only 0.85 in the intermediate zone and in the metropolitan area. It would seem that the effect of internal R&D on the development of innovation in this group is much more dominant than in the high-tech industry. In all regions, the probability of innovating by firms that do not have internal R&D greatly decreases, even if they employ a relatively high rate of highly skilled labor, irrespective of the scale effect. Singular in this regard is the peripheral zone, where the innovation probability of large firms (of over 80 employees) with the above characteristics rises to 41%. These findings emphasize the innovativeness of the periphery as manifested by the traditional industry group.

5.3. The Extended Model – evaluating the potential innovation of regions

A calculation of the posterior probabilities in the model provides the locational preference of firms belonging to different industrial branches that have chosen to develop technological innovation. This contrasts with the results obtained by the Logit model presented in phase I above. The latter identifies the chances that firms already located in the region will innovate (as reflected by their innovativeness index). The innovation potential, however, is influenced, on the one hand, by the ability of the region to attract firms from each of the industrial branches (the a-priori probabilities) and, on the other hand, by the region's innovativeness, a result that was obtained in the previous phase. The results are shown in Tables 6 and 7.

Findings relating to the high-tech industry group (Table 6) indicate the high innovation potential of the metropolitan area as opposed the two other regions examined. The metropolitan area might attract half of the innovative high-tech firms destined to locate in the northern region. The ability of the intermediate zone to attract innovative high-tech firms decreases to 37%, and that of the peripheral zone to a mere 13%.

In all three regions, the regional innovative potential is much higher in firms with internal R&D and employing a high rate of highly skilled labor. Of the 50% of the innovative high-tech firms that will be attracted to the metropolitan area, most (47%) conduct internal R&D; in a large proportion of these firms (37%), the rate of highly skilled labor exceeds 20%. Contrary to the higher innovativeness of large firms, the metropolitan area will rather attract smaller firms of this type than large firms. This finding is due to the fact that the metropolitan area acts as an incubator for high-tech plants, as most commence their activity there. These plants move to the intermediate zone mostly in the maturity phase, with the move to mass production. In the intermediate zone, accordingly, the main innovative potential of this type of firms is found to be distributed more evenly among both large and small firms.

Contrary to the high innovativeness found in high-tech firms with the optimal structural characteristics mentioned above, and almost no dependency on their spatial location (see Table 3 above), the *innovation potential* of the metropolitan area is higher than that of the intermediate zone and the peripheral zone (Table 6).

A region's innovation potential relative to firms belonging to traditional industries further enhances spatial differences. The regional innovation potential derived from the traditional industry group shows trends that are totally opposite to those of the high-tech industry. The periphery here holds distinctive advantages for this type of industry, as expressed in the region's ability to attract innovative traditional industries. Of the innovative firms in this group, 51% of those that are expected to go to the northern region will indeed locate there, whereas a third will locate in the intermediate zone, and only 16% in the metropolitan area.

Relative to this industry group, the innovation potential in all three regions occurs mainly in firms having internal R&D and a high rate of highly skilled labor. In contrast to the high-tech industry, there is a marked positive influence of the scale effect when most of the innovative firms with the above-mentioned structural characteristics belong to the larger firms.

Table 6. Posterior probabilities matrix – innovation in hi-tech industries

<table>
<tr><td>Location</td><td colspan="8">Metropolitan area
0.50</td><td colspan="8">Intermediate zone
0.37</td><td colspan="8">Periphery zone
0.13</td></tr>
<tr><td>Internal R&D</td><td colspan="4">Yes
0.47</td><td colspan="4">No
0.03</td><td colspan="4">Yes
0.36</td><td colspan="4">No
0.01</td><td colspan="4">Yes
0.12</td><td colspan="4">No
0.01</td></tr>
<tr><td>Skilled Labor force</td><td colspan="2">High
0.37</td><td colspan="2">Low
0.11</td><td colspan="2">High
m.o</td><td colspan="2">Low
0.02</td><td colspan="2">High
0.29</td><td colspan="2">Low
0.08</td><td colspan="2">High
m.o</td><td colspan="2">Low
0.01</td><td colspan="2">High
0.07</td><td colspan="2">Low
0.04</td><td colspan="2">High
m.o</td><td colspan="2">Low
0.00</td></tr>
<tr><td>Size of Firms</td><td>Large
0.10</td><td>Small
0.27</td><td>Large
0.03</td><td>Small
0.07</td><td>Large
m.o</td><td>Small
m.o</td><td>Large
0.01</td><td>Small
0.00</td><td>Large
0.13</td><td>Small
0.16</td><td>Large
0.07</td><td>Small
0.01</td><td>Large
m.o</td><td>Small
m.o</td><td>Large
0.01</td><td>Small
m.o</td><td>Large
0.02</td><td>Small
0.05</td><td>Large
0.04</td><td>Small
0.00</td><td>Large
m.o</td><td>Small
m.o</td><td>Large
0.00</td><td>Small
0.00</td></tr>
</table>

m.o = Missing observation.

