Physics in Italy between 1900 and 1940: The Universities, Physicists, Funds, and Research

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THE AIM OF this paper is to give a detailed picture of the institutional context of physics research in Italy and a quantitative analysis of the papers published in *Il nuovo cimento*, taken as representative of Italian physical research in the period 1900–1939.

1. THE UNIVERSITIES

In 1861, at its political unification, the Italian state inherited nineteen universities, fifteen of which were state universities, the other four "free." The annexation of Veneto in 1866, and of the remainder of the papal state in 1870, brought in the state universities of Padua and Rome. Besides the universities, there were engineering schools and various superior institutes. The latter were mainly professional schools, although some of them had links with the university or, as in the case of the Superior Technical Institute of Milano, they might be engineering schools under a different name.

In order to evaluate the changes in university structure, we have focused our attention on the academic years 1871/2 and 1926/7. We chose the latter year because of the availability of information from the Istituto Centrale di Statistica;[1] the former is the earliest year consistent with accessibility of sources and homogeneity of university

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The following abbreviations are used: CNR, Consiglio Nazionale delle Ricerche; MPI, Ministero della Pubblica Istruzione; *NC, Il nuovo cimento*; SIPS, Società Italiana per il Progresso delle Scienze.

1. "Statistica dell'instruzione superiore nell'anno accademico 1926–1927," *Annali di statistica, 14* (Rome, 1933). Unfortunately we could not use this source for "professori incaricati" and assistants since it does not fully disaggregate them. Therefore, as explained in the notes to Table 2, we have derived all our data on the teaching staff for the academic year 1926/7 from primary sources.

structures.

The Italian university of 1927 differed from that of 1872 chiefly in novelties represented by the founding of new faculties or schools: agricultural sciences, economic and commercial sciences, political sciences, and "Magistero" (a university course of literature open to students coming from training schools for elementary school teachers). These novelties came to be in a largely stagnant environment, as appears clearly from an analysis of the composition of the teaching staff (see Tables 1 and 2).

The tables show that despite the founding of new faculties and schools, the distribution of chairs between humanities and science faculties scarcely changed in fifty-five years. The new faculties and schools in the humanities seem to have grown at the expense of the faculty of law (-4.8%); the new scientific ones, and the engineering schools (+5.1%), at the expense of the faculty of sciences (-9.2%). These variations can be correlated only partially with changes in the student distribution among the faculties (see Table 3).

The decrease of students in the faculty of sciences and the parallel increase in the engineering schools may be correlated with the corresponding changes in the distribution of chairs; but the similar trend in the faculties of law and of literature and philosophy cannot, since, in 1927 the number of students per chair was much higher in the first faculty (40) than in the second (14). Other factors evidently affected the distribution of chairs: academic power, political connections, support of industry (in engineering schools). These factors and their influence on the teaching staff's composition have received some historical analysis.[2]

The picture changes somewhat if we take into account the assistants and the "professori incaricati" (teachers without chairs appointed every year). If we group together all three (chaired professors, "professori incaricati," and assistants), we find a decrease of more than 5% in the humanities and an exactly equal increase in the sciences (Table 2, last column). The total number of assistants increased sixfold from 1872 to 1927, almost entirely within the sciences; in the humanities, in 1927, there were only 50, equivalent to 3.4% of the total. At first sight it seems that the assistant was conceived with the needs of the experimental disciplines and medical services in mind. However, the concern shown by mathematicians for securing assistants (see Table 4) suggests that experimental activity and the practice of medicine were not the only forces at work.

2. R. Maiocchi, "Il ruolo delle scienze nello sviluppo industriale italiano," *Storia d'Italia Annali, 3* (Turin, 1980), 865–999.

The faculty of sciences suffered a considerable loss in the number of chairs (-9.2%) and in the total number of researchers (-11.4%). This decline did not occur across the board, however, as can be seen from Table 4. In 1872 the chairs of mathematics constituted more than one third of the faculty. From 1872 to 1927 the experimental disciplines gained at the expense of mathematics and drawing. The change in numbers of assistants is, as usual, more pronounced than the change in chairs: particularly significant is the increase of mathematics (by a factor of 18) and earth sciences (by a factor of 6) when compared with a factor of 3 for physics, chemistry, and biological sciences. The large decrease of assistants in astronomy is only apparent, a consequence of the replacement of assistants by "observers".

The undiminished academic power of humanities faculties between 1872 and 1927 is associated with a conspicuous flow of students to them from scientific faculties (about 12%; see Table 3.) This fact, together with the growth of engineering schools (in both academic staff and students) and the concomitant reduction of the science faculty are clear hints of a cultural, social, economic, and political disposition to undervalue "pure" science and its importance for the overall development of the country. Moreover, among the experimental disciplines in the science faculty, physics and chemistry suffered special neglect. Similar conclusions can be drawn from Maiocchi's data, which relate to the years 1862–1894. These numbers suggest that the usual association of a slow-down in the development of science in Italy during the first decades of our century with Croce's and Gentile's philosophy is mistated. Science in Italy began to decline in the universities long before Croce and Gentile became important and in ways much more direct than those resulting from their subtle speculations. Their positions on science and science's underdevelopment in Italy should be viewed as products of the cultural, social, economic, and political background rather than as direct causes of attitudes toward science.

