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# The invisible businessman: Nuclear physics, patenting practices, and trading activities in the 1930s

> In 1935 a group of Italian scientists led by Enrico Fermi applied for a US patent on a process that looked, at the time, about as impractical as a bridge of butterflies' wings. While working together in Rome, they had discovered that neutrons…could be slowed down by passage through water or paraffin. Thus slowed, the neutrons were more likely to be captured by other elements, making them radioactive. *Time magazine*, 10 Aug 1953.

IN THE 1920s and 1930s, independent groups coming from different national identities collaborated in establishing the existence of nuclear particles, defining theoretical models of atomic structure, and analyzing in their laboratories effects of nuclear reactions.[1] Yet, if international cooperation shaped the emergence of nuclear physics in the U.S. and Europe, then no less significant was the international competition between individual research groups working in local contexts. The race to make a new discovery not only marked individual contributions but also defined new ways of exploiting research findings linking discoveries with the world of business and industry.

The reasons why international collaboration has been emphasized in the emergence of nuclear physics are well known. During the 1940s, the international

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The following abbreviations are used: ACS, Archivio Centrale dello Stato (National archive), Rome, Italy; BN, Brevetto Neutroni, carte 1934-35, box 1, file 2 in CNA; CNA, Collezione Nuovo Amaldi, Edoardo Amaldi Papers, Institute of Physics, University of Rome, Italy; EFP, Enrico Fermi Papers, Special Collection Research Center, University of Chicago; *LRS, La ricerca scientifica*; NBL, Niels Bohr Library, Center for the History of Physics, American Institute of Physics, Bethesda, MD; and *PRS,* Royal Society of London, *Proceedings*.

1. Victor Weisskopf can speak for them all: "In Copenhagen, Cambridge and all the countries I went through, people from abroad were highly appreciated…there was a typically international atmosphere which attracted people like myself very much." V.F. Weisskopf, "Physics and physicists the way I knew them," in Charles Wiener, ed., *History of twentieth*

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dimension of the wartime Manhattan Project and the convergence of scientists of many different nationalities within the same research endeavor helped to preserve, and perhaps to project back, with this climate of collaboration.[2] On the other hand recent historical work has revealed that international rivalry was also extremely significant in the early days of nuclear physics. Strong competition between national networks of physicists and industrialists promoting the adoption of different atomic models flourished in the thirties.[3] The existence of a widespread industrial interest in the application of discoveries in nuclear physics has also been recently understood in greater detail.[4] Thus we now know that the relationships among nuclear physicists, businessmen, and industrialists were a part of this international dimension of nuclear physics. Trading activities centered on nuclear research were also significant and they resulted in the promotion of several types of new industrial methods and instruments.

These revisions also add to historical studies focusing on industrial patents in physics and its allied sciences. Geoffrey Bowker showed the significance of patents and patenting as tools of socio-technological change within the context of scientific research in geophysics.[5] Peter Galison has indicated the importance of patenting in the "trading zones" of physics in connection with looking at Einstein's work as a patent officer in Bern before 1905. Galison finds that the material culture of relativity was shaped by the analysis of inventions such as new electro-magnetic clocks and instruments.[6]

This paper draws on these studies and revisions to appraise the historical trajectory of nuclear physics in Italy in the 1930s. Here, I consider the research activities

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*century physics. Proceedings of the international school of physics "Enrico Fermi," Varenna 1972* (New York, 1977), 437.

2. Cf. Charles Wiener, "A new site for the seminar. The refugees and American physics in the thirties," in Donald Fleming, ed., *The intellectual migration. Europe and America, 1930-1960* (London, 1969), 190-228, on 190.

3. Jeff Hughes, "Engineering the atom: Dogma, dissent and Dr. Tutin" (unpublished) shows the existence of competing atomic models in 1930s Britain and relates these to different industrial interests and practices; Brian Cathcart, in *The fly in the cathedral. How a small group of Cambridge scientists won the race to split the atom* (London, 2004), discusses the "race" between Cambridge scientists and their American rivals in "splitting the atom" by high-tension devices.

4. See J.L. Heilbron and Robert W. Seidel, *Lawrence and his laboratory. A history of the Lawrence Berkeley Laboratory*. Vol. I (Berkeley, 1989); Thomas Lassman, "Industrial research transformed: Edward Condon at the Westinghouse Electric and Manufacturing Company, 1935-1942," *Technology and culture*, *44*:*2* (2003), 306-339.

5. Geoffrey Bowker, "What's in a patent," in Wiebe E. Bijker and John Law, eds., *Shaping technology/building society. Studies in socio-technological change* (Cambridge, 1992), 53-74; H. Etzkowitz and A. Webster, "Science as intellectual property," in J. Peter, G. Markle, S. Jasanoff, and T. Pinch, eds., *Handbook of science, technology, and society* (Beverly Hills, 1994), 480-505.

6. Peter Galison, *Einstein's clocks, Poincaré maps* (London, 2003), and *Image and logic* (Chicago, 1997), 803-844.

of Enrico Fermi and his nuclear physics group in Rome chiefly from a consideration of patents and industrial applications. Historians have discussed in detail the significance of Fermi's research for nuclear physics, but not the significance of consequent business relations.[7] In the 1930s the discovery of a method to slow down neutrons coincided with Fermi's attempt to exploit the method industrially. The method seemed to have promise for the production of artificial radioactive elements useful in medical diagnosis and treatment. A market already existed for natural ones. Artificial isotopes promised to be cheaper and more varied. And the nuclear reactions involved suggested the possibility of useful power generation. After 1934 one of Fermi's priorities was ensuring the filing of patents to protect the intellectual property of his group in the industrial development of his method.

Fermi's "trading activities," his attempts to partner with industrialists and promote the adoption of the patented methods, were informed by a national agenda. His group worked in a totalitarian regime that sought to increase the number of patented inventions made in Italy, and made a place for this political goal within its research on nuclear reactions. Many within the Italian scientific community and the regime were concerned about the low number of patents filed in Italy or by Italians in foreign countries. The imbalance forced Italian industrialists to buy innovation abroad rather than exploit the national R&D system. Scientific leaders in Italy during the 1930s stressed the need to upgrade scientific research that could bring about technological change and innovation.[8]

Fermi's patron, Orso Maria Corbino, made the group aware of the importance of filing patents as well as publishing scientific papers. Fearing the possibility of interference in patent matters, the group became more reticent about communicating research findings after the discovery of the efficacy of slow neutrons. The industrial and patent agents who dealt with Fermi and his group pressured them against communicating research results to colleagues abroad without previous consultation.