Table 7. Posterior probabilities matrix – innovation in traditional industries

Location	Internal R&D	Skilled Labor force	Size of Firms
Metropolitan area 0.16	Yes 0.16	High 0.13	Large 0.10
			Small 0.03
		Low 0.03	Large 0.03
			Small 0.01
	No 0.01	High 0.00	Large 0.00
			Small 0.00
		Low 0.00	Large 0.00
			Small 0.00
Intermediate zone 0.33	Yes 0.32	High 0.24	Large 0.18
			Small 0.06
		Low 0.08	Large 0.06
			Small 0.03
	No 0.01	High 0.01	Large 0.00
			Small 0.00
		Low 0.00	Large 0.00
			Small 0.00
Periphery zone 0.51	Yes 0.48	High 0.30	Large 0.20
			Small 0.08
		Low 0.18	Large 0.15
			Small 0.03
	No 0.03	High 0.02	Large 0.02
			Small 0.01
		Low 0.01	Large 0.01
			Small 0.00

m.o = Missing observation.

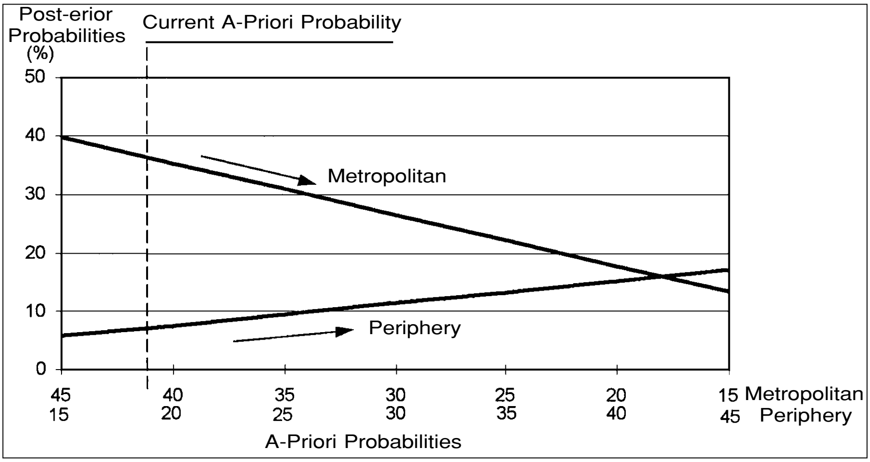


Fig. 1. Probabilities of attracting innovative high-tech firms to the periphery and the metropolitan area

5.4. The effectiveness of a policy to attract firms to different regions

The findings obtained from running the Extended Model show the disadvantages of the peripheral zone, compared to the metropolitan area, in attracting innovative high-tech firms to these regions. These disadvantages could have a negative affect on the economic growth of these regions as has been indicated by various studies (see, for example, Suarez-Villa 1993; Davelaar 1991; Feldman 1994; Feldman and Kutay 1997; Davelaar and Nijkamp 1997).

The findings thus point to the need for devising a public policy that is designed to enhance the attractiveness of peripheral regions. The Extended Model facilitates an empirical examination of the effectiveness of alternative policies. The test selected for presentation evaluates the increase in the attractiveness of the periphery for innovating high-tech firms having internal R&D and employing a high rate of highly skilled labor. This increase will be a function of a government policy that, in general, gives higher priority to these regions over other regions, as a location for high-tech industries.

The test involves computing a change in the preference of high-tech firms to locate in the peripheral zone, as expressed by the increase in the model's *a-priori* probability of high-tech firms' locating in the region at the expense of the metropolitan area. In other words, it is an examination of the decrease in the attractiveness of the metropolitan area (in this presentation, the probability of attracting high-tech firms to the intermediate zone remains constant).