2. THE PHYSICISTS

Despite the losses in professorial chairs by the scientific faculties the number of physicists increased by a factor of 3.3 over the 68 year period considered in Table 5 and figure 1. The rate of increase (number of physicists per year) was 1.2 from 1872 to 1900, 1.7 from 1900 to 1915, and 2.5 from 1915 to 1927. Between 1927 and 1940 the number of physicists did not change. If we take into account the fact that the first world war reduced the number of chaired university

Table 1
Academic year 1871/2
State universities[a]

Faculty or School	Professors		Professori Incaricati		Assistants		Total	
	no.	%	no.	%	no.	%	no.	%
Law	154	22.5	23	21.7	1	0.4	178	17.4
Literature & Philosophy	95	13.9	11	10.4	1	0.4	107	10.4
Theology	16	2.3	2	1.9			18	1.8
Humanities Faculties	265	38.7	36	34	2	0.8	303	29.6
Medicine	198	28.9	31	29.2	108	46.8	337	33.0
Veterinary Medicine	13	1.9	4	3.8	7	3.0	24	2.3
Pharmacology	8	1.2			3	1.3	11	1.1
Sciences	170	24.8	25	23.6	90	39.0	285	27.9
Engineering	31	4.5	10	9.4	21	9.1	62	6.1
Science Faculties	420	61.3	70	66	229	99.2	719	70.4
Total	685	100	106	100	231	100	1022	100

a. "Professors" include "ordinari" and "straordinari." "Professori incaricati" required appointment every year. "Assistants" are both "assistenti" and "aiuti" (assisants of higher degree). For the composition of the faculty of sciences see Table 4. Source: *Annuario della pubblica istruzione del Regno d'Italia pel 1871/2* (Rome, 1872).

Table 2
Academic year 1926/7
State universities[a]

Faculty or School	Professors		Professori Incaricati		Assistants		Total	
	no.	%	no.	%	no.	%	no.	%
Law	219	17.7/-4.8	74	10.4/-11.3	2	0.1/-0.3	295	8.7/-8.7
Lit. & Phil.	173	14.0/0.1	62	8.8/-1.6	9	0.6/0.2	244	7.2/-3.2
Theology		/-2.3		/-1.9				/-1.8
Magistero	20	1.6/1.6	11	1.6/1.6			31	0.9/.9
Political Science	11	0.9/0.9	18	2.5/2.5	3	0.2/0.2	32	0.9/0.9
Eco. & Comm. Sciences	70	5.6/5.6	103	14.5/14.5	33	2.3/2.3	206	6.1/6.1
Others	3	0.2/0.2	8	1.1/1.1	3	0.2/0.2	14	0.4/0.4
Humanities Faculties	496	40.0/1.3	276	38.9/4.9	50	3.4/2.6	822	24.2/-5.4
Medicine	326	26.3/-2.6	118	16.7/-12.5	766	52.8/6.0	1210	35.6/2.0
Veterinary Medicine	32	2.6/0.7	15	2.1/-1.7	46	3.3/0.3	93	2.7/0.4
Pharmacology	17	1.4/0.2	27	3.8/3.8	37	2.6/1.3	81	2.4/1.3
Agricultural Science	54	4.3/4.3	48	6.7/6.7	50	3.4/3.4	152	4.5/4.5
Sciences	193	15.6/-9.2	89	12.6/-11.0	280	19.3/-19.7	562	16.5/-11.4
Engineering	122	9.8/5.1	110	15.5/5.6	220	15.1/5.9	452	13.3/6.9
Others			26	3.7/3.7	2	0.1/0.1	28	0.8/0.8
Science Faculties	744	60.0/-1.5	433	61.1/-5.4	1401	96.6/-2.7	2578	75.8/4.5
Total	1240	100	709	100	1451	100	3400	100

a. "Magistero" was a university course of literature open to students from training schools for elementary school teachers. The numbers to the right of the slashes represent the percentage variations with respect to the academic year 1871/72. Sources: MPI, *Annuario* (Rome, 1927), and in the case of the entries marked with an asterisk, from the same journal for 1929/30.

Table 3
Students
State universities[a]

Faculty or School	1871/1872 Students no.	%	Students per professor no	1926/1927 Students no.	%	Students per professor diff.	no.
Law	2015	30.0	13	8748	21.7	-8.3	40
Literature & Philosophy	190	2.8	2	2433	6.0	3.2	14
Theology	4	0.1	0.25			-0.1	
Magistero				1067	2.6	2.6	53
Political Science				406	1.0	1.0	37
Economics & Comm. Sciences				5636	13.9	13.9	81
Humanities Faculties	2209	32.9	8	18290	45.2	12.3	37
Medicine	1788	26.7	9	7918	19.6	-7.1	24
Veterinary Medicine	517	7.7	40	861	2.1	-5.6	27
Pharmacology	655	9.8	82	3100	7.7	-2.1	182
Agricultural Science				983	2.4	2.4	18
Sciences	927	13.8	5	2772	6.9	-6.9	14
Engineering	612	9.1	20	6486	16.1	7.0	53
Science Faculties	4499	67.1	11	22120	54.8	-12.3	30
Total	6708	100	10	40410	100		33

a. For explanations and sources see notes to Tables 1 and 2. We have only counted students "in corso," i.e., students who have passed the minimum number of examinations established for each year.

