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Useful science is good science: empirical evidence from the Italian National Research Council

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Abstract

Useful science is good science. According to Pavitt's claim (Research Policy 27 (1998) 793), the aim of this paper is to show that the differences in innovation intensity of the scientific bodies (institutes) belonging to the largest public research institution in Italy (National Research Council, CNR) are affected rather by the carrying out of basic scientific activities than the development of research activities suitable to the innovation needs of firms.

CNR has remarkable records of scientific achievements, mainly in basic science, medicine, biology, computer science and engineering, performed by 108 institutes spread over all Italian regions.

Regarding its mission, a novel framework of CNR technology production has been introduced, in order to guide an empirical analysis into the determinants of the differences in technology production of CNR institutes.

This framework relates the CNR patenting data and a selected set of scientific indicators, in order to single out the kind of link between technological production and scientific activities. The analysis shows the following results: There is a positive correlation between scientific activity, measured by bibliometric analysis, and technological production; The collaboration with other public or private institution and market oriented activity do not affect the innovation intensity of the CNR institutes.

Keywords: Technological change; Patent; Bibliometric analysis

1. Intoduction

Does a research activity suitable to the innovation needs of firms lead to a technological production capacity—of public scientific institutions—greater than the self development of a basic research activity does?

The aim of this paper is to answer the above question by means of an empirical exploration of the differences in innovation intensity of the scientific bodies (institutes) belonging to the largest public research institution in Italy: the National Research Council (CNR).

In Italy, at the present time, policy makers strongly believe in the need to create a closer link between public research bodies and firms.

This opinion is supported by several scientific studies aimed at defining the factors and the mechanisms that lead the technological change processes.

Some of these analyses explain the more rapid growth of some industrialized nations as a result of an effective complementary role of the government in providing the domestic economy with an adequate technology base, as well as broad and rapid utilization of such base (Tassey, 1991).

Other studies—based on the model of national innovation systems (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Metcalfe, 1995)—enhance the systemic approach to the technological change, putting special emphasis on the importance of the territorial link, more or less formalized, between innovation infrastructures and firms (Porter and Stern, 2001; Furman et al., 2002).

From this framework, a systemic view of the technological change determinants develops and, at the same time, this model emphasizes the need to promote not only a suitable national scientific and technological base, but also to carry out all the necessary steps to make the R&S results available and their exploitation easier in the different national industrial sectors.

Without these actions, scientific and technological advances may diffuse to other countries more quickly than they can be exploited at home. For example, although early elements of VCR technologies were developed in

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the United States, three Japanese companies successfully commercialized this innovation on a global scale in the 1970s (Porter and Stern, 2001).

Etzkowitz and Laydesdorff (2000), with their triple helix model claim that the contribution of university and public research bodies is basic to produce innovations suitable to the development of the national production system.

All these studies agree with the need to develop an effective net of relations between public research bodies and firms in order to create favourable conditions promoting the technological change process.

However, in order to plan research policy actions consistently with the goal of supporting the technological development of the national industrial system, it is crucial to understand how science contributes to technological change.

For this reason, in the next section, the thoughts of various authors on the main channels and mechanisms by which science helps technological change are summarized. At the same time, a possible answer to the initial question is introduced. Section 3 shows a novel framework of CNR technology production in order to guide an empirical analysis on the determinants of differences in technology production of CNR institutes. This framework relates CNR patenting data and a selected set of scientific indicators (discussed in Section 4), in order to single out the kind of link between technological production and scientific activities (discussed in Section 5).

Final remarks are illustrated in Section 6 and show that the basic scientific activities ensure more opportunities to reach innovative results than the realization of research activities suitable to the innovation needs of firms.

2. How science helps technological change

Several empirical studies have shown how science performed by academic research bodies contributes to technological change.

Nelson (1959) has used several examples to suggest that more useful knowledge is produced in the long term by allowing basic scientists to pursue their own interests, than by fixing practical goals for their work.

Narin and Frame (1989) have shown sharply upward trends in the frequency with which US patents, originating in a number of countries, contain citations to publications other than patents: from about 0.2 citations to other publications per US patent in 1975, to between 0.9 citations for US patents of US origin—and 0.4 citations for US patents of Japanese origin—1986. On this basis they claim that the technology reflected in the US patents is much more science-dependent than 10 years ago.