The model indicates the resulting changes in the posterior probability in view of this change; that is, the increase in the probability of the peripheral zone's attracting the same kind of high-tech firms that have elected to generate innovations is examined. Results are displayed in Fig. 1.

Calculating the gradient metropolitan and periphery lines in the figure enables us to test the possible modifications that might occur with a change in the periphery's attractiveness to high-tech firms relative to that of the metropolitan area. It is evident that a reduction in the probability of attracting innovative high-tech firms (with the above-mentioned structural characteristics) to the metropolitan area as a result of applying a policy encouraging high-tech firms in general to move to the periphery is higher than the increase in the probability of the periphery's attracting innovative high-tech firms. Every 1% increase in the *a-priori* probability of the periphery's attracting high-tech firms will have only a 0.38% increase in the chance that these firms will be innovative (posterior probability). Every 1% decrease in the *a-priori* probability of attracting high-tech firms to the metropolitan area, however, will diminish the chances by 0.88% that the high-tech firms coming to the region will be innovative (posterior probability). This means that the metropolitan area's loss will be 2.4 times greater than the periphery zone's gain.

Data obtained from the sample of firms (Table 6 and Fig. 1) indicate that the probability of attracting innovative high-tech firms having internal R&D and employing a high rate of highly skilled labor to the metropolitan area is 37%, as opposed to the mere 7% probability of attracting these firms to the peripheral zone (see Fig. 1). Doubling the periphery's ability to attract this type of innovative firms (14%) will necessitate conducting an aggressive policy of granting considerable incentives to firms. It is doubtful whether such a policy can be applicable, as this goal will be reached only if 36% of all high-tech firms destined to locate in the northern region select the periphery as their preferable location. Currently, only 19% of the high-tech firms are actually attracted to this region. Thus this scenario would come at the expense of the metropolitan area, to which only 24% of the high-tech firms will be attracted, as opposed to the current figure of 42%. As a result, the chances that the metropolitan area will attract innovative high-tech firms of this type would have to diminish to 21%, compared with 37% today.

5.5. The impact of R&D investment on the innovativeness of the regions

One of the main findings obtained from the results described above is the low rate of innovation achieved by high-tech firms located in the peripheral zones, compared to those that locate in the core area. Do these empirical results reflect a reasonable situation based on the limited capability of these firms in the non-metropolitan areas? Or, perhaps is the rate of technological innovation in the lagging region below the optimal? If the latter case, could a regional policy bring about a change in the innovation behavior of plants by raising their tendency to engage in innovation?

As the results also show, R&D activity within a firm is by no means a principal factor for increasing its' innovativness. One of the variables that measure the intensity of R&D activity is the firm's expenditure on R&D per employee. The contribution of this factor to the probability of innovating in hi-tech industrial branches was tested in order to examine their optimal investment in R&D. The results obtained from the test can lead to a regional policy that rewards greater incentives for investment in R&D in the peripheral area, which will increase the probability of innovation in the hi-tech firms located there. The test was conducted by using the Logit model; the variables were the R&D investment per employee and the location variable. The results for the three types of regions are shown in the following logistic equation (t-value in brackets):

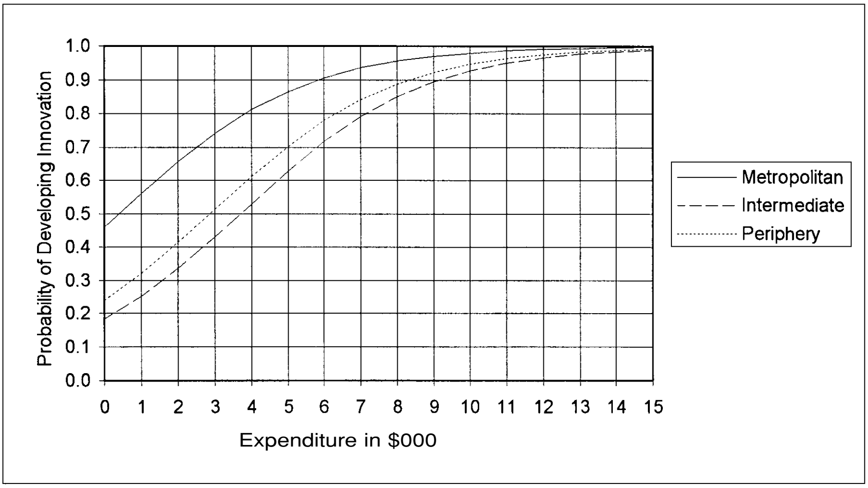


Fig. 2. Changes in the probability of creating innovation in hi-tech firms, as a function of increasing the expenditure on R&D, by location

$$P(Zi) = Ln\frac{Pi}{1-Pi} = \underset{(-0.25)}{-\ 0.1609} + \underset{(3.18)}{0.4033}\ \text{R\&D} - \underset{(-1.57)}{1.333}\ \text{INTER} - \underset{(-1.19)}{0.9983}\ \text{PERIPH} \quad (4)$$