Table 4
Faculty of sciences
State universities[a]

Discipline	Professors					Assistants				
	1871/2		1926/7		diff	1871/2		1926/7		diff
	no.	%	no.	%	%	no.	%	no.	%	%
Astronomy	7	4.4	8	4.1	-0.3	15	17.2	2	0.7	-16.5
Physics	13	8.1	20	10.4	2.3	15	17.2	45	16.1	-1.1
Chemistry	17	10.6	18	9.3	-1.3	17	19.6	50	17.8	-1.8
Bio. Sci.	31	19.4	42	21.8	2.4	22	25.3	68	24.3	-1.0
Earth Sci.	21	13.1	31	16.1	3.0	8	9.2	47	16.8	7.6
Mathematics	59	36.9	64	33.1	-3.8	3	3.5	54	19.3	15.8
Drawing	12	7.5	10	5.2	-2.3	7	8.0	14	5.0	-3.0
Total	160	100	193	100		87	100	280	100	

a. The number of professors for 1871/2 reported here differs from that in Table 1 because we have subtracted five professors in agricultural sciences (this discipline belonged to the faculty of sciences in 1872 but not in 1927) and a few others who do not fit into any of the groups. The last reason also accounts for the difference of three in the number of assistants. We have listed mathematical physicists under mathematics because the research they did seldom concerned physics, their chairs were controlled by mathematicians, and only mathematicians were assigned the course of mathematical physics when it was given to a chaired professor as an additional appointment. There were two professors of mathematical physics in 1872 and eight in 1927, and no assistants in either year. Sources: as in Tables 1 and 2.

Table 5
Number of physicists[a]

Academic Year	1871/2	1899/00	1914/5	1926/7	1939/40
Professors	17(2)	25(3)	22(6)	24(8)	29(4)
Incaricati	4	1(1)	5(1)	26	13(4)
Assistants	17	31+2	45+1	48+3	60+4
Liberi Docenti		12	23	25	20
Total	38	71	96	126	126
Technicians	23	23	30	35	36
Researchers per Technician	1.7	3.1	3.2	3.6	3.5

a. This Table includes physicists from private universities. Numbers in parentheses indicate mathematical physicists; the second term of the sum in the entries for assistants designates voluntary (unpaid) assistants. A "libero docente" had to pass an examination based on his scientific work and to give a satisfactory lecture before being eligible to give a course, for which he was not paid. Usually he had a job outside the university: it is therefore difficult to establish how much of his time went to research. Sources: as in Tables 1 and 2.

professors by about 6% and that the number of physicists probably suffered a similar decrease, the biggest variation in the number of physicists occurred in the seven years between 1920 and 1927.[3] The number of technicians per physicist decreased from 1872 to 1927 and thereafter remained more or less constant.

It appears that a typical research group in 1872 was composed of a professor with chair, an assistant, and a technician; in 1915, the group had given by perhaps one more assistant in 1915. This composition did not change before 1940. We have not included the "professori incaricati" and the "liberi docenti" because the number of the incaricati involved many contingencies and the latter cannot be considered as members of the research group.

In the five year period from 1905/6 to 1909/10 the average number of physics students per year was about 100, for graduates about 15.[4] Since 14 universities could confer a physics degree there was an average of 7 students and 1 graduate per university. The situation had not changed by the outbreak of the first world war: the physics students then numbered 107 and the graduates 18.[5] However, twelve years

3. *Annuario statistico italiano, 6* (1918), 99; *8* (1925), 155.
4. *Annuario statistico italiano, 1* (1912), 65–66.
5. *Annuario statistico itailano, 6* (1918), 98.

later, in 1926/7, we find 251 students and 44 graduates, or 18 students and 3 graduates per university.[6] We have not found systematic data for later years; but the fact that in the University of Rome the average number of graduates per year over the nine years from 1930/1 to 1939/40 (we have not found data for 1934/5) was 3.7,[7] together with other scattered data, suggests that the number of graduates remained essentially unchanged from 1927 to the outbreak of the second world war.

3. FINANCIAL SUPPORT OF RESEARCH

It is not easy to calculate the amount of money spent on research. The Ministero della Pubblica Istruzione (MPI, National Ministry of Education), the Consiglio Nazionale delle Ricerche (CNR, National Council of Research), and the universities did not report research expenditures. For example, the 1914/5 budget for the MPI uses the following categories: "Grants for purchase of scientific materials, for maintenance of clinics, for office and administrative expenses, maintenance and adaptation of rooms and furniture. Supplement to the grants and various expenses. Expenses and encouragement for experimental research."[8] Starting in 1924, this last item appeared separately as "Expense for the encouragement of scientific research and for contributing together with state or private institutions to strengthening scientific and teaching faculties, schools, and institutes."[9] The university budgets are clearer but usually no more detailed; in some of them, however, it is possible to discover grants to the individual institutes. This is the most precise information available from published documents. The annuals of the Istituto Centrale di Statistica that were intended to give an exhaustive account of all institutions and activities of the country did not even mention scientific research. This indifference reflects the fact that research was carried on mainly in universities, where it was a voluntary activity, poorly financed, and not subject to external assessment.

Data on research funding are reported in Tables 6 and 7, and also in figure 1. There we have plotted as a function of time the number of physicists, the total number of chaired professors, the grants to

6. Ref. 1.

7. Rome, University, *Annuario*, 1930/1–1939/40.

8. Atti Parlamentari, Legislatura XXIV, Sessione 1913–5, n. 450, Camera dei Deputati, *Rendiconto generale consuntivo della Amministrazione dello Stato per l'esercizio finanziaro 1914–15,* parte 1, vol. 2 (Rome, 1915), 906–939.

9. "Disposizioni sull'ordinamento della Istruzione Superiore," Regio Decreto, 30 Sep 1923, no. 2102, *Gazzetta ufficiale,* 11 Oct 1923, no. 1601.

state universities, and the total expense of MPI for universities. These last two quantities are given both in real terms and as the ratios of their value and the national income of the corresponding year. Furthermore, each quantity is divided by the value it had in 1872 in order to make the trends clear.