Pavitt (1991) has shown the complexity of science's impact on technology, emphasizing the role of the scientific unplanned research results in the development of new technologies. In a subsequent study, Pavitt (1998) summarized the main channels and mechanisms by which science contributes to technological problem-solving.

Mansfield (1995), analyzed the characteristics of more than 200 academic researchers cited for their usefulness by industrial practitioners from 66 US firms. He showed that most of the useful basic research was performed in university departments with high academic ratings according to the US Academy of Sciences. In other words, he showed that useful science is good science.

On the basis of this framework, the aim of the present work is to demonstrate that the innovations produced by public research institutions, measured by means of patenting production, are affected rather by the carrying out of basic research activities than the development of research activities suitable to the innovation needs of firms.

For this reason, the patenting production of CNR institutes is related, through the setting up of a technological production function, to some indicators that represent the output of research activities (either unplanned or applied) carried out by the institutes themselves.

In particular, Pavitt (1998) argues that one of the main purposes of academic research is to produce codified theories and models to explain and predict natural reality and therefore the main output of the academic research is the publication of scientific papers. The notion that the publications capture the essence of the scientific productive output is widely accepted. Within scientific production, one of the most important measures is the citation of publications used as an approximate measure of quality and as a reflection of the use that the scientific community makes of the results of research (Bonaccorsi and Daraio, 2002).

Given this, let the citation be a proxy of the quality of the scientific papers and these be the main output of basic research, my hypothesis is that the quality of the output of the scientific activities carried out by public research bodies, measured by means of citations, is positively correlated with the technological production of those same institutions (Fig. 1).

In order to verify the previous assumption, I chose to analyze the CNR because it is the largest public research institution in Italy and one of the largest in Europe, it takes up 12% of the total research budget and 6% of the researchers working in the country (Boschi, 1998). CNR has almost 4000 researchers and 8000 employees in all; it has remarkable records of scientific achievements, mainly in basic science, medicine, biology, computer science and engineering performed by its own research institutes (108) spread over all Italian regions.

In order to get an idea of the size of CNR, in Table 1 the data on the human and economic resources of the main European public research institutions are shown.

CNR is used as a case study in order to understand the determinants of technological production of the public research bodies in Italy, in consequence of its size and particularly because it has the largest patent production

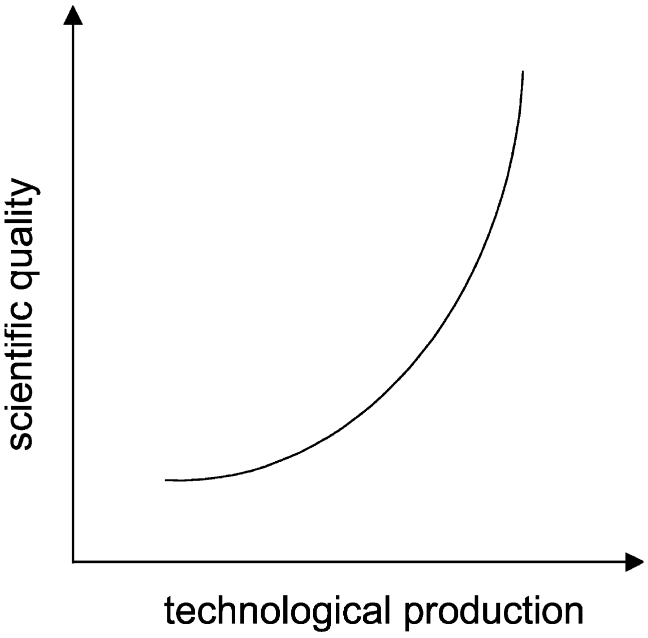

Fig. 1. Useful science is good science.

and productivity, in the period 1982–2001, with 59% of EPO and US patents granted to the Italian public research system (Piccaluga and Patrono, 2001).

The study of technological production of a research institution is a very complex practice as the public value of the knowledge, its accumulation process and how it is carried out (Abramo, 1998).

For this reason, the goal of the present paper is not the measurement of the social and economical impact of the CNR technological production, but providing some elements in order to define the variables that determine the production itself.

3. The framework

The present study takes a novel framework based on the concept of national innovative capacity, introduced by Furman et al. (2002), as a starting point to define the CNR technology production function.