Using the logistic function (4), a calculation of the probability of innovation development by hi-tech industrial firms, in accordance with gradual changes in R&D expenditure is depicted in Fig. 2.

The findings show the relative advantage of the metropolitan area over the two other regions in developing innovation within the hi-tech industry. As for non-metropolitan areas, the peripheral zone shows a slightly higher chance for developing innovative product than the intermediate zone, although the gap is small. This result is related to the fact that many of the intermediate hi-tech firms are large mass-production plants. Their investment in R&D is geared toward adopting new products or improving the production processes. On the other hand, the electronics plants located in the peripheral zone are small and engage more in developing new products.

The probability of innovation development in the hi-tech industry is particularly high in the metropolitan area, where it reaches a level of more than 70% of all firms, even when annual investment in R&D is as low as $3,000 per employee[1]. On the other hand, in the intermediate zone and in the periphery,

[1] The results of this simulation pointed to the existence of the probability of developing product innovation even without any investment in R&D. These results are related to the pattern of the Logit model. It is also a result derived from those cases in which firms have developed new products and reported on zero investment in R&D. These situations occur where a firm does not relate their investment directly to R&D; for example, firms where the engagement of employees in R&D is only part time. In most such cases, a low level of innovation was indicated.

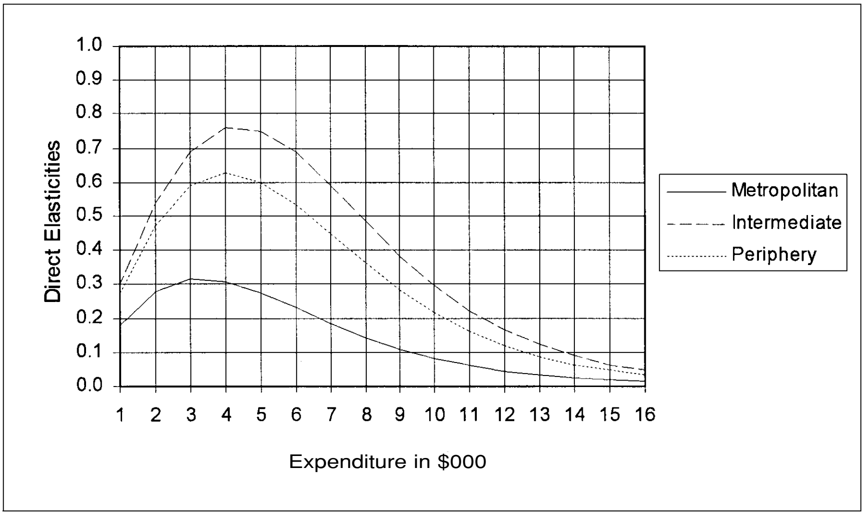


Fig. 3. Marginal effect on the probabilities of creating innovation in hi-tech firms, as a function of increasing the expenditure on R&D, by location

the probability of innovating reaches only 40% with the same amount of investment in R&D. From Fig. 2, we can see that when the level of investment in R&D is higher than $6,000 per employee, the probability that hi-tech firms will innovate is more than 90% in the metropolitan area. To reach such a level of probability in the other zones there is need for a policy that will bring about an investment in R&D of $8,000 per employee in the periphery, and $9,000 per employee in the intermediate zone.

One of the parameters that might help to determine the desirable amount of investment in R&D is the Direct Elasticity measurement. Results from the Logit model enable us to compute the elasticity of the change in the probability of making the decision to develop innovation $E_{Xik}^{P(Zi)}$, as a function of the change in the value of the independent variable, as shown in Eq. 5:

$$E_{Xik}^{P(Zi)} = [1 - P(Zi)] * Xik * \beta \tag{5}$$

where:

$P(Zi)$ = the probability that firm "i" will decide to develop product innovation;
Xik = value of the independent variable – the amount of investment in R&D in firm i;
β = the coefficient of the independent variable.