Table 6
Expenditures for State universities
(Thousands of lire)[a]

Academic Year	Grants to Univ.[b]	% of Nat. Income	Expen. for Univ.[c]	% of Nat. Income
1871/2	1,513	0.0154	6,328	0.0645
1899/00	2,206	0.0187	11,105	0.0939
1914/5	4,505	0.0222	25,642	0.1260
1926/7	39,798	0.0290	96,649	0.0704
1938/9	44,057	0.0303	131,378	0.0902
1939/40	42,488	0.0258	131,144	0.0797

a. For academic year 1871/2 we have used the national income of 1872; for the other years, in which the state budget began in July, we have used the average of the two relevant values. Sources: as in Table 1; Atti parlementari, Camera dei Senatori, *Discussioni*, Legislatura XX, Sessione III, 1899, 692–720; ref. 7; Ministero della Pubblica Istruzione, *Bolletino ufficiale*, parte 1; *Sommario di statistiche storiche italiane (1861–1955)* (Rome, 1958), 216.

b. The entries here appear in the budget of the Ministero della Pubblica Istruzione as "Materials" for the years 1871/2 and 1899/00 and under a different denomination in later years. As explained in the text, only about 50% of the grants went to the institutes.

c. Entries in this column include personnel expenses, the grants of the preceding column, and extraordinary expenses (mainly construction and maintenance of buildings, but also purchase of furniture and scientific instruments).

Between 1872 and 1915, the increase in the number of professors paralleled a similar increase of total MPI expenses, whereas the increase of the grants (normalized with respect to the national income) was lower, by a factor of about 25%. In real terms, the value of grants increased from 1872 to 1900 regularly in proportion to the number of professors holding chairs, while in 1915 it was higher by a factor of 1.5. In order to understand the later changes we must remember that, starting on October 1, 1924, the state universities were divided into two groups, A and B, and that B universities received grants but not funds for personnel.[10] Therefore, although the total expenses of the

10. Ibid.

Table 7
Financial support of research: A miscellany
(Thousands of lire)[a]

A) Annual budget of CNR from 1923/4 to 1926/7	175
Annual budget of CNR from 1927/8 to 1939/40	675
B) Funds for the building of CNR and the founding of laboratories (distributed over seven years, starting in 1932/3)	3500
C) Grant to a medium size university in the 1930s	706–823
D) Annual budget of the "Istituto Nazionale di Elettrotecnica" Galileo Ferraris	2000
E) Annual grant to a physics institute in the 1930s	22.5–30
F) Annual budget of the Fermi group ca. 1935	375

To estimate corresponding values in 1984 lire, multiply by 665. Sources: Various years of the *Annuarii* of various universities: Genoa, 1939/40, 428–450; Milan, 1931/2, 573, 1933/4, 481, 1939/40, 440–453; Turin, 1939/40, 163–180 (when two values are given, the upper is for Milan, the lower for Genoa); F. Rasetti, "Progressi recenti della fisica nucleare," SIPS, *Atti, 27* (1937), 97; *Annuario statistico italiano* (Rome, 1985), 545.

MPI for universities decreased abruptly, there was an increase in grants that in real terms reached a value 5.5 and 6.3 times that of 1872, in 1927 and 1939, respectively. The decrease of total expenditures of the MPI on universities was only partially compensated by the intervention of provinces, municipalities, and other institutions (figure 1). Nonetheless, this intervention was sufficient to maintain at least the total expenditure for universities in 1927 at the level of 1915.

Between 1872 and 1915, the fraction of national income devoted to universities doubled, from about 0.06% to 0.12%. The law of 1923, known under the name of the then minister of National Education, Giovanni Gentile (senior), which divided the state universities into two groups, resulted in a reduction of the fraction of national income spent by the state on universities in 1927 (also including provinces, municipalities, and other institutions) to values near those of 1872 (figure 1 and Table 6). Thereafter a slow recovery took place, but the index remained below that of 1900. As we have seen, the grants, considered in real terms, increased by a factor of 5.5 from 1872 to 1927, which signified an increase in the average value of the grants per researcher by a factor of 1.7. The situation did not change significantly