The Furman et al. formulation is illustrated:

$$A_{j,t} = \delta_{j,t}(X_{j,t}^{\mathrm{INF}}, Y_{j,t}^{\mathrm{CLUS}}, Z_{j,t}^{\mathrm{LINK}}) H_{j,t}^{A\lambda} A_{j,t}^{\phi} \qquad (1)$$

where $A_{j,t}$ is the flow of new-to-the-world technologies from country j in year t, $H^{A\lambda}$ the total level of capital and labor resources devoted to the ideas sector of the economy and $A_{j,t}^{\phi}$ is the total stock of knowledge held by an economy at a given point in time to drive future ideas production.

These elements are borrowed from the Romer (1990) growth model that articulates the economic foundations for a sustainable rate of technological progress by introducing the “ideas sector” for economy, which operates according to the national ideas production function. In this framework, the rate of new ideas production is a function of the number of ideas workers and the stock of knowledge available to these researchers.

The function (1) is more general than the Romer formulation because the national innovative capacity framework introduced by Furman et al. (2002) suggests that a broader set of variables determines innovative performance.

According to Furman et al. (2002), the national innovative capacity is the ability of a country to produce and commercialize a flow of innovative technology over the long term.

This model embodies three different views that identify country specific factors that determine the flow of innovation: ideas-driven endogenous growth theory, the cluster based theory of national industrial competitive advantage (Porter, 1990) and research on national innovation systems (Nelson, 1993).

From this point, the Romer growth model puts on more general formulation adding the following new variables:

- X^{INF} refers to the level of resource commitments and policy choices that constitute the common innovation infrastructure;
- Y^{CLUS} refers to the particular environments for innovation in a country’s industrial cluster;
- Z^{LINK} measures the strength of linkage between the common infrastructure and the nation’s industrial cluster.

Each of the above-mentioned variables is measured by a selected set of qualitative and quantitative parameters.

Examining the relationship between international patenting and the selected variables, the function (1) is used to guide an empirical exploration into the determinants of country-level differences in innovation intensity.

On the other hand, the subject of the present study is a subset of the national innovation system, particularly

Table 1
Total resources of the main European research institutions

Year	CNR (I)		CNRS (F)		CSIC (E)		Max Planck (D)	
	2000	2001	2000	2001	2000	2001	2000	2001
Budget (€ mio)	765	793	2426	2457	359	404	1145	1261
Personnel	7377	8082	25,032	23,094	8891	7678	11,218	11,612
Researchers	2845	3694	11,409	11,643	2133	2259	3116	3229

Source: CNR Report, 2002.

the research institutes of the largest public research institution in Italy.

For this reason, in this analysis only the core idea is taken from function (1) regarding the possibility to determine differences in innovation intensity relating the technological production to a set of variables that could determine the production itself.

It follows that all the potential variables able to affect the patent production of the CNR research institutes have been taken into consideration in order to set up a possible CNR technological production function.

Therefore, considering the CNR mission, the following variables have been selected for each institute:

- The stock of technological knowledge, and the economic and human resources, borrowing the Romer (1990) growth model;
- The amount and quality of the scientific knowledge, deeply related to the technological production (Pavitt, 1998);
- The ability of each institute to relate itself to the socio-economic system in which it works in order to carry out research activities suitable to the innovation needs of firms (Porter and Stern, 2001).

On this basis a possible function of the technological production of the CNR research institutes has been set up:

$$A_{j,t}^{CNRPROD} = \delta(Z_{j,t}^{CNRLINK}, W_{j,t}^{CNROUTC})H_{j,t}^{CNRINF}A_{j,t}^{CNRSTOCK} \quad (2)$$

where $A^{CNRSTOCK}$ is the stock of technological knowledge of the CNR research institute j; H^{CNRINF} are the available economic and human resources of the CNR research institute j in time t; $Z^{CNRLINK}$ is the ability of each CNR institute j to relate itself to the socio-economic system in which it works in order to carry out research activities suitable to the innovation needs of firms; $W^{CNROUTC}$ are the scientific outcomes produced by the CNR institute j, particularly the number of scientific publications and their quality measured by means of citation analysis.

As regards the variables of function (1), the parameters relating to the political, socio-economic and innovation context have not been taken into consideration in function (2), because I assume the CNR belongs to the system itself and, therefore, these variables affect in the same way the technological production of each institute.