The elasticity parameter expresses the marginal output achieved from one unit of investment. The results of computing the elasticity indicators in various investments in R&D is depicted in Fig. 3.

In hi-tech firms located in the intermediate and peripheral zones, the yearly investment in R&D of up to $4,000 per employee will increase the marginal effect; beyond that, the marginal effect decreases. On the other hand, the range in the metropolitan area is smaller, not more than $3,000 per employee. This result is connected to the high probability of creating innovation that exists among hi-tech firms located in the metropolitan area, even with a small level of investment in R&D.

According to the empirical data, the yearly expenditure in R&D by half the hi-tech firms located in the peripheral zone of Northern Israel, does not exceed $1,800 per employee. This level of investment minimizes the chance that these firms will engage in innovation; thus, the probability of innovating is less than 35% for 50% of the firms in this region. The optimal investment in R&D that will have an increasing effect on the probability of innovating in these firms is about $4,000 per employee as mentioned above (see Fig. 3). At this level of investment, the probability of innovating will rise to 60%. In fact, an analysis of the empirical data show that 69% of the firms in the peripheral region invest less than $4,000 per employee in R&D. This means that there is a messing need for a policy, that grants greater incentives for investment in R&D in the peripheral region. A check of the implication of such a policy for raising the investment in R&D found it to be very reasonable. In 1995 the government gave about $131.2M in incentives for investment in R&D to all Israeli electronics firms. That means that the total complementary investment needed for electronics firms in Northern Israel to achieve an optimal level of innovation barely reaches 2.5% of this figure.

6. Conclusions

This study has estimated the innovativeness and the innovation potential of various regions with a view to testing the effect of an efficient investment policy on attracting innovative firms to peripheral zones. The paper presents, for the first time, an empirical application of an Extended Innovative Model, based on the Logit and Bayesian models, for evaluating the probabilities of creating an innovation atmosphere in various regions.

The research results clearly indicate that high-tech firms exhibit a much higher innovative ability than do firms belonging to the traditional industries. From the spatial aspect, the relative advantage held by the high-tech industry is demonstrated in the metropolitan area and in the intermediate zones, but not in the peripheral zone. The metropolitan area's innovation potential, which is manifested in its ability to attract innovative high-tech firms, is high in comparison with the potential of the intermediate and peripheral zones. On the other hand, the periphery's innovation potential is mainly manifested in its ability to attract innovative firms of the traditional industry type. The conclusion is that *in the northern region of Israel, a correlation exists between firms' location and their needs.*

Applying the model made it possible to evaluate the additional impact of several structural characteristics within a firm on the innovativeness and the innovation potential of the three regions. It was found that the innovativeness of firms having internal R&D and a high rate of highly skilled labor is much higher than that of other firms; this held for all types of industries examined. Nevertheless, this ability is differentially dependent on the industrial branch and a firm's spatial location. The advantage that the metropolitan area offers to these firms emerges not only from their willingness to invest in internal

R&D, but also from the production milieu, which assists and supports the high-tech firms' needs; that is, it provides a supportive innovation milieu. This advantage is not found in the intermediate and the peripheral zones, where highly skilled labor is not as available.

This spatial difference is also manifested the other way around as expressed by the periphery's ability to attract innovative firms belonging to a traditional industry that invest in developing internal R&D. This fact will ensure a relatively high probability of developing innovations in the peripheral zone.

From the findings, it is possible to conclude that further progress should be made toward directing industries to different regions based on natural trends proven to be effective in fitting industries to a spatial location. Hence, a policy that effects a change in location preference might harm the economic efficiency derived from the existing localized compatibility.

Defining a regional policy aimed at attracting innovative firms to less attractive regions might be extremely limited, as firms are ready to locate in regions where the environmental conditions match the specific needs of firms belonging to the different industrial branches. Improved conditions relating to the availability of land, development, and operational costs already exist in the peripheries; therefore, the effect of a regional policy in this regard might be limited.

On the other hand, it seems feasible to examine a regional policy based on giving preference to the internal characteristics of a firm that were identified in this study as having an influence on the innovativeness of firms in different industrial branches. Such a policy might involve training the labor force, giving incentives to skilled labor to stay, and even encouraging migration to the peripheral zones. Encouraging the development of internal R&D might positively affect the ability of firms to develop innovations in these lagging regions over and above their natural ability, which is restricted by the prevailing characteristics of the production milieu.

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