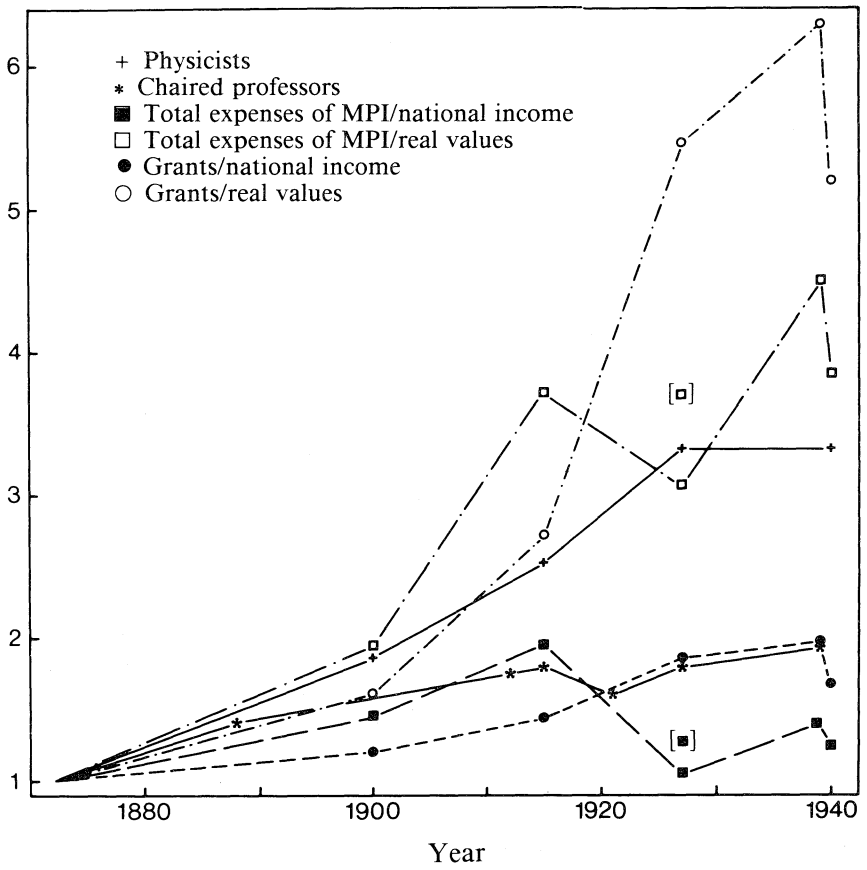

FIG. 1 Each entry is the ratio between the current value of the quantity and its value in 1872. The symbols in parentheses for the year 1927 take into account the contribution of municipalities, provinces, and other institutions. The number of chaired professors comes from the *Annuario statistico italiano.*

during the following years.

As we have stressed, it is not easy to determine how much of the money given to universities under the rubric of "grants" was used for research. The budgets of three universities (Genoa 1938/9, Milan 1938/9, and Turin 1939/40), indicate a range from 38% (Turin) to 52% (Genoa). In Table 8, we have reported among other data the grants of two physics institutes in the 1930s. For the science faculties in Milan (1938/9) and Genoa (1938/9), we also have the average grants per researcher ("professori incaricati" excluded): 4690 lire (Milan) and 4647 lire (Genoa). No such details are available for the earlier years. However, if we suppose that the criteria of distribution

Table 8
Classification of papers published in *NC*[a]

Class	Field	Content
I	Classical physics	Mechanics, optics, acoustics, thermodynamics, electromagnetism
II	Condensed matter	Properties of solids and liquids
III	Atoms and molecules	Properties of atoms and molecules
IV	Nuclear physics	Radioactivity, nuclei, cosmic rays, elementary particles
V	Relativity	Special and general relativity
VI	Quantum and statistical mechanics	Quantum and statistical mechanics, quantum electrodynamics
VII	Applied physics	Scientific instrumentation, "true" applied physics
VIII	Other	Papers not attributable to any of the preceding seven groups

a. Group VIII contains papers on astronomy, geophysics, various rays (including x-rays), rarefied gases, didactics, and history of physics. It also contains papers on spectroscopy not expressly intended for the study of atoms or molecules. We have only counted papers by Italian physicists or by foreign physicists working in Italy. We have not counted review papers written by invitation from the editorial staff.

of grants between humanities and science faculties and among the science institutes did not change drastically, we can infer from our data that the grant to the physics institute in Milan in 1934 (30,000 lire) corresponded to one of 3770 lire in 1915 and 1845 lire in 1900. This result will be used later when we compare our data with those reported by Forman, Heilbron, and Weart.[11] The amounts of money

11. P. Forman, J.L. Heilbron, S. Weart, "Physics circa 1900," *HSPS, 5,* (1975), 1–186.

given the institutes through the MPI grants represented a lower limit of their budgets. They could get other funds from their universities and from MPI; from public and private institutions; and, after its founding in 1923, from the CNR, which, however, did not have much to give. Relations between universities and industries were so loose that no consistent industrial financial support could materialize.

Table 9
Number of papers published in *NC*[a]

Period	Number of papers
1900–1904	262
1905–1909	255
1910–1914	278
1915–1919	161
1920–1924	148
1925–1929	189
1930–1934	195
1935–1939	155

a. For definition of the population of papers counted, see note to Table 8.

The main source of money for research remained the MPI. The CNR essentially played a consultative role. Its budget, rated from 1928 at 675,000 lire per year, was of the same order of magnitude as the grants to the institutes of a medium-size university.[12] Although the Italian government gave little money to the CNR, it paid considerable attention to it between 1923 and 1940, during which time its structure was changed four times. This contradiction was probably owing to several factors: a substantial lack of understanding of the importance of research for the development of the country; a distorted view of research and its condition; a constant underevaluation of the necessary financial effort; and, last but not least, the discrepancy, typical of fascism in many fields, between words and facts. All these factors may also be seen in the consequences for research of the autarkic policy launched in the late 1930s. In this case too, the limitation of funds, the tendency toward immediate applications, the urge to get results quickly in a context of underdevelopment of research, can be accounted for by the factors we have mentioned.[13]

12. All data reported in this paper on the CNR can be found in CNR, *Annuario* (1940). From 1923 to 1928 its annual budget was 175,000 lire.