Hence, attention has been placed only on the variables able to show the whole CNR research activities and, therefore, able to affect patent production of the research institutes.

The next step was to verify the framework, through a correlation of the data relating to the selected variables.

4. Data restriction and variables selection

The indicator used to measure the technological performance of the CNR institutes is the number of patents granted, in Italy or abroad, in the period 1999–2001 to inventors working in CNR. The information source is the CNR patenting data base. In the period 1999–2001, 71 patents have been produced by 40 CNR institutes. The analysis concerns only the CNR institutes that have produced at least a patent in the investigated period. Therefore, function (2) gives us information about the elements that determine differences in the innovation intensity of CNR institutes as changes in the number of patents carried out.

Related to this, it is necessary to emphasize that there are different tendencies in patenting, connected to the institute's scientific fields. Table 2 shows the scientific fields of the CNR institutes involved in the analysis and the related number of patents.

At the same time, the use of patenting data as an indicator of technological production has its own strengths and limitations. For example, the patents are the outcomes of those inventions which are expected to have a business impact; but not all inventions are patented or are technically patentable. However, in consideration of the high possibility to generate business applications the patenting could be used as an indicator of technological activities (Archibugi and Pianta, 1992).

Once patenting was selected as a technological performance indicator, a set of indicators, consistent with each class of variables, was defined in order to relate them to patent production and to verify the degree of correlation. The data have been drawn from the scientific results obtained by the CNR institutes investigated, in the period 1999–2001. Table 3 shows the indicators selected for each class of variables and their relevant meaning.

To measure the stock of technological knowledge of an institute ($A^{CNRSTOCK}$), according to the framework introduced by Furman et al. (2002), the number of patents carried out by the institute from the year of its establishment has been considered.

To evaluate the input data H^{CNRINF} the following indicators have been considered (Sirilli, 1997):

Table 2
Number of patents per institutes scientific field

Scientific field	No. of institutes	No. of patents
Physics	12	20
Chemistry	10	19
Medicine	1	4
Agriculture	6	13
Engineering	3	3
Innovation	3	7
Environment	3	3
Biotechnologies	2	2

Table 3
Variables of the technological production function of the CNR institute *j*

Class of variable	Indicators	Description	Source
$A^{CNRPROD}$	N_patents (99_01)	No. of patents granted to CNR inventors in the period 1999–2001	CNR, Servizio III DAST
$A^{CNRSTOCK}$	N_tot_patents	No. total of patents carried out by CNR institute	CNR, Servizio III DAST
H^{CNRINF}	R&D_R	No. CNR researchers (average 99–01)	CNR report
H^{CNRINF}	R&D_$	R&S budget of CNR institute (99–01)	CNR report
$Z^{CNRLINK}$	coll_uni	No. of collaboration with university per project (average 99–01)	Report CNR institutes
$Z^{CNRLINK}$	coll_firm	No. of collaboration with firms per project (average 99–01)	Report CNR institutes
$Z^{CNRLINK}$	coll_oth	No. total of collaboration with other institution per project (average 99–01)	Report CNR institutes
$Z^{CNRLINK}$	$_mark	% R&D budget arising from the market (self-financing) (99–01)	CNR report
$Z^{CNRLINK}$	N_train	No. of outside training personnel (average 99–01)	Report CNR institutes
$W^{CNROUTC}$	Pub_jcr	No. of JCR articles carried out CNR authors (99–01)	CNR report
$W^{CNROUTC}$	MOCR	Mean observed citation rate (articles 1999, citation windows of 3 years)	ISI-SCI data elaboration
$W^{CNROUTC}$	RCR	Relative citation rate (articles 1999, citation windows of 3 years)	ISI-SCI data elaboration

- The budget of the CNR institutes;
- The financial resources of the researchers working in each institute during the investigated period.

The value of the class of variables $Z^{CNRLINK}$, used to emphasize the ability of the institute *j* to relate itself to the socio-economic system in which it works, in order to develop research activity suitable to the innovation needs of firms, was measured by the following indicators:

- The link set up by the institutes with other institution (firms and universities) through the development of joint research activity;
- The ratio between the level of budget arising from the market and the total available budget for each institute (self-financing);
- The training activities of outside personnel employed by each institute.