By patenting the slow neutron process and promoting its sale to several American and European firms, Fermi and his group sought to profit from it. Jeff Hughes has highlighted that research communities working in nuclear physics during the 1930s could rely upon a network of "invisible industrialists" who provided tools for research in return for novelties that could be used industrially.[9] The case of Fermi

7. Some aspects relating to patenting and trading are discussed in Emilio Segrè, *Enrico Fermi. Physicist* (Chicago, 1970), 83-85; Edoardo Amaldi, "From the discovery of the neutron to the discovery of nuclear fission," *Physics reports*, *111* (1984), 5-331, on 154-160; Laura Fermi, *Atoms in the family. My life with Enrico Fermi* (Chicago, 1954).
8. Helge Kragh has observed "whether he liked it or not, Fermi was part of Italian politics and his research group in Rome, in reality, was protected by the fascist state." Helge Kragh, *Quantum generations. A history of physics in the twentieth century* (Princeton, 1999), 239. But I believe that it's more appropriate to understand the relationship between Fermi's group and the Facist regime in terms of convergence on a specific aspect of science policy.
9. Jeff Hughes, "Plasticine and valves: Industry, instrumentation and the emergence of nuclear physics," in J.P. Gaudillere and Ilona Lowy, eds., *The invisible industrialist: Manufacturers and the construction of scientific knowledge* (London, 1998), 58-101.

and his group not only confirms this argument, but also shows that the "invisible businessman" figured importantly in the emergence of nuclear physics in Italy. Previously unexamined archival documents show that to exploit the slow-neutron process Fermi worked with Gabriello Giannini, a young Italian émigré in America. Acting as consultant to the group, he sought to bolster his position as a businessman and his contacts with the representatives of industrial companies.

The commercial expectations of Fermi's group soon led it into competition with other foreign researchers who looked toward similar applications. Fermi and Giannini considered partnerships with some competitors in order to strengthen their position against others. These negotiations opened the possibility of forming new companies to which Fermi's and others' patents would be assigned. These attempts to join forces and shape alliances were not successful. By 1939 business seemed bleak and Giannini sought a quick sale of the European patents.

Even so, the interplay between Fermi, Giannini, and the companies involved in the slow neutron "business" deserves historical consideration. Not only does it reveal new motives for the development of nuclear physics in Italy in the prewar years, it also shows that at an international level, competition and trading activities informed the relationships established by the nuclear physicists among themselves and with the industrial world.

## 1. PATENTS, INNOVATION, AND SCIENCE POLICY IN FASCIST ITALY

At the beginning of the 20th century, Italy was a mix of different people and languages: a hodgepodge of cultures and technological systems without nationally structured railways or electrical networks. Shortly before World War I, Italian governments shaped a new progressivist faith in science and technology, considered as stimuli to the development of industrial manufacturing. In 1923, the establishment of an Italian national research council (Consiglio Nazionale delle Ricerche, CNR) responded to the urgency to develop a system of new national laboratories and schools of specialization to link academic and industrial research.[10] When the Fascist party rose to power in 1922, it was unable to outline a clear industrial, economic, and scientific policy.[11] The international economic crisis of 1929 focused its attention; scientific and technological innovation would be a tool to overcome the state of economic depression by the introduction of new methods of industrial production. A year after the crisis, the expenditure of the Italian government on

10. See Luigi Tomassini, "Le origini," and Raffaella Simili, "La Presidenza Marconi," in Raffaella Simili and Giovanni Paoloni, eds., *Per una storia del Consiglio Nazionale delle Ricerche*, 5-127.

11. Between 1922 and 1929 Italy enjoyed a moderate industrial expansion largely fuelled by lack of state intervention. The 1929 world economic crisis enhanced state intervention. In 1935 the beginning of economic autarky made the state a central actor in national economy. Gianni Toniolo, *L'economia dell'Italia Fascista* (Bari, 1980); William G. Welk, *Fascist economic policy* (Cambridge, 1938), 159.

scientific research grew markedly.[12] In the late 1920s the two major centers for investigations in radioactivity and cosmic rays were established at the Institute of Physics in Rome and Florence University.

In 1927, after a few years of political turmoil and lack of direction, the CNR operated as an organization directly controlled by the chief of government, Benito Mussolini. Guglielmo Marconi became its director. Fascist propaganda portrayed him as a symbol of "Italian genius." But many within the Italian scientific community understood that he personified a pragmatic and successful approach to scientific research, which consisted in securing profits by patenting novelties rather than committing to academic research and publishing.[13] Marconi had patented his apparatus to transmit and detect electromagnetic waves and formed a successful business, the Marconi Wireless Telegraph Company, to exploit it.[14]

Italians regarded Marconi's achievements as consequences of an enlightened patenting practice that provided a better protection of intellectual rights than one could obtain in Italy.[15] The problem was an important one for fascist economic policy. Since the late 19th century, Italian inventors had filed far fewer patents annually than those in other industrialized countries. The number of Italian patent applications grew significantly from 1883 to 1913, but fell sharply between 1913 and 1929.[16] The output of Italian patents continued below that of Britain, France, Germany, Switzerland, and Holland. Moreover, Italian companies relied on foreign patents (especially German ones) in industrial processes since Italians filed so few.[17] One of Marconi's main objectives was to direct the Italian scientific community towards patentable research of industrial significance. New legislation on patents was enacted. The CNR was responsible for outlining new standards of patent examination.[18]

12. Lucia Orlando, "Physics in the 1930s: Jewish physicists' contribution to the realization of the 'new tasks' of physics in Italy," *HSPS, 29:1* (1998), 141-181.
13. Segrè: "Marconi was interested in patent applications, not scientific papers, and for this reason he was rather secretive about his procedures, a habit that has presented additional difficulties for anyone trying to reconstruct his way of methodology." Emilio Segrè, "Preface," in Giancarlo Masini, *Marconi* (New York, 1995 [1975]), 10.
14. Anna Guagnini, "Patent agents, legal advisers and Guglielmo Marconi's breakthrough in wireless telegraphy," *History of technology*, *24* (2002), 171-201.
15. The Italian mechanical engineer Antonio Meucci invented the first telephone (the "teletrofono"); the patent was assigned to Alexander Graham Bell. See Basilio Catania, "The U.S. government versus Alexander Graham Bell: An important acknowledgement for Antonio Meucci," *Bulletin of science, technology and society, 22* (2002). 426-442.
16. Renato Giannetti, *Tecnologia e sviluppo economico italiano,1870-1990* (Bologna, 1998), 47-51.
17. During the late 19th century only 39 percent of Italian patents were filed by Italian inventors. *L'Italie économique en 1867* (Florence, 1867), 63.
18. Marconi wrote in 1932: "The fascist government has taken a notable step forward in the training and encouragement of promising inventors. The new legislation on intellectual ownership constitutes considerable progress in this direction, but above all it is with the standardization of examination for patents, now realized through the initiative of the CNR,

Between 1922 and 1929 industrial production in Italy grew by about 75%, a rate that equaled France (78%) and far surpassed the U.S. (40%), Britain (21.5%), and Germany (24.5%). Exports almost doubled (up by 73.63%), led by automobiles and chemicals. However, these industries relied heavily on the importation of raw materials, which also grew markedly. Consequently, the regime sought new ways to produce chemicals, fuels, and other substitutes for raw materials. Marconi was made chairman of a government committee, Scarce Raw Materials and Substitutes.[19] Securing these substitutes through Italian rather than foreign patents became state policy.