13. An analysis of the impact on research of the autarkic policy can be found in references (2) and (15).

4. RESEARCH AND INDUSTRY

At the political unification of the country, the technical patrimony of Italian industry was poorer than that of most developed nations.[14] This gap, progressively widened in the absence of a serious policy concerning development of both research and technical innovations,[15] One of the few attempts at creating research centers outside the university provides a sound example of the difficulties and limitations of relationships among industry, research, and university. We are referring to the foundation of the Istituto Nazionale di Elettrotecnica "Galileo Ferraris" in Turin in the mid-1930s. Born as a project of a private firm in 1929 with an appropriation of about ten million lire, it risked collapse owing to the world-wide financial crisis. The decisive intervention of both the municipality and the central government allowed the project to go forward; and eventually the institute was inaugurated in 1935. The various circumstances that led to its birth can be clearly recognized in its final structure. The staff either held appointments from the university or was hired only for definite terms (this was a novelty for a research institute financed by the state).[16] The state contribution amounted to two million lire per year, three times larger than the budget of CNR. The institute was unique because of the joint efforts of state and private firms; the flexible system of hiring staff; and the high ratio of technicians to researchers. The "Galileo Ferraris" represented a possible new and productive departure from the normal Italian methods of conducting research. Unfortunately, the impact of the experiment was severely limited by the choice of research field, the marked tendency toward immediate applications, and the reduction of relations with industry to little more than quality control. The outbreak of the war did the rest.

In 1907 the Società Italiana per il Progresso delle Scienze (SIPS) was founded. Its first president was the eminent mathematical physicist Vito Volterra. The first article of its statutes states, "Its aim is to

14. Ref. 2.

15. A. Russo, "Science and industry in Italy between the two world wars," *HSPS, 16* (1986), 281–320; see also ref. 2.

16. G. Vallauri, "Attività dell'Istituto Elettrotecnico Nazionale, Galileo Ferraris, nel suo quinto anno di vita," *La ricerca scientifica, 9:1–2* (1940), 4–44. In 1939 the staff had 20 people with university degrees, 12 with high school degrees, and 33 technicians or mechanics. The ratio between technicians and researchers was much higher than that of a typical physics institute. See table 5.

promote the progress, the coordination, and the spread of the sciences and their applications and to establish relations between scholars."[17] From the start SIPS brought together scholars from science and the humanities. It held sessions on multidisciplinary topics and several professional meetings, including the annual congress of Italian physicists (like those of other scientific disciplines), took place within its congresses until the second world war. The hopes and the feelings of SIPS' founders were expressed in Volterra's speech opening the first meeting in Parma in 1907. He stressed the importance of science as a source of true knowledge and of beneficial technical applications. Science had become a structural element of modern societies. As Volterra eloquently put it: "The body of new scientific facts...has developed and strengthened a completely new, modern, and original feeling, which I would call a scientific feeling, which beneficiently dominates our era, as other no less universal forms of feeling have dominated past eras....It is he, [the scientist], the young hero, whose call makes our old association rise again."[18] Three other points of Volterra's speech are worth recalling: the necessity of a deeper diffusion in society of "scientific feeling," the crucial importance of collaboration between scholars from several disciplines, and the hope that SIPS would be able to refer problems put forward by industries and more generally by society to the laboratory or institute most suitable for solving them.

The annual meetings of SIPS heard many instructive reflections on the state of research in Italy and its relationships with the culture and economy of the country. Since no general history of SIPS or its meetings exists, we will confine ourselves to a critical review of the activities of the society made in 1928 by the then president Filippo Bottazzi.[19] Bottazzi began with the acknowledgment that SIPS was not able to promote science and that its only effective activity was spreading results of research into the wider society. Even this had been done against many difficulties because of scarce funding and the indifference of past governments. Bottazzi then criticized past governments and industry for allowing the general underdevelopment of science in Italy with respect to other countries; for giving priority to technical applications of science rather than to science itself; for not reducing the technological dependence of Italian industries on foreign

17. SIPS, *Atti, 1* (1907), xviii.

18. Ibid., 4. Volterra's last words refer to the fact that the founders of SIPS considered the new association to be a continuation of the twelve meetings Italian scientists held in the 19th century, beginning in 1839 in Pisa and ending in 1875 in Palermo.

19. F. Bottazi, "La Società Italiana per il Progresso delle Scienze e il mancato progresso della Scienza in Italia," SIPS, *Atti, 17* (1929), 7–27. Cf. refs. 2 and 15.

countries; and for not recognizing the need for a Ministry for Scientific Research or at least a "General Authority for Scientific Research." It is hard to disagree with Bottazzi's criticism. His corrective, however, left much to be desired. He did not mention anything that academics should do to change matters, but instead referred them to the fascist regime. This attitude then was very common: it reflected the tendency of academics to demand solutions for the problems of research without considering the role they might play, and to place their faith in the fascist regime.

5. COMPARISON WITH OTHER COUNTRIES

We begin our comparison with the data on Italy given by Forman, Heilbron, and Weart (henceforth FHW). They found 63 academic physicists in Italy in 1900. We find 69. Apart from differences in some data for instance, the number of our "liberi docenti" and of FHW's "privat-dozenten"), FHW used approximate procedures to avoid counting an individual twice and included mathematical physicists whom we omit. According to FHW, the average annual budget (equipment and maintenance) of an Italian physics institute was 5,700 DM in 1900. Our value of 2,400 DM (calculated as indicated above and using the conversion factor DM-lire used by FHW), is less than half of theirs. Furthermore, our reverse calculation gave 3,770 lire for the average annual grant to a physics institute in 1915. According to a 1917 report,[20] the annual grant then ranged between 1,000 and 12,000 lire with most of the institutes grouped around 3,300 lire. Our values may therefore be more reliable than theirs.

