Università degli Studi di Salerno
DIPARTIMENTO DI SCIENZE ECONOMICHE E STATISTICHE

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Internal and external sources of innovation in the Italian biotech sector

WORKING PAPER 3.206

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Note of the authors: this paper is the result of a strict collaboration among the authors. Nevertheless, the parr. 1 and 2 may be mainly attributed to Rosamaria D'Amore; as regards the empirical analysis, the creation and submission of the questionnaire, the imputation of data deriving from the answers must be attributed exclusively to Rosamaria D'Amore (see par. 3.1); the analysis of the data (par. 3.2) could be attributed mainly to Roberto Iorio; the conclusion has been jointly written.

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Abstract

A common view among many academics and policy makers is that biotech offers enormous opportunities for improving competitiveness and economic growth. For this reason there is a growing need to set up appropriate policy to improve the adoption and diffusion of biotech innovation. Nevertheless, there are many interpretative problems about the identification of the biotech firms, due to the uncertainty about the border of the sector itself. This paper provides a contribution to better define and understand the biotech industry, pointing out the differences inside the sector and the different behaviour of the firms according to their typology. In fact this paper, basing on a previous work of classification of the Italian biotech firms according to the OECD standards, uses such a classification in order to better understand the different importance, inside the biotech sector, of the internal and external sources of knowledge, in the production of innovation. Our hypothesis is, in fact, that the relation between internal and external source, on one side, and innovation, on the other side, has different characteristics if we distinguish between the different classes in which the production activities are divided, according to the OECD classification. We try to test this hypothesis trough the analysis of the data coming from a questionnaire we submitted to several Italian biotech firms.

Key words: Biotech innovation, Italian biotech industry, Sources of innovation, Knowledge-based Economy, Policy indicators.

JEL: L2, O3

1. Introduction and definitions

Biotechnology is acknowledged as a key technology nowadays. It is both a broad emerging technological area and a specific activity. One of the main cause of the innovation is the uncertain, market, and complex processes involving knowledge that generates a pattern of change in industry structure and evolution.

One of the main characteristic is its multidisciplinary. Its definition covers a broad range of knowledge fields. Therefore, there are many different definitions existing in the literature and different are the definitions of sector ranging from reports published by internationally influential bodies, such as OECD, OTA, BIO, *et alia,* where the different point of view is based on the diversity in interpretation, measurement and policy ideas. In general, the most frequently used definition is the OECD definition (OECD, 1989): "Biotechnology consists in the use of scientific and engineering principles (based on microbiology, genetic, biochemistry, chemical and biochemical engineering) to transform materials using biological agents (such as micro organism, enzyme, animal or vegetable cells) with the purpose to obtain good and service".

The OECD *Statistical Framework for Biotechnology* (2001) also defined biotech activities identifying six classes. The first distinction is between production and service activities. Then, among production activities, it distinguish between active, innovative and dedicated biotech, firms in order to identify those activities more or less focused on biotech. In particular, a biotechnologically active firm (BAF) is defined as a firm engaged in key biotechnology activities, such as the application of at least one biotech technique to produce goods or services and/or the performance of biotechnology R&D. A dedicated biotech firm (DBF) is a BAF whose *predominant* activity involves the application of biotech techniques to produce good or services and/or the performance of biotech R&D. An innovative biotech firm (IBF) is defined as a BAF that applies biotech techniques for the purpose of implementing new products or processes.

Among service activities, it distinguishes R&D, market and other service oriented firms. In particular, a Biotechnology R&D firm with no product sales is classified by Italian national statistical offices into the R&D service industry category. Targeted firms include firms classified as wholesalers, for instance local operations of large foreign pharmaceutical firms, whose local affiliate performs biotechnology research but acts mainly by a wholesale distributor. Other types of services firms are

included if they are using biotech techniques for the purpose of providing a services (for example waste management and environmental remediation firms).