In the early 1930s, fascist science policy was embedded within the context of the corporate state of which the CNR, as promoter of Italian scientific and technological innovation, was an essential ingredient.[20] Marconi and Nicola Parravano, a university professor and chairman of the CNR's committee for chemistry, were now keen to sustain collaboration between individual research groups and Italian companies in some leading sectors such as chemistry and metallurgy.[21] The collaboration also fostered production of ersatz materials centered on new types of fuels such as alcohols, vegetable oils, and gases.[22] The situation for power generation and transmission was similar. Giuseppe Volpi di Misurata was chairman of the Società Adriatica di Elettricità (one of the largest Italian electrical firms) as well as the Minister of Finance between 1925 and 1929. He stressed that the transmission of electric power over long distances depended on "pioneers in the science of electricity and its practical application."[23]

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that the problem has been reduced to practical terms," *Il Popolo d'Italia,* 28 Oct 1932 (quoted in Masini, ref. 13, 327).

19. Anton Stefano Benni, "The industrial growth of fascist Italy," in Tommaso Silani, ed., *What is fascism and why?* (London, 1931), 281-289. Coal, coke, mineral oil, and derivatives could represent up to 20.6% of the total imports of Italy. Rolf Petri, "Technical change in the Italian chemical industry: Markets, firms and state intervention," in A.S. Trevis et al., eds., *Determinants in the evolution of the European chemical industry, 1900-1939* (Dordrecht, 1998), 280, 286.

20. "The state, the *corporazioni* national organizations bringing together companies, industrialists, technocrats and workers' representatives, and the economy as a whole, in the face of the inherent uncertainty of economic development, had to behave like an individual entrepreneur gambling on the long-term benefits of [technological innovation]." Petri (ref. 19), 285-286. See also Vera Zamagni, *The economic history of Italy* (Oxford, 1993), 242-317.

21. Renato Giannetti, "Il CNR e le politiche per la ricerca e l'innovazione industriale," in Simili and Paoloni (ref. 10), 224-239.

22. Luigi Casale's patents on a catalytic process to produce methanol underwrote a new plant in the city of Terni thanks to the Società Italiana Ricerche Industriali (SIRI), a leading agency specialized in chemical R&D. In 1928, Giulio Natta, a chemical engineer at Turin University, supervised the production of methanol in new plants built by Montecatini. In 1931, a new chemistry committee of the CNR stressed the priority of research on alcohols as fuels. Luigi Cerruti, "La chimica," in Simili and Paoloni (ref. 10), 406-447.

23. Giuseppe Volpi di Misurata, "Hydro-electric development in Italy," in Silani (ref. 19), 290-298.

Fermi's patron, Corbino, was a staunch supporter of the fascist new economic deal and one of Marconi's allies. A physicist interested in the commercial applications of electricity, he had filed a few patents on high-tension equipment, but since 1927 had effectively given up active research to pursue a career as scientific manager and politician.[24] Corbino was on the board of directors of many Italian companies including Italian General Electric and the Edison Company of Milan. He was active in the Italian Bureau of Standards and the national patent office, and, withall, was a Senator, Minister of Public Education, and Minister of Economics and Industry.[25]

Corbino had more than enough clout to establish a chair for Fermi. In 1926, following study at the Universities of Pisa (1918-1922) and Göttingen, he returned to Rome to take up his professorship.[26] Fermi soon established a group of keen students interested in theoretical as well as applied research. Helped by his former fellow student in Pisa, Franco Rasetti, Fermi attracted students from the faculty of engineering, who were fascinated by Fermi's lectures and appreciated the potential of physics for practical applications. These included sons of entrepreneurs such as Emilio Segrè (the son of a general manager in hydroelectric power and papermaking companies) and Bruno Pontecorvo (the son of a textile manufacturer).[27] The fathers of other group members such as Ettore Majorana, Edoardo Amaldi, and Giovanni Gentile were distinguished academics. Fermi's group reflected a social network uniting various strands of the new middle class, particularly industrial managers and university professors.

Corbino helped Fermi to gain positions of responsibility within industrial and research establishments. In 1927, Fermi was made chairman of the CNR physics committee.[28] In March 1929, a report of the political police indicated that Volpi di Misurata, the most influential businessman in Italy, had sponsored Fermi's appointment as a member of the newly established Accademia d'Italia and that Fermi was developing "a formula for a new type of fuel" for Volpi's company.[29] Fermi

24. O.M. Corbino, "Transformation of polyphase current into practically constant current," U.S. 1390504, issued 13 Oct 1921; and O.M. Corbino [with Giulio Cesare Trabacchi], "Improvements in or relating to apparatus for obtaining high-tension one direction current from three-phase currents," GB 129,092, issued 30 June 1919.

25. Franco Rasetti, interview with John Kennedy, 1966, Fermi documentary film collection, Harvard Project Physics, box 1, Background research materials and interviews, NBL; Eduardo Amaldi, "Personal notes on neutron work in Rome," in Wiener (ref. 2), 317.

26. Francesco Cordella, Alberto De Gregorio, and Fabio Sebastiani, *Enrico Fermi. Gli anni italiani*, (Rome, 2001), chapts. 3-5.

27. Pontecorvo joined the group only in 1933. Miriam Mafai, *Il lungo freddo. Storia di Bruno Pontecorvo, lo scienziato che scelse l'URSS* (Milan, 1992), 43; Emilio Segrè, *A mind always in motion* (Berkeley, 1993), 9.