From FHW's data it appears that, in 1900, the number of physicists (faculty members plus assistants) was greater in the British Empire, France, Germany, and the United States than in Italy by factors of 2.1, 1.5, 2.3, and 2.0 respectively. In 1910 they became 2.7, 1.4, 2.7, and 3.0. The growth of the physics community was thus slower in Italy than in the other countries, apart from France. The comparison is even more unfavorable for Italy if we consider the average budget (equipment plus maintenance) per institute. In 1900, this was higher in France, Germany, and the United States than in Italy by factors of 2.7, 1.5, and 2.3 respectively. In 1910 these factors became 4.2, 3.0, and 10.8. The only aspect in which Italy came out on top is in its number of technicians. A significant comparison can be made

20. G. Colombo, "Relazione del Presidente Prof. Sen. Giuseppe Colombo sull'opera del Comitato Tecnico Scientifico nell'anno 1916–1917," SIPS, *Atti* (1917), 14. The data reported by Colombo refer to the physics and chemistry institutes grouped together. To get the value for physics we have divided by three following Colombo's indications.

only with Germany for which FHW reported detailed data. It turns out that in 1900 there was one technician for every 3.1 researchers in Italy and for every 5.6 researchers in Germany. This supremacy seems to have been conserved in later times: in 1915 there was one technician for every 3.2 researchers in Italy and, in 1910, one technician for every 7.1 researchers in Germany.

From these comparisons it appears that in 1910 the institutional status of physics in Italy was weaker than in several other countries, and that, more significantly, the rate of growth of human and material resources devoted to physics was much slower there than elsewhere. The data reported earlier suggest that this situation probably obtained also for the years following 1910.

6. RESEARCH

To give a general picture of the physics research carried out in Italy in the first forty years of our century, we have surveyed the papers published in *NC*. We have divided them into eight groups according to content, as indicated in Table 8, and into three categories by their nature (experimental, theoretical, survey).

Figures 2 and 3 summarize the results obtained by quinquennium. Figure 2 confirms that the activity of Italian physicists was mainly experimental: the experimental papers begin at 87% in the period 1900–1904 and never fall below 70% except between 1920 and 1924, when both theoretical and survey papers reach their maximum. It is worth noting that the publication of survey papers follows that of theoretical ones, which suggests a relationship between the two.

From figure 3 it appears that classical physics (group I) constituted the major part (about 33%) of the production for the first ten years. It then decreased, revived slightly between 1915–1919, and 1925–1929, and then fell rapidly to the lowest value of the entire period (about 8% in 1935–1939). This trend is just what one would expect in view of the advent of the "new" physics.

The papers of applied physics (group VII) are surprisingly numerous: they start around 22% and never fall below 12%. Most of them deal with scientific instrumentation but a significant number feature topics of applied physics properly so-called. We do not wish to overestimate the significance of this result. However, taking into account the fact that several papers included in group II (properties of condensed matter) are oriented to or motivated by possible applications, our numbers counsel caution in drawing conclusions about lack of interest in applied research. We believe that the relatively high fraction of papers on applied research indicates a positive disposition of Italian physicists toward cooperation with industry and that the

failure of such a collaboration to develop should be explained in terms of general economic, industrial, political, and cultural conditions.

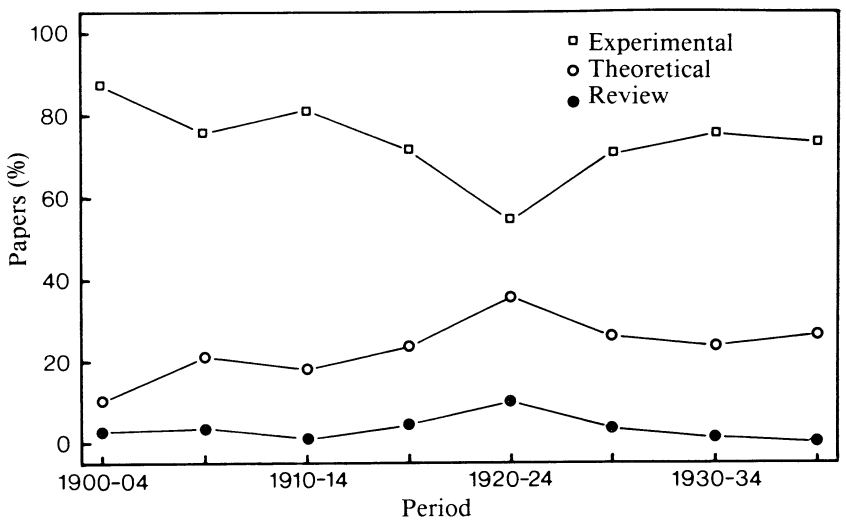

FIG. 2 Distribution of papers published in *NC*, 1900–1939, by subject. For the total number of papers, see Table 9.

Also, group II, like applied physics, shows a substantially steady trend. The papers consist mainly of reports of experiments on the properties of solids, especially electrical and magnetic properties.

Work on atoms and molecules (group III) developed slowly during the first three decades and increased significantly only in the period 1930–1934. This increase came mainly from papers on the Raman effect, which constituted about one third of the papers of this group during the period. The papers of group IV (nucleus and related topics) are quantitatively and qualitatively negligible until the late 1920s. They attained notable quantitative levels and international quality only in the last decade (1930–1939) through the work of Fermi's and Rossi's groups.

The fraction of relativity papers (group V) is significant between 1915 and 1924. However, as pointed out by Maiocchi,[21] a fundamental role in the diffusion of relativity in Italy was played by mathematical physicists and mathematicians. Without their contribution, the line of group V in figure 3 would have been much flatter.

21. R. Maiocchi, *Einstein in Italia. La scienza e la filosofia italiane di fronte alla teoria della relatività* (Milan, 1985).