Table 1 sums up this classification

Table 1: Biotech firm typologies in OECD taxonomy

• Biotechnology **active** firm (BAF) • **Innovative** biotechnology firm (IBF) • **Dedicated** biotechnology firm (DBF)	Production
• Biotechnology **R&D** firm • **Targeted** firm • Other **service** firm	Services

Source: OECD *Statistical Framework for Biotechnology* (2001)

D'Amore and Vittoria (2005) identified 995 Italian biotech firms and were able to classify 865 of them according to OECD classification. Table 2 shows the results of this classification:

Tab. 2 Italian biotech firm distribution (OECD typologies), 2005

Firm typologies	Profit	No profit	
BAF	50	1	
IBF	139		
DBF	61		
Total A	250	1	251
R&D	58	278	
Targeted	83		
Other services	110	85	
Total B	251	363	614
Total A+B	501	364	865

Our aim is to analyse the relation existing between internal and external resources, on one side, and the innovation output on the other side: our hypothesis is that this relation has different characteristics if we distinguish between the three classes in which the production activities are divided, according to the above discussed OECD classification: BAF, IBF and DBF.

In the paragraph 2 we report some bibliographic references about the relation we want to investigate: from this theoretical and mostly empirical review, it should be concluded that those relations are unclear.

Our idea is therefore that it is possible to shed some light on this relations if we operate the distinction among the different classes of activities.

In order to empirically investigate this theme we sent a questionnaire to the 250 Italian biotech firms classified in the *production activity* category; the results coming from the analysis of the questionnaires we received are shown in the paragraph 3.

Some final considerations conclude the paper.

2. Internal and external firm resources and innovation: a literature review

Innovation is critical for firm sustainability in the biotechnology industry. The innovation process (Dosi 1988) is the result of complex activity and it requires a combination of several elements, internal and external to the firm: indeed, it is important to consider not only the organizational and managerial capabilities of individual companies, their investment or the size of the firm, but it is important to consider also a series of external elements, such as the collaboration with other firms or with universities that can improve the internal activity. In addition, Oerlemans et. al., (2001) and Freel (2003) demonstrated the importance of internal and external resources in the innovation process, stressing the positive relation between investments in R&D, collaborations and knowledge diffusion. In the case of Italy (Piga and Vivarelli, 2003) demonstrated that external resources have a positive influence on the choice to make R&D.

According to Coombs and Deeds (2000) the biotech industry is characterized by its creativity in structuring strategic alliance, so the strategic alliance and other forms of collaborative agreements among biotechnology firms, larger industrial companies and universities are methods used to achieve innovation. A common strand all over the literature on firm strategy and performance is the diffuse utilization of strategic alliances or collaboration at all steps of the innovation process to accelerate innovative activities (Audretsch, 2001; Bagchi-Sen 2004; Terziovsky and Morgan, 2006). In this way firms can improve their competitiveness position by integrating technology in the innovation process and facilitating intra and inter firm knowledge and technology transfer (Amir-Aslani and Negassi, 2006; Boer et al, 2001).

Lastly it was analyzed the way to combine resources to achieve innovation as the key of determinants of successful innovation efforts in biotechnology. For example, Deeds and Hill (1996), Freeman (1991), Hagedoorn (1995) analyzed the topic of the relation between firm's rate of new product development and the number of strategic alliances and they concluded that higher levels of expenditures in R&D and technological cleverness are positively correlated with higher levels of collaboration. Internal capability and external collaboration have been found to be complements rather than substitutes (Arora and Gambardella 1994; Pisano et al, 1988; Rothaemel, 2001). In particular, Pisano at al., (1988) it studied the relationship between in-house R&D and collaboration and they found the two to be complementary, as in-house R&D capability attracts collaborative partners. Shan et al., (1994) examined the relationship between the number of collaborators and innovative output. They conclude that, while collaboration advances innovation, innovation does not necessarily require collaboration, that larger firms produce more innovative output and that public firms collaborate more than privately held firms. According to Arora and Gambardella (1994), Nambisan (2002) and Rothaermel (2001) companies with strong internal research capabilities are more likely to collaborate, because they can bring skills and technologies to the table, making them desiderable collaborative partners. In conclusion Hall et al., (2007) demonstrated that innovation performance is a function of firm-level characteristics (e.g. R&D intensity), as well as specific innovation strategies depend on the stages of innovation firms focus on. They also conclude that there is a strong relationships among R&D, innovation and performance in the US Biotechnology industry.