28. Giovanni Battimeli and Michelangelo De Maria, "La fisica," in Simili and Paoloni (ref. 10), 285.

29. Sergio Romano, *Giuseppe Volpi. Industria e finanza tra Giolitti e Mussolini* (Rome, 1997), 214.

became a member of the board at the National Broadcasting Company (the Ente Italiano Audizioni Radiofoniche) as well as director of research laboratories at the electro-technical firm Magneti Marelli. With a strong research group, a solid academic position, several consultancies in large Italian firms, and Corbino's political backing, Fermi was well placed to develop nuclear physics.

In the mid-1930s, Italian reformers and science policy-makers had to acknowledge a significant setback in their program, as they could not maintain sufficient research funding to have an impact on the number of patents filed by Italian inventors. In 1935, Giulio Provenzal, editor of the CNR journal *La ricerca scientifica*, lamented the poor national output of patents. Only 33 percent of 10,000 patents filed in Italy were taken out by Italian inventors: multinationals accounted for the rest. Provenzal urged the filing of Italian patents abroad and in 1935 an Associazione Nazionale Fascista degli Inventori (National Fascist Association of Inventors) sponsored by the CNR committee on inventions, came into existence.[30] But in that year sanctions brought by the League of Nations after Italy's colonial adventure in Ethiopia shook the national economy by depriving it of an international market and essential imported resources.[31]

Marconi had repeatedly but vainly asked Mussolini for more funding for research to accomplish the autarchic plan. When Marconi suddenly died of a chest infection in 1937, fascist science policy was already failing.[32] In addition to economic limitations, the lack of intellectual freedom in Italy hampered scientific research. Well before the promulgation of the racial laws that in 1939 deprived Italian Jewish academics of their occupations, strict governmental control over political, cultural, and social life held back intellectual activities. Political conformity, rather than technical ability and intellectual capacity, became the dominant factor in the selection of new scientists and engineers.[33]

The trajectory of Fermi's group followed the rise and fall of fascist science policy. In its growth phase, the group became aware of possible industrial applications deriving from its research. They considered the significance of patenting their work and linking it to the world of finance and industry as the fascist regime desired. However, the lack of economic support from the regime combined with the increasing lack of intellectual freedom made it impossible for them to continue these activities and ultimately led to the group's collapse.

## 2. THE NEUTRON PATENT AND THE INVISIBLE BUSINESSMAN

When Fermi's group entered nuclear physics, its chief preoccupation was the cost of radium. In the early months of 1934, Rasetti salvaged depleted natural

30. Giulio Provenzal, "La prima mostra nazionale delle invenzioni," *LRS*, *6:2* (1935), 91-106.
31. Denis Mack Smith, *Mussolini* (London, 1993), 196-203.
32. Arturo Russo, "Science and industry in Italy between the two world wars," *HSPS*, *16:2* (1986), 281-320, on 293.
33. Welk (ref. 11), 246-247.

radioactive sources at Rome University's department of physics for re-use in experiments.[34] Research took off when Majorana suggested using neutrons as projectiles in nuclear reactions.[35] Together with Amaldi, Segrè, and the radio-chemist Oscar D'Agostino (who had just returned to Italy from Paris, where he gained research experience with the French physicist Frédéric Joliot-Curie), Fermi bombarded fourteen elements with a neutron source of beryllium and radon and obtained important new radio-activities.[36] They published the results in *LRS* and *Natur*e, thereby attracting the interest of other competing groups in Europe. Seeking publicity and recognition, Segrè and Amaldi brought Rutherford a comprehensive account of the group's experiments. At Rutherford's suggestion, the account was published by the Royal Society.[37] That summer, Amaldi and Pontecorvo observed that similar nuclear reactions seemed to have greater efficiency if the apparatus was placed on a wooden desk rather than on a marble one.[38] The following autumn, Fermi made some experiments with blocks of paraffin and came to understood that substances rich in hydrogen or other light elements could slow down neutrons and increase their efficiency in nuclear transformations.

This time Fermi was more circumspect about publishing research results that might have commercial value. He sent no communication to *Nature* or to Rutherford for the Royal Society. *Ricerca scientifica* published an incomplete account sent on October 22, 1934. Until then the group had been very eager to publish. Their new reluctance followed Corbino's directives. The old physicist and policy-maker insisted that the group file a patent application before publishing further.[39]

Four days after sending the letter to *LRS*, Fermi posted a patent application to the engineer Letterio Laboccetta.[40] The Italian privativa went to the Italian Ministry of Industry with the names of Fermi and six other inventors—Rasetti, Segrè, Pontecorvo, Amaldi, D'Agostino, and Giulio Cesare Trabacchi (the director of the

34. Rasetti obtained a strong source of radium D from radium salts abandoned 14 years earlier. Franco Rasetti, "Sopra un forte preparato di Radio D ottenuto nell'Istituto Fisico di Roma," *LRS*, *5* (1934), 3-5.
35. See B. Kröger, "On the history of the neutron," *Physis, 22* (1980), 175-190.
36. Fermi, "Radioactivity induced by neutron bombardment," *Nature, 133* (1934), 757.
37. Fermi, Amaldi, D'Agostino, Rasetti, and Segrè, "Artificial radioactivity produced by neutron bombardment," *PRS*, *146* (1934), 483-500; Segrè (ref. 7), 77.
38. Gerald Holton, "The miracle of the two tables. Enrico Fermi, a piece of parraffin and the way towards nuclear fission," *Times literary supplement* (11 Jan 2002), 12-13, on 12.
39. Laura Fermi (ref. 7), 101; Amaldi (ref. 7), 317; Mario George Salvadori, "The Italian navigator," unpub. msc., 1986, p. 33, NBL. Fermi's wife, Laura, claimed years later that: "One morning....Corbino came into the laboratory....They were preparing to write a more extensive report on their experiments..., Corbino became incensed. "What? Do you want to publish more than you have already?....Are you crazy? Can't you see that your discovery may have industrial applications? You should take a patent before you give out more details on how to make an artificial radioactive substances!"
40. Laboccetta to Fermi, 26 Oct 1934, BN. Labboccetta was an engineer expert in measurement standards.

medical institute that had provided the neutron source for the experiments).[41] Shortly afterwards, a letter patent in English was drafted for transmission to the British patent office. The draft claimed intellectual property with respect to instruments and processes for producing radioactive substances by placing a neutron source and a target with a moderating material such as paraffin, another hydrogenated substance, or any substance "of atomic weight less than 14."[42] The patent also claimed rights in any artificially produced radioisotope resulting from the slow neutron process.[43] By protecting the process (bombardment by low energy neutrons), the apparatus (neutron tubes deployed in a medium rich in hydrogen), and the products (the artificial radioisotopes), the Italian inventors made their claims extremely (indeed, excessively) wide.