The relationship indicators could be used to measure the knowledge spillover activities (Jaffe et al., 1993). The self-financing variable could be used as an indicator of codified technological transfer, while the training activities could be taken into consideration to determine the so-called tacit technological transfer (Coccia and Rolfo, 2000).

The class of variables concerning the scientific outcome, $W^{CNROUTC}$, is measured by the following indicators:[1]

- The number of articles published in journals, collected in the Journal Citation Reports (ISI), produced by CNR institutes during the investigated period;
- The mean observed citation rate (MOCR), the average number of citations received by a set of articles published in 1999 by a CNR institutes in the following 3-year period (ISI Science, 1999, 2000, 2001);
- The relative citation rate (RCR) that measures the ratio between the mean observed citation rate and the mean expected citation rate (MECR). In this way the number of citations obtained is compared to the number of expected citations calculated on the basis of the journals in which the papers have been published.

The joint use of such indicators gives us an overall vision on the publication strategy providing information on the quality of the publication channel used by the researchers (Braun, 1999).

The analysis is organized around a log specification, except for variables expressed as a percentage. The estimates thus have a natural interpretation in terms of elasticity, are less sensitive to outliers, and are consistent with the majority of prior work in this area (Jones, 1998).

5. Empirical results

In Table 4 the mean and the variance of each investigated indicator are shown.

On the basis of the available data, first of all, the correlation coefficient *R* of the indicators related to the different classes of variables has been calculated.

Table 5 shows the result of this simple correlation.

Table 4
Mean and variance of the investigated sample

Indicators	N	Mean	Variance
n_patents (99_01)	40	1.775	1.974
N_tot_patents	40	3.450	5.997
R&D_$ (mld lit)	40	5.246	17.695
R&D_R	40	23.500	198.462
coll_uni	40	2.424	2.983
coll_firm	40	0.671	0.492
coll_oth	40	4.960	8.949
$_mark	40	0.535	0.041
N_train	40	36.650	1022.695
Pubb_jcr	40	77.425	2729.122
MOCR	40	3.036	4.939
RCR	40	1.542	0.870

[1] For further information on the above-mentioned bibliometric indicators, see Schubert and Glanzel (1983); Braun et al. (1985) and Schubert and Braun (1986).

Table 5
Correlation between patenting and selected indicators

	Ln_n_patents (99_01)	Ln_n_tot_patents	Ln_R&D_$	Ln_R&D_R	LN_coll_uni	LN_coll_firm	LN_coll_oth	Ln_$_mark	Ln_N_train	LN_Pubb jcr	Ln_MOCR	Ln_RCR
Ln_n_patents (99_01)	1											
Ln_n_tot_patents	0.719376	1										
Ln_R&D_$	0.051901	0.132591	1									
Ln_R&D_R	−0.04523	0.199428	0.501178	1								
LN_coll_uni	−0.06108	0.163091	0.120313	0.234518	1							
LN_coll_firm	−0.02962	0.100868	0.042062	−0.12949	0.333789	1						
LN_coll_oth	−0.11085	0.111441	0.200177	0.227157	0.843941	0.499681	1					
Ln_$_mark	−0.18475	−0.15041	0.618776	0.062179	−0.12955	0.070554	−0.00678	1				
Ln_N_train	−0.04167	0.157606	0.504553	0.552096	0.311847	0.142048	0.187114	0.033776	1			
Ln_Pubb_jcr	0.15631	0.316461	0.490296	0.639207	0.381858	−0.02891	0.182315	0.115367	0.50524	1		
Ln_MOCR	0.472813	0.349381	0.156546	0.18718	0.101425	−0.35482	−0.08978	−0.07441	0.10274	0.442296	1	
Ln_RCR	0.26781	0.171627	−0.02342	−0.15182	−0.02575	−0.13876	0.006047	0.069958	−0.22481	0.018339	0.638597	1

The results included in Table 5 show that:

- There is a positive correlation between the patent production; and
  - The stock of technological knowledge of each institute;
  - The quality of the scientific production of the institutes (MOCR);
- There is a negative correlation between the patent production and the parameters that measure the class of variables Z^{CNRLINK}, used to emphasize the ability of the institute j to relate itself to the socio-economic system.
- There is no correlation between patenting and resource indicators (H^{CNRINF}).

The next step consists of the measurement of the R^2 value carrying out a simple regression in order to validate the proposed technological production function.