R&D expenditure drives research based innovation, collaboration is a strategy for advancing innovation by providing the complementary assets and technologies firms need to achieve success. Firm size, measured in term of employment, financial and technological resources, plays an important role in the firm's potential to innovate. The comparison between large and small firms in the innovation process has been the subject of a long debate. If Schumpeter (1942) argued that innovation activity is promoted by large firms on a large scale, Jexkes, Sawers and Stillerman (1958) demonstrated that most inventions arose from individuals or small groups. Mueller (1962), with his analysis on the Du Pont's 25 most important innovations, showed that the major part of these innovations originated from smaller firm or individual and they were not internal to DU Pont. His conclusion was that DU Pont has been more successful in making

product and process improvement than in discovering new products. The following literature (such as Arrow, 1983; Scherer and Ross, 1990; Christensen, 1997; Giarratana, 2004; Levinthal and March, 1993) hypothesized that large firms have comparative advantages in large-scale development and commercialization of innovation, instead smaller firms are better suited for more exploratory and inventive research.

This assumption was confirmed by the empirical literature on innovation. For example, Acs and Audtretsch, (1990) demonstrated that R&D expenditure grow proportionally with the firm size, but the number of innovation increase less then proportionally. According to Damanpour (1992) a smaller firm might be more, because it would be expected to be more flexible and therefore to be able to accept and effect the change then in a large firm, where there is more difficulty in communication and coordination of R&D. Another important aspect is that in the small firms the motivation is greater than in a large firm because, for example, there is a visible impact on the firm's overall performance (Kamien and Schwartz,1982). Anyway, in general, the literature about firm size and innovative or inventive outputs shows mixed results. Other researches (for example Bound et al., 1984) demonstrated that the number of patents increases at a rate that is less than proportional to firm size and other authors; Acs and Audretsch (1987, 1991), confirm the same results using the number of innovation as output variable; others authors like Halperin and Chakrabarti,(1987) use of number of scientific publications. But there is another current of literature, for example Henderson and Cockburn (1996), Mansfiel,(1980) that showed that larger firms have in some cases an advantage in innovation.

According to Hall at al., (2007), in order to analyze the associations among R&D intensity at the firm level, innovation performance, and the factors that influence innovation strategies in firm, it is necessary to analyze the nature of the relationships between R&D intensity and innovation performance in firms.

In particular they demonstrated that there is a positive correlation between R&D intensity and the number of domestic and international patent applications field and with domestic and international patent approval received. On the other hand, when they analyzed the relationships between R&D spending and production-based innovation, the results indicated that R&D intensity and the number of new production introduction are negatively correlated. These results make sense

theoretically as it has been shown that a life cycle pattern exists in the innovation process in biotechnology and other industries.

3. The empirical analysis

3.1 The survey and the sample

Our empirical analysis is based on the results of a survey about the firms belonging to the class of *production activities* in the biotech sector.

A questionnaire has been sent by e-mail, answering several qualitative and quantitative data about the characteristics and the innovative activity of the firms. We describe here the only information we used for this paper.

Type of Biotechnology identifies in which sector of biotech the firm operates;

Size of the firm: number of employees in the year period 2000- 2005;

R&D expenditure in the period 2000-2005;

Innovation process or product: how many innovations of product or process the firm introduced in the period 2000-2005;

External collaborations: we asked if the firm collaborated with other partners to realize research projects and/or technical development. In particular it was asked if they have collaborations with: Italian firms, foreign firms, private research centre, Italian universities, foreign universities, public research centres, other public institutions, consulting firms, firms with experience in the biotech sector.

It was not asked the frequency of collaboration, but only if the collaboration took place or not. Therefore the answer was codified as a dummy variable.

The biotech firms belonging to the class of production activities, that are the object of our analysis, are divided into BAF, IBF and DBF. As we have illustrated in Table 2, according to D'Amore and Vittoria (2005) each group included, respectively, 50, 139 and 61 firms (total 250) .

The questionnaire has been sent to all such firms.

The number of the firms that answered to the questionnaire is just 21 out of 250: 8 of them are dedicated firms (DBF) and 13 are innovative firms (IBF). So in this analysis there aren't firms belonging to the active group (BAF). So, it is important to note that the results of the analysis is referred

just to a little sample of the total number of the firms belonging to the class of production activities of the Italian biotechnology industry. Indeed, it is hard to extend these results to the general context.