Between October 1934 and June 1935, the group's publications relating to the slow-neutron process appeared only in the Italian science journals *LRS* and *Il nuovo cimento*, which in fact became the main sources of information about their experiments for foreign investigators. Only in February 1935 (six months after the patent was filed) did they send a complete account of the slow neutron process to Rutherford for the *PRS*.[44] Did the resistance to publish research results in journals with a wide, international audience reflect a deliberate attempt of Corbino or Fermi to protect the "invention"? We have no definitive evidence proving that there was a shift in the group's communication strategy. But the fact that this resistance to publish coincided with the beginning of international trading activities centered on the neutron patent makes the conjecture suggestive.

Gabriello M. Giannini, a former student of Fermi's who had set up as a businessman in New York, hosted Fermi in the summer of 1935 when Fermi participated in a summer school at the University of Michigan. Segrè, Amaldi, and Rasetti also spent time in New York as Giannini's guests. Giannini was the son of Torquato C.

41. The Italian Ministry of Industry's inventory of Italian patents shows that the taxes for the Italian *privativa* n. 324.458 filed by Labboccetta on Fermi's behalf were paid for the period 1934-1938. Carte del Ministero dell'Industria, ACS.
42. Amaldi, D'Agostino, Fermi, Pontecorvo, Rasetti, and Segrè, "Method for increasing the efficiency of nuclear reactions and products thereof," GB 465,045, Convention date (Italy), 26 Oct 1934; Application date, 25 Oct 1935; issued, 26 Apr 1937. The patent did not list radioisotopes produced or chemical reactions involved, although claim n. 7 claims on any radioisotope produced through the method.
43. The radioisotopes produced by neutron bombardment were "chemically different" from those used as sources. For example iron allows producing a radioisotope of manganese, while chlorine allows the synthesis of radioactive phosphorus. E. Fermi, "Trasmutazione degli elementi," *Sapere,* 31 Jan 1935.
44. Amaldi, D'Agostino, Fermi, Pontecorvo, Rasetti, Segrè, "Artificial radioactivity produced by neutron bombardment. II," *PRS*, *149* (1935), 522-558. It is significant that most of the researchers abroad interested in reproducing the phenomena during this period had to rely on Fermi, Amaldi, Pontecorvo, Rasetti, and Segrè, "Azione di sostanze idrogenate sulla radioattività provocata da neutroni," *LRS, 5* (1934), 282-283. This was the case for a group of physicists working at St. Bartholomew Hospital (A. Brasch et al., "Liberation of neutrons from beryllium by x-rays: Radioactivity induced by means of electron tubes,"

Giannini, vice-president of the society "Dante Alighieri," established in 1889 to spread Italian language and culture abroad. It had become a promoter of commercial relations between Italy and other states.[45] Giannini had studied in Rome with Fermi and then left Italy, starting a business career in New York. His office was located at 30 Rockefeller Plaza in the heart of the Manhattan financial district.

Giannini and Fermi identified medicine as the main field of application for natural radioisotopes, which had a role in diagnosis (as x-rays emitters) and therapy (leukemia and cancer).[46] They anticipated that artificial isotopes would replace natural ones for these purposes quickly.[47] They also foresaw applications of artificial radioactive isotopes as tracers in laboratory research in chemistry, biology, and metallurgy. So did others. In 1935 C.G. Tubbs, the London manager of the Nitrate Corporation of Chile (NCC), a large chemical manufacturer, inquired about Fermi's method from his agent in Rome, Dr. Luigi Raineri:[48]

> In view of the secondary elements in Chilean Nitrate [radioactive isotopes of nitrogen, silicon and phosphorus] it might be of interest if you would make enquiries into the findings of Signor Fermi….If these seem to have any bearing on the elements present in Chilean Nitrate we would be glad to have a report from you and also to receive two copies of any of the scientific papers which have been published on this subject of [artificial creation of radio-elements].

Further-fetched was the possibility of liberating atomic energy. In 1934 the Hungarian physicist Leo Szilard had stressed that the production of artificial "radium" for medical purposes was a sound commercial proposition and foresaw that, if the new experimental methods were successful in harnessing this energy, "The production of energy and its use for power production would be possible on such a large scale and probably with so little cost that a sort of industrial revolution could be expected."[49] At the same time Corbino pointed out that nuclear physics should

*Nature, 134* (1934), 494) and for James Chadwick and Maurice Goldhaber (Chadwick and Goldhaber, "Disintegration of slow neutrons," *Nature, 134* (1934), 495).

45. G. Prezzolini, "Il Brevetto delle scoperte atomiche italiane comprato dagli SU per trecentomila dollari," 1 Aug 1950, *Il Corriere della sera*,copy in "Giannini," Scatola 2, Fascicolo 2, CNA.

46. Fermi, Amaldi, Pontecorvo, Rasetti, and Segrè, "Process for the production of radioactive substances," U.S. patent n. 2,206,634, 2 Jul 1940, p. 1.

47. Fermi, "Recenti risultati della radioattività artificiale," *LRS*, *6* (1935), 399-402. Two years later, Segrè, in collaboration with physiologists at the University of Palermo, was able to test the efficiency of radioactive phosphorus as tracer for studying metabolic disturbances. Emilio Segrè to CNR, 18 Jul 1937, Fondo CNR, Versamento I, Busta 155, ACS.

48. C.G. Tubbs to Luigi Raineri, early 1935. I am most grateful to Peter Morris, curator at the London Science Museum for providing me with this information, which is now the State Archive of Chile.

49. Leo Szilard, "Memoradum of possible industrial applications arising on a new branch of physics," 28 June 1934, in Spencer R. Weart and Gertrud W. Szilard, eds., *Leo Szilard: His version of the facts. Selected recollections and correspondence* (Cambridge, 1978), 39.

be considered a "super-chemistry" in which "nuclear reactions can be compared to combustion in which the combustible is the neutron, the only entity that can reach the nucleus against the electrical repulsive forces."[50] Corbino calculated that the quantity of energy freed in the transformation process with just 50 grams of hydrogen could power Italy for one year.[51]

In the summer of 1935, Fermi's group had filed patent applications in Italy and Britain. The threat of sanctions by the League of Nations created concerns, however, as the properties of Italian citizens abroad might possibly be seized by the national authorities. Although the U.S. was not a member of the League, Giannini feared that the American government would follow the European states in penalizing Mussolini's country, its citizens, and their trading activities. He thus established a new American company that would receive the assignment of rights for Fermi's application. On October 3, 1935 G.M. Giannini & Company Incorporated filed application number 43,462, describing the process to slow down neutrons in the U.S. patent office.[52]