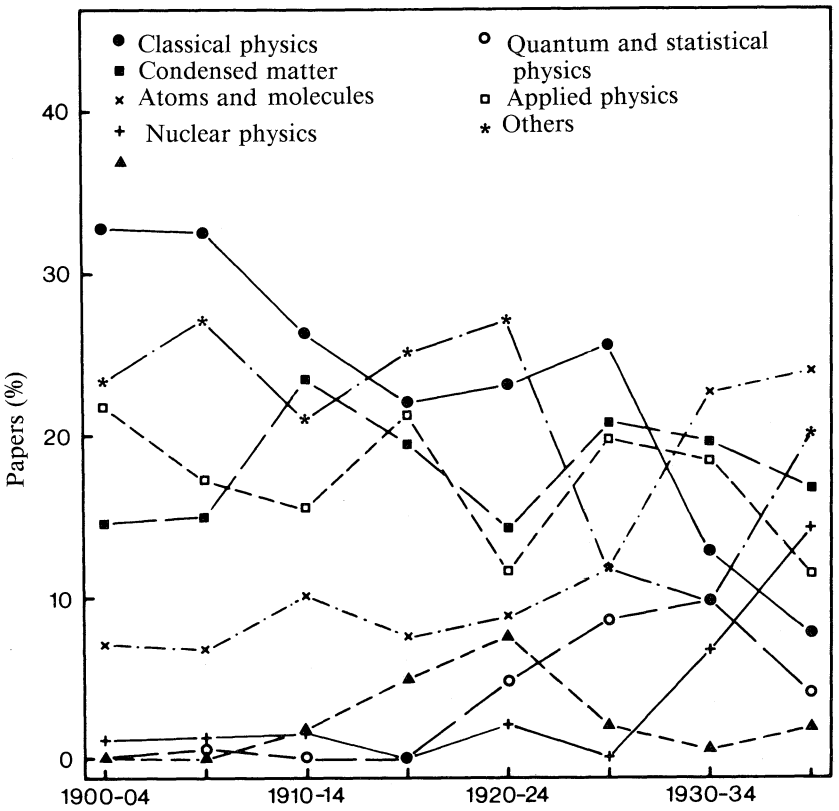

FIG. 3 Distribution of papers published in *NC*, 1900–1939, over the eight categories of Table 8.

In quantum and statistical mechanics, the physicists did not receive any help from their colleagues in mathematics. Therefore, the delay in tackling quantum and statistical mechanics reflected better than did the spread of relativity the obstacles Italian physicists had to face in dealing with the "new" physics. As the case of radioactivity shows, those obstacles could also effect experimental work. The interest Italian physicists took in the discoveries of radioactivity was frustrated by the difficulties of getting radioactive materials. As Orso Mario Corbino put it in 1911: "It cannot be ascribed only to our deficiencies if we have been cut off from this brilliant field of modern physics....Doubtless, to work on radioactivity one has to be gifted, but one also needs to get radium, and plenty of it."[22]

22. Corbino, in SIPS, *Atti, 5* (1912), 304.

As indicated in the notes to Table 8, we have neglected review papers written upon invitation by the editors of *NC* and aimed at "reporting on the main features of the most recent and fundamental progress of the various parts of physics."[23] From 1909 to 1913 (after that year the publication of papers of this kind ceased until 1926), 30 review articles were published: of these only one was on relativity theory (by Corbino in 1910 on the "mass of energy") and five on the quantum theory of black-body radiation or related topics. Few of the other 24 papers dealt with "fundamental progress of the various parts of physics." The fact that Italian physicists wrote more reviews of the new quantum approach than of relativity may be owing, among other things, to the feelings that the former might have a greater impact on their work than the latter. The first original paper on black body radiation in *NC* was published in 1910 and began: "Among the various forms attributed to the function that expresses the emissivity of black bodies, the one that seems to reproduce the experimental results best is that given by Wien."[24] The first contribution to quantum physics was Fermi's of 1923.[25] Statistical mechanics fared no better: after a paper of 1906, we must wait until 1920 for another.

The delay with which new physics spread in Italy had an obvious consequence for the formation of new physicists. To give an example: in the 1930s, 20th century physics was taught in three courses: mathematical physics (given in general by a mathematician), advanced physics, and theoretical physics. This last course had been introduced into all but one of the fourteen universities that could confer the physics degree in 1936. The content of the three courses on modern physics depended strongly on the teacher. The old quantum theory figured in at least one of the courses; the special relativity theory was not so widespread; more than the elements of quantum mechanics were taught in only four or five universities in 1937.

The overall picture that emerges from our study has the following main features. In the period under consideration (1900–1940), the Italian physics community was a small group facing formidable challenges with inadequate cultural and material means. The smallness of the group limited the possibility of a collective and prompt assimilation of developments within the discipline. Its slow rate of increase made this task even more difficult. The more general cultural, economic, social, and political context was not conducive to the growth of scientific disciplines. The distribution of academic power

23. *NC, 17* (1909), 241.

24. V. Polara, "Sul potere emissivo dei corpi neri," *NC, 19* (1910), 329.

25. E. Fermi, "Il principio delle adiabatiche ed i sistemi che non ammettono coordinate angolari," *NC, 25* (1923), 171–176.

and of students between the various faculties, the modest funds devoted to research, the technological underdevelopment of industry were causes and effects of a feedback process typical of a country in which the overall demand for science was not a high priority. We conclude that the necessary conditions were lacking for bringing Italian physical research up to competitive levels and for favoring the widespread rooting of new fields of research. It would be interesting to see how Fermi's group could be fitted into the general frame we have described.