Regarding the period of our analysis, we considered just 2005, because it is the only year we received completed answers.

3.2 The results of the analysis

As said before, our aim is to observe the link between internal and external resource of the firm and its innovation capacity. In our empirical analysis we considered the following variables: the total number of innovation as a measure of the innovation activities, the R&D expenditure as a measure of internal resources, the collaboration with other partners as a measure of external resources and the number of employers to control for the firm size. We considered these value in a single year, 2005, because of the low number of observations in the other years.

Before analysing such relationships we compared the mean values of the considered variables in the two groups, IBF and DBF, in order to point out the different characteristics of the two classes of firms (we called this one "comparison analysis").

a) The comparison analysis between groups

The comparison analysis among the magnitude of the variables considered in the analysis, within the two groups, IBF and DBF, shows that the DBF introduce more innovation than IBF, even if the last group has more R&D expenditure. This result is consistent with the characteristics of the firms: in fact dedicated firms introduce more innovations because their activity is focused on innovation; on the other hand the innovative firms leave some room for a more basic research, so they tend to spend great amount of money in R&D.

Regarding the size of the firm, dedicated firms are on average bigger than innovative, but the difference is not relevant.

Finally, as regards collaboration, the frequencies of collaboration is the same in both groups, like the actors with they have relations.[1]

[1] It may be interesting to report here another information emerging from the questionnaire: the distribution of time and resources among four different type of research activities, that are basic research, applied research, experimental development and industrial development, is almost the same in the two groups of firms.

a) The analysis of the correlations

In order to analyse the relationships we are interested in, we conducted a bivariate correlation analysis. The limited number of the observations advised us against conducting a multivariate analysis. We analysed the correlations by couples of variables; more precisely, we considered the following relations:

1) between size and other variables (size and R&D expenditure; size and collaborations; size and innovation);
2) between internal and external input of the research (R&D expenditure and external collaborations);
3) between inputs and outputs of the research (R&D expenditure and number of innovations; external collaborations and number of innovations).

We analysed such correlations both in the whole sample and in the two groups of firms separately. In the following section we show and comment the results.

1a) Size and R&D expenditure

The result of this correlation is the same in the two groups of firms (IBF and DBF) and for the whole sample. In fact there is a positive correlation between R&D expenditure and size in every group of firms.

Tab. 1 Correlation between size and R&D expenditure

R&D expenditure and Size		
Whole sample	IBF	DBF
0.816**	0.942**	0.981**
** correlation is significant at the 0.01 level		

Source: our elaboration on RP Biotech Data Base

1b)Size and external collaborations

In this case there is a strong correlation between the two variables in the innovative class, but not in the whole sample and in the dedicated class.

Tab.2. Collaboration and size of the firm (only significant correlations are reported)

Whole sample	IBF	DBF
	Consulting society 0.700*	
	Firm with experience in the sector 0.700*	
	Foreign University 0.595*	
*correlation is significant at the 0.05level		

Source: our elaboration on RP Biotech Data Base

1c) Size and number of innovations

There is a positive but not significant correlation between the number of innovation and the size of the firms, both in the whole sample and in the single groups.

Tab.3 Correlation between number of innovations and size of the firm

Number of innovations and Size of the firm		
Whole sample	IBF	DBF
0.369	0.593	0.408

Source: our elaboration on RP Biotech Data Base

2a) R&D expenditure and external collaborations

In the whole sample there is a positive and significant correlation between R&D expenditure and the collaboration with foreign firms and consulting society; there are no significant correlations between R&D expenditure and other forms of external collaborations. In the single groups the results are different. In fact the dedicated firms do not show significant correlations between R&D and any kind of collaboration; on the other hand, the innovative firms present a positive and significant correlation

between R&D expenditure and several kinds of collaboration, precisely with foreign firms, foreign universities, other publics institutions, consulting society and firms with experience in the sector.