Giannini tried to persuade General Electric and Westinghouse to develop artificial radioactivity either by licensing or buying Fermi's process. According to Giannini, Westinghouse was willing to acquire the license for about $ 25,000.[53] In July 1935 Harvey Rentschler, the director of research at the Westinghouse Lamp Division of Bloomfield (New Jersey), recommended the acquisition of Fermi's patent and set aside funding to start research on the neutron process. Negotiations continued throughout the following year, but by the summer of 1936 Rentschler had decided that Fermi's method could be contested. He complained that Giannini's patent application was incomplete, while his agreement with the inventors would not protect Westinghouse in the case of litigation between them and the assignor.[54]

The breakthrough for Fermi's and Giannini's neutron business came when Segrè contacted Cornelius Bakker, whom he had known since his study trip to Amsterdam in 1931.[55] Bakker worked for the Dutch firm Philips Gloeilampenfabriken. The company immediately showed an interest in Fermi's method probably because it already had a well-developed research laboratory producing x-ray vacuum tubes such as the newly designed Metalix. These tubes were already employed in radiology and in the treatment of illnesses such as skin carcinoma.[56] The Philips

50. O.M. Corbino, "Prospettive e risultati della fisica moderna," *LRS*, *5* (1934), 615-620, on 618.
51. Ibid., 617.
52. Giannini to Fermi, 11 Nov 1935, BN.
53. Giannini to Fermi, 25 Nov 1935, BN.
54. Giannini to Fermi, 11 Oct 1935, BN; Lassman (ref. 4), 315-317.
55. Segrè (ref. 27), 66.
56. Philips to Segrè, 20 Sep 1935, and H. Hijmans, Chef des Services des brèvets d'invention des usines, Philips to Fermi, 20 Sep 1935, BN; Kees Boersma, "Tensions within an industrial research laboratory: The Philips laboratory's x-ray department between the wars," *Enterprise and society*, *4* (2003), 65-98, on 77.

managers perceived that a license on Fermi's process would entitle them to produce tubes using slowed neutrons.[57] In October 1935, Giannini agreed with E. Hijmans, the company's patent manager, that Philips would take over the administration of European patents. In exchange, Giannini and the inventors would receive five percent of the royalties until 1938.[58] On October 14, 1935 Hijmans visited Rome and was impressed by the simple and effective method designed by the group, as well as hopeful about its industrial application.[59] A few days earlier, Hijmans had approached the pharmaceutical company Sharpe & Dome.[60] The contract with Philips was the most significant success obtained by Fermi and his associates. It convinced them that further research developments in the field would allow them to profit from their patented method.

While finalizing these agreements, Fermi was again made aware of the importance of controlling the publication of findings. Philips provided guidelines requiring that research findings be communicated "promptly" to the company, and that "in no case should publications of any sort be made before a patent was filed."[61] The international competition on radioisotopes production had intensified.

## 3. FERMI'S COMPETITORS AND THE RESEARCH CORPORATION(S)

Fermi was not the only one who had forseeen the economic potential of nuclear physics. Other physicists in Europe and the U.S. had devoted time and energy to similar activities applying for patents on transmutation processes, instruments, and products. It was thus inevitable that the beginning of Fermi and Giannini's trading activities ensued fierce competition as well as attempted to shape new business alliances. On January 2, 1936 Giannini filed a second patent in the U.S. and Canada. It incorporated research Fermi had conducted since 1934 on sixty elements that when bombarded with slow neutrons, emitted $\beta$-rays after neutron absorption. The patent, "Composition of matter and method of producing the same" indicated the wide-ranging goals of Fermi's program, which now aimed to "make available a large group of new chemical substances, isotopes of the natural elements."[62] Among the elements considered in the patent was number "93," which had been the subject of

57. A neutron-generating tube, designed by Frans Michael Penning, was assigned to Philips. Frans M. Penning, "Electronic device," U.S. patent n. 2,211,668, filed 7 Jan 1938, issued 13 Aug 1940.
58. Giannini to Hijmans, 18 Nov 1935, BN. Hijmans was a patent expert employed by Philips in 1921 in connection with the transfer of Dutch rights to General Electric's patents relating to the manufacture of icandescent lamps and glass, and the establishment of a new patent department in Eindhoven. A. Heerding, *The history of N.V. Philips' Gloeilampenfabriken* (2 vols., Cambridge, 1986), *2*, 333.
59. Hijmans to Fermi, 16 Oct 1935, BN.
60. Hijmans to Fermi, 10 Oct 1935, BN.
61. Sannes to Fermi, Mar 1936, BN.
62. The patent was never issued in the U.S. Enrico Fermi, "Radio-active isotope production," is Canadian patent CA 407559, issued 22 Oct 1942.

media interest since Fermi had started research on β-emitting isotopes in 1934.[63] Slow neutron bombardment of uranium followed by β-decay had led to the creation of some "trans-uranic" elements.[64]

In the meantime the director of the Radiation Laboratory at Berkeley, Ernest Orlando Lawrence, labeled "ridiculous" Fermi's attempt to patent all neutron activations, and not only those strictly deriving from slow neutron bombardment.[65] Throughout the 1930s, Lawrence had tried to achieve the same goals as the Italians. From 1932 he had used a new high-tension machine, the cyclotron, to bombard various elements with deuterons and he had obtained many new radio activities.[66] He had focused on the production of radio-sodium (Na-24) from normal table salt and was hopeful that the radioisotope could soon replace natural radium in the treatment of cancer.[67] In 1935 Rasetti visited Berkeley to confirm the productivity of the cyclotron. He discovered that the machine could generate 10 billion neutrons per second, a quantity far surpassing what Fermi's group could obtain with neutron tubes. Lawrence's daily output of radiosodium emitted a quantity of γ-rays equivalent to 100 mg of radium.[68] In 1937, Lawrence considered the prospects of radio-phosphorus (P-32) and radio-iron (Fe-59), which could be used to treat leukemia. Treatments of this kind generated a market ranging between $200,000 and $500,000 each year in the U.S. alone.[69] Soon Fermi became aware that if he wanted his patents to be successful in the American and European markets, his method would have to offer more than Lawrence's.