Table 6 (column f) shows the whole result of the simple regression of function (2).

The R^2 value concerns only the parameters referable to the CNR mission. The variables referring to the political, socio-economic, and innovation context, that according to function (1) significantly contribute to the R^2 value, have not been taken into consideration in function (2), because I assume the CNR belongs to the system itself and, therefore, these variables affect the technological production of each CNR institute in the same way.

The next step consists of emphasizing the single contribution of each class of variables towards the total regression result. In particular, some partial regressions have been carried out relating the technological production indicator with the parameters related to each of the four classes of variables.

The results of such partial regression, shown in Table 5, suggest that:

- The parameter on the stock of the institute's technological knowledge gives the main contribution to the R^2 value (column a);
- The variables of the quality of scientific publications give a relevant contribution to R^2 value (column d);
- The class of variables that measures the ability to carry out research activities suitable to the innovation needs of firms has a lacking impact on the R^2 value. This is also confirmed by the null F value (column c);
- The contribution of economic and human resources to the regression is null (column b).

6. Conclusion

The analysis of the above illustrated results leads to the following general assumptions:

1. The size of the economic and human resources does not affect the technological production of the CNR institutes.

Table 6
Determinants of the CNR technological production function

		Dependentvariable = Ln_n_patents(99_01)				
		(a) $A^{CNRSTOCK}$	(b) H^{CNRINF}	(c) $Z^{CNRLINK}$	(d) $W^{CNROUTC}$	(f) Total function
Ln_N_tot_ patents		0.580				0.505
Ln_R&D_$			0.075			0.170
Ln_R&D_R			−0.091			−0.264
Ln_coll_uni				0.064		−0.132
Ln_coll_firms				0.034		0.063
Ln_coll_oth				−0.210		−0.102
Ln_$_mark				−0.231		−0.286
Ln_N_train				−0.016		−0.101
Ln_N_pubb_JCR					−0.053	−0.058
Ln_MOCR					0.469	0.345
Ln_RCR					−0.119	−0.183
	R	0.791	0.097	0.224	0.481	0.832
	R^2	0.517	0.009	0.05	0.232	0.693
	Adjusted R^2	0.505	−0.044	−0.089	0.169	0.556
	F	40.756	0.177	0.359	3.63	5.079
	Stat t	−2.779	−2.265	−2.025	−2.060	−2.342

There is not, in fact, any correlation between these indicators. This result could be related to the different patenting aptitude of the CNR investigated institutes depending on the various scientific fields in which they work. For instance, it is possible to find institutes with the same size, but with different patenting production because they work in different scientific fields;

2. The ability of the institutes to carry out research activities suitable to innovation needs of the firms is not determinant in their own innovation intensity. This result could be explained considering that the collaboration with the firms could start alternate mechanisms for the diffusion and exploitation of the scientific and technological knowledge as knowledge spillovers. At the same time, conditions that do not allow patenting as suitable tools for new ideas protection (disclosure paradox) may arise. With regard to collaboration with the university, it is more targeted toward the investigation of scientific topics than technological ones. It is possible to verify this claim in Table 5. The values show a positive correlation whether between the scientific production and the collaboration with university or between the scientific production and the training activities. The self-financing activities could have poor technological impact because the research topic, founded by external sources, could involve problems related to intellectual property rights;
3. Technological production is deeply affected by the stock of technological knowledge of each institute, particularly by the total number of patents produced by the institute itself in the previous years;
4. There is a positive correlation between patent production and the quality of the scientific papers published in international journals, that mostly represent the results of scientific research activity (Pavitt, 1998). In particular, the high technological production of a CNR institute is positively correlated with the number of citations obtained from the set of articles produced by the institute itself in the same period and, therefore, it is affected by the impact of the scientific results on the international scientific community.

The last result confirms the positive correlation between the quality of the basic research activity output and the technological production of the CNR institutes, as shown in Fig. 1, confirming at the same time the original assumption that useful science is good science.

Therefore, the ability of the public research institutions to carry out basic research activities ensures more opportunities to achieve innovative results than the realization of research activities suitable to the innovation needs of firms.

In this last case, the danger for public research institutions might be research activities too tightly linked to prompt business applications that, as shown, do not affect their own innovative production.

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References

Abramo, G., 1998. Il sistema ricerca in Italia: il nodo del trasferimento tecnologico. Economia e Politica Industriale 99.