Tab. 4 Correlation between R&D expenditure and external collaborations (only significant correlations are reported)

R&D Expenditure and Collaborations		
Whole sample	IBF	DBF
Foreign firms 0.520*	Foreign universities 0.660*	
Consulting societies 0.582*	Other public subjects 0.611*	
	Consulting societies 0.660*	
	Firm with experience in the sector 0.660*	
* correlation is significant at the 0.05level		

Source: our elaboration on RP Biotech Data Base

3a) R&D expenditure and number of innovations

There is a positive but not significant correlation between R&D and number of innovations in the whole sample. There is the same evidence also into two subgroups with a little difference: in the innovative group the correlation is stronger than in the active group .

Tab. 5 Correlation between R&D expenditure and number of innovations

R&D expenditure and number of innovations		
Whole sample	IBF	DBF
0.173	0.475	0.339

Source: our elaboration on RP Biotech Data Base

3b)External collaborations and number of innovations

In the whole sample there is no significant correlation between the number of innovation and any kind of collaboration.

In the single groups, instead, there are some significant correlations, even if there are some differences.

The innovative firms present a positive and significant correlation between the number of innovation and some kinds of collaborations: with public research centres, others public institutions, consulting society and firm with experiences in the biotech sector.

Also in the case of dedicated firms there is a positive correlation between the number of innovation and some kind of collaborations, but in this case only with others public institutions and with firms with experience in the sector.

As we can see, the merge of two group causes waste of the correlation between the variables.

Tab.6 Correlation between external collaborations and number of innovations (only significant correlations are reported)

Number of innovations and collaborations		
Whole sample	IBF	DBF
	Public research office 0.873**	Other public subject 0.829*
	Other public subject 0.837**	Firm with experience in the sector 0.829*
	Firm with experience in the sector 0.598*	
* correlation is significant at the 0.05 level ** correlation is significant at the 0.01 level		

Source: our elaboration on RP Biotech Data Base

4. Conclusion

The results of our surveys, even based on a limited number of cases, may be useful to bring a contribution to the analysis of the utilization by the firm of internal and external sources of innovation.

First of all, it is interesting to consider the role of firm size in the use of internal and external sources: while there is a clear relationship between size and the amount of R&D expenditure, the relationship between size and external collaboration do not emerge so clearly: it seems that external collaborations are a source of innovation that is easily accessible also to small firms. In an analysis focused on internal and external sources of innovation, it is not possible not to take into consideration the problem if the two kind of resources are complementary or substitute. The answer emerging from our survey is more oriented toward the complementarity, as we observe some positive correlations between R&D expenditure and external collaborations, even if they are not extended to the whole sample and not to all kinds of collaborations; anyway, no clear signs of substitution emerge.

Another interesting result is the importance of the external sources of knowledge for the innovation: while in our sample a clear relationship between R&D expenditure and number of innovation do not emerge, a significant correlation exists between some kinds of external collaborations and the innovative performance. Observing more in detail the specific forms of collaborations that our analysis reveals as useful to favour the innovation, it is interesting to underline the relevance of collaboration with firms with experience in the sector but also with the public sector, even it is surprising that public research offices and other public subjects are cited, but not university.

Beyond the possible interest of such results, that can be included in the stream of the theoretical and empirical literature on these topics, that we previously reviewed, and that are in fact generally consistent with the more frequent results of such studies, the more original contribution of this paper is probably the analysis of the mentioned relationships in different kinds of firms, much less frequent in the existing literature. Our analysis, focused on the biotech sector, underlined that in those firms that have the introduction of new products as their specific goals, the level of complementarity between internal and external resource is particularly strong and stronger is the importance of the external collaborations to produce innovations.

Our analysis was conducted inside one specific sector, the biotech one, and, because of the limited dimension of our sample, we could take into consideration only two kinds of firms (innovative an dedicated), classified according to their specific activity. But the relevant differences observed between the two groups, let us to formulate, more than a conclusion, an hypothesis that should be verified in more extended studies: if the aim is to analyse in depth the complex relationships between the internal

characteristics of the firms, the different inputs of the research and the output of the resource, we have to take explicitly into consideration the specific activities of the firms; in other words, from our analysis inside a sector whose borders are blurring, probably a more general conclusion derives: it may be possible that the usual classification by productive sector is not enough, but it is needed to go more in depth.

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Finito di stampare il 14 dicembre 2009