Lawrence was not Fermi's only rival. Szilard had patented similar methods. By 1934, he had become obsessed with a "chain reaction" that he tried to patent.[70] The patented method consisted of three parts: generation of neutrons to provoke reactions; separation of radioisotopes produced by the neutron process; and utilization of the heat liberated in the transmutation for energy purposes.[71] Szilard's patent

63. "New heavy element created," *The times*, 4 June 1934, *Nature*, *134* (1934), 863. See also Fermi, Rasetti, D'Agostino, "Sulla possibilità di produrre elementi di numero atomico maggiore di 92," *LRS*, *5* (1934), 533.
64. In accordance with Fascist nationalistic rhetoric, element 93 was named "Esperio" and 94 "Ausonio the Esperii and Ausonii were two ancient Italian populations. The elemento were not transuranic. Battimelli, De Maria, and Paoloni, *L'istituto Nazionale di Fisica Nucleare. Storia di una comunità di ricerca* (Bari, 2001), 15.
65. E.O. Lawrence to H.A. Poillion, 24 Sep 1940, in Heilbron and Seidel (ref. 4), 204.
66. Heilbron and Seidel (ref. 4), chapt. 2; Cathcart (ref. 3), 193-196.
67. Ibid., 188.
68. Fermi doubted Lawrence's production in the range of the microcuries when he expected millicuries. To convince him, Lawrence sent a millicurie of radiosodium by post. Ibid., 187.
69. Heilbron and Seidel (ref. 4), 197.
70. William Lanouette, *Genius in the shadow. A biography of Leo Szilard, the man behind the bomb* (Chicago, 1992), 15; Leo Szilard, "Improvements in or relating to the transmutation of chemical elements," GB 630,726, filed 28 June 1934.
71. Heilbron and Seidel (ref. 4), 199-200.

lacked sufficient experimental details, and found no industrial takers. He obtained an interview with the research director of General Electric's branch in England, Clifford C. Paterson, who refused to take the matter further.[72] Using his network of acquaintances in Britain, including the Hungarian physical-chemist Michael Polanyi at Manchester University, Szilard tried to gather the support of the chemist and Zionist leader Chaim Weizmann, but this attempt also was unsuccessful.[73]

So by mid-1930 at least three discoverers: Fermi, Lawrence, and Szilard, together with their associates and business partners, were competing to open new international markets by exploiting radio activations. Fermi's method worked well but his natural sources of neutrons were weak. Szilard's method combined the two by using high-tension devices to activate a strong neutron source, but was "never reduced to art."[74]

These strengths and limitations influenced their patronage and industrial relations. Lawrence could rely on the Research Corporation, which was also the assignee of his cyclotron patent. The corporation was established in 1914 by chemist Frederick G. Cottrell with a plan to "serve the growing number of men in academic positions who evolve useful and patentable inventions." It reinvested the proceeds of its patents in grants to promising professors.[75] In the 1930s, the Corporation, directed by Howard A. Poillon, tried to achieve a monopoly on radioisotope production by controlling rights on the cyclotron patent and essential features of the Van de Graaff generator.[76] Poillon promoted Lawrence's method with Westinghouse and American Cynamid, which were by then considering manufacturing cyclotrons.[77] This no doubt helped cool Westinghouse's interest in Giannini's commercial propositions. If Poillon succeeded, no competitor would have rivaled the Corporation with respect to rights to use high-tension devices to produce strong sources of radioisotopes.

Fermi and Giannini believed that they could defeat Poillon but they needed more powerful sources of neutrons. They also considered that the availability of these sources depended on the possibility of using particle accelerators. This meant also that they had to shape a business alliance with someone (or some company) that owned rights to accelerating machines. The Research Corporation's control on Lawrence's and Van der Graaf's devices made it impossible for Giannini to find such a partner in the U.S. Thus, in March 1936, he decided to go to Britain in an attempt to build a collaborative industrial network.

72. Lanouette (ref. 70), 138.
73. Polany to Szilard, 11 Nov 1934, and 28 June 1935, and Weizmann to Polany, 5 Jul 1935, in Weart and Szilard (ref. 49), 41-43. According to Amaldi, "All of them [Szilard's patents] refer to ideas or results of theoretical considerations without experimental well-founded grounds." Amaldi (ref. 3), 159.
74. Heilbron and Seidel (ref. 4), 199; Amaldi (ref. 73).
75. Ibid., 102.
76. Lassman (ref. 4), 314 and Cathcart (ref. 3), 196-200.
77. Heilbron and Seidel (ref. 4), 197.

Giannini had a plan to obtain a license on the generator designed in 1932 by John Cockcroft and Ernest T. Walton at the Cavendish Laboratory. The machine's rights were owned by the British firm Metropolitan-Vickers. But when Giannini met the company's representative, Thomas E. Allibone, to negotiate rights relating to the Cockcroft-Walton device, his offer was rejected. Metropolitan-Vickers countered with an offer to buy an option on Fermi's patent for a three-year period for $2,000 a year. Since Giannini had already signed the contract with Phillips, he could not accept the offer.[78]

Informed by Segrè about Szilard's patents Giannini also decided to meet the Hungarian to purchase the rights to his process.[79] But Szilard had another plan. In a letter to Fermi he stressed that patents ought not be considered private property; "they should be controlled with a view of public policy." Szilard suggested setting up a research corporation based on profits deriving from selling patented methods to boost research. He proposed that he and Fermi share responsibility in the new research corporation, unite forces, and pool their patents.[80]

Moreover, when Giannini met Szilard and offered $2,500 for an exclusive license for his invention, he realized that Szilard had filed patents based on other scientists' discoveries.[81] That worried him. After the meeting, Giannini wrote Fermi that Szilard's proposals were unrealistic.[82] "[Szilard] only wanted to take parents in countries in which the patent procedure was entirely secret, thus preventing some Central European governments from knowing of his ideas and using them for militaristic purposes against other nations." In any case, since Philips already had filed the German version of Fermi's patent, an agreement with Szilard on a partnership basis was now unthinkable. The best Giannini could propose was "a sort of non-interference agreement with him [Szilard]."[83]

Giannini left England empty-handed. He had decided that the Italians had to go it alone in the artificial radioisotopes market. No patent pools could be put together; the only possibility for the Italians was to perfect existing neutron tubes. If they wanted, they could also try to "invent around" existing (and patented) high-tension devices in order to make better use of their invention. Szilard was a little more successful. In 1936, he assigned the European patent on the "chain reaction"