Archibugi, D., Pianta, M., 1992. The Technological Specialization of Advanced Countries. A Report to the EEC on International Science and Technology Activities, Kluwer Academic Publishers, London.

Bonaccorsi, A., Daraio, C., 2002. NPRNet Conference: Rethinking Science Policy, March 21–23, 2002, London. The organization of science. Size, agglomeration and age effects in scientific productivity
Boschi, D., 1998. La valutazione della R&S in Italia: rassegna delle esperienze del CNR e proposta di un approccio alternativo. Working Paper Ceris-CNR n. 8/1998.
Braun, T., Glanzel, W., Schubert, A., 1985. Scientometric Indicators. 32 Country Comparison of Publication Productivity and Citation Impact, World Scientific Publishing, Singapore.
Braun, T., 1999. Bibliometric indicators for the evaluation of universities-intelligence from the quantification of the scientific literature. Scientometrics 45, 425–432.
Coccia, M., Rolfo, S., 2000. Ricerca pubblica e trasferimento tecnologico: il caso del Cnr in Piemonte. In: Rolfo, S., (Ed.), Innovazione e Piccole imprese in Piemonte, Franco Angeli, Milano.
CNR Report 2000, 2001, 2002. Consiglio Nazionale Delle Ricerche. D'Anselmi Editore/Hoepli, Roma.
Etzkowitz, H., Laydesdorff, L., 2000. The dynamics of innovation: from national system and "Mode 2" to a triple helix of university–industry–government relations. Research Policy 25, 109–123.
Freeman, C., 1987. Technology Policy and Economics Performance. Lessons from Japan, Frances Pinter, London.
Furman, J.L., Porter, M.E., Stern, S., 2002. The determinants of national innovative capacity. Research Policy 31(6), 899–933.
ISI, Science Citation Index, 1999, 2000, 2001. Compact disc edition, Thomson/ISI, Philadelphia.
Jaffe, A.B., Trajtenberg, M., Henderson, R., 1993. Geographic localization of the knowledge spillovers as evidence by patent citation. Quarterly Journal of Economics CVIII(3), 577.
Jones, C., 1998. Introduction to Economic Growth, WW Norton & Co, New York.
Lundvall, B.A., 1992. National System of Innovation, Printer, London.
Narin, F., Frame, J., 1989. The growth of Japanese science and technology. Science 245, 600–604.
Nelson, R., 1993. National Innovation Systems. A Comparative Analysis, Oxford University Press, New York.
Nelson, R., 1959. The simple economics of basic scientific research. Journal of Political Economy 67, 297–306.
Mansfield, E., 1995. Academic research underlying industrial innovation: source, characteristics and financing. Review of Economics and Statistics 77, 55–62.
Metcalfe, J.S., 1995. The economics foundations of technology policy: equilibrium and evolutionary perspectives. In: Stoneman, P., (Ed.), Handbook of the Economics of Innovation and Technological Change, Blackwell, Oxford, pp. 409–512.
Pavitt, K., 1991. What makes basic research economically useful? Research Policy 20, 109–119.
Pavitt, K., 1998. The social shaping of the national science base. Research Policy 27, 793–805.
Piccaluga, A., Patrono, A., 2001. L'attività brevettuale degli enti pubblici di ricerca italiani. Un'analisi sul periodo 1982–1999. Economia e Politica Industriale 109, 1982–1999.
Porter, M.E., 1990. The Competitive Advantage of Nations, Free Press, New York.
Porter, M.E., Stern, S., 2001. Innovation: location matters. MIT Sloan Management Review Summer 2001, 28–36.
Romer, P., 1990. Endogenous technological change. Journal of Political Economy 98, S71–S102.
Schubert, A., Glanzel, W., 1983. Statistical reliability of comparison based on the citation impact of scientific publications. Scientometrics 5, 59–74.
Schubert, A., Braun, T., 1986. Relative indicators and relational charts for comparative assessment of publication output and citation impact. Scientometrics 9, 281–291.
Sirilli, G., 1997. Science and technology indicators. The state of the art and prospect for the future. In: Antonelli, G., De Liso, N. (Eds.), Economics of Structural and Technological Change, Routledge, London.
Tassey, G., 1991. The functions of technology infrastructure in a competitive economy. Research Policy 20, 345–361.

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