78. T.E. Allibone, "Metropolitan-Vickers Electrical Company and the Cavendish Laboratory," in John Hendry, ed., *Cambridge physics in the thirties* (Bristol, 1984), 150-173, on 171.
79. Giannini to Szilard, 8 Mar 1936, BN. Szilard had used a high-voltage impulse generator different from both the cyclotron and the Van der Graaff accessible to him at High Tension Laboratory of the A.E.G. in Germany. Arno Brasch et al., "Liberation of neutrons from Beryllium by x-rays: Radioactivity induced by means of electron tubes." *Nature, 134* (1934), 494.
80. Szilard, Clarendon Laboratory to Fermi, 13 Mar 1936, BN.
81. Amaldi claimed that patent n. U.S. 440023 included methods that "had been developed by other people," in Amaldi (ref. 3), 159; Cockcroft judged that in business matters Szilard was a "mildly dangerous character." Giannini to Fermi, 24 Mar 1936, BN.
82. Giannini to Fermi, 17 Mar 1936, BN.
83. Ibid.

to the British Admiralty. The corresponding American patent was assigned to Isbert Adam, a Havana importer and a relative of Brasch's, in return for $15,000 in research support.[84]

## 4. ECONOMIC FAILURE AND REFUGE

By the late 1930s, it had become painfully clear that the slow neutron process promised more than it could actually deliver. Moreover, fascist science policy had turned out to be financially unsustainable and Femi's group had started to dissolve. The beginning of 1936 saw only Fermi and Amaldi conducting research at the Institute in Rome. Segrè had gone to the University of Palermo, D'Agostino to the CNR, Pontecorvo to France.[85]

In 1937 the deaths of Corbino and Marconi deprived Fermi of political and financial support. At the beginning of that year Fermi produced a new proposal for the CNR general meeting making clear that high-tension devices could be thousands of times more efficient than the tubes he employed. Either the Fascist regime made available funding to build a high-tension device or no industrial application of commercial relevance would ensue.[86] In June 1938, Fermi's proposal was rejected and he received less than half the funds he had requested.[87] With the means available, research on the slow neutrons was at a dead end.

To add to the difficulties, the patents turned out to have a flimsy commercial value. By 1936, the crumbling of Fermi's group had made it difficult even to finalize the contract with Philips. The final contract included three amendments implying the possibility of the disintegration of the group.[88] The lack of immediate industrial applications complicated matters further.

Writing to Fermi in April 1939, Giannini stressed that the efficiency of the Philips neutron tube was "substantially higher than expected," but still of the order of magnitude indicated in the first experiments. Although Philips was trying to develop a "commercial version of this instrument," the cyclotron had improved

84. Heilbron and Seidel (ref. 4), 205.
85. Segrè (ref. 7), 87.
86. Fermi told Hijmans that Trabacchi's institute would build a high-tension device for radioisotope production. The institute would allow Fermi access to the machine if Philips did not ask for royalties. Fermi to Hymans, 9 Jan 1937, BN.
87. Ivana Gambaro, "Acceleratori di particelle e laboratori per le alte energie: Roma e Parigi negli anni Trenta," *Rivista di storia della scienza, 1* (1993), 105-154. Giovanni Battimelli and Ivana Gambaro, "Da via Panisperna a Frascati: Gli acceleratori mai realizzati," *Quaderni di storia della fisica, 1* (1997), 319-333.
88. Giannini wrote Hijmans that "some of them [the inventors] feel that the inventivity [sic] in the future is not likely to remain uniform, particularly if the group disintegrates between various laboratories and countries" and that selling their future findings to Philips "may preclose [sic] them the possibility of accepting, eventually, industrial research jobs, or professorships with US universities of a particular type." Giannini to Hijmans, 21 Feb 1936, BN.

more rapidly. Philips had been able to sell only three neutron tubes for a price "in the neighborhood of $1,000."[89] Although doubtful about future profits deriving from the invention, Philips was happy to continue a five percent licensing agreement for the coming years. Fermi responded that Giannini should try to sell the European rights in the range of $5,000.[90] Giannini sold them to Philips for $3,200.

News from the U.S. fuelled moderate optimism. In 1939, the prospects of Giannini and Company, Inc. had improved substantially. Giannini had established a partnership with the Philips representative in New York, the consultant engineer L.V. Graner, and had brought together executives of Philips and the General Electric X-Ray Corporation. GE was now considering a purchase of Fermi's patents.[91] At the same time, Fermi and his associates continued their struggle with the U.S. patent office. The examiners had objected to issuing the two patents on the ground that several publications had anticipated their claims. The examiners cited papers by Fermi's competitors and widely known works describing recent discoveries in nuclear physics.[92]

Apparently the novelty of Fermi's invention (the use of low energy neutrons) was difficult to grasp.[93] The examiners liked a paper by the American physicist Karl K. Darrow, who had reviewed recent advances in nuclear physics and mentioned the use of neutrons as projectiles.[94] The used it to reject the first patent for the second time, in December 1936. The examiners pointed out that using slow neutrons was no invention as "it is customary to use the material to be bombarded in a paste form, a petroleum jelly usually being used as the base for forming such a paste."[95] Amaldi wrote to Giannini that the objection was an "idiocy exceeding even the standards to be usually expected by that office."[96] He thought that even Darrow would agree, if asked, to provide the patent office with a written statement

89. Giannini to Segrè (copy to Fermi), 18 Apr 1939, "Segrè Emilio," box 11, folder 13, EFP.
90. Giannini to Fermi, 8 Apr 1939, BN.
91. Giannini to Segrè (ref 89), "Segrè (ref. 89).
92. The papers included Gilbert N. Lewis, M. Stanley Livingston, and E.O. Lawrence, "The emission of alpha-particles from various targets bombarded by deutons of high speed," *Physical review, 44* (1933), 55-56; E.O. Lawrence, M. Stanley Livingston, and G.N. Lewis, "The emission of protons from various targets bombarded by deutons of high speed," *Physical review, 44* (1933), 56; Frédéric Joliot-Curie and Irène Curie, "Artificial production of a new kind of radio-element," *Nature*, *133* (1934), 201-202.
93. One of Fermi's attorneys remarked: "It must be admitted that the production of heavy isotopes of hydrogen by reaction of a proton and a neutron was known. It was not known, however, that low energy neutrons should be used for this reaction. On the contrary it was specifically stated that the neutrons used had energies of several million volts." Newell to Fermi, Giannini, Rasetti and Hijmans, 13 Feb 1936, BN.
94. Karl K. Darrow, "Contemporary advances in physics, XXVII. The nucleus, second part," *Bell System technical journal*, *13* (1934), 102-157.
95. Newell to Giannini, 15 Dec 1936, BN.
96. Amaldi to Giannini, 15 Jan 1936, BN.

about the novelty of Fermi's invention. Giannini replied that the examiners were not "wholly familiar" with the subject.[97]

In 1939, the examiners finally rejected the first patent. Fermi's U.S. attorney, Truman Safford, petitioned the U.S. patent office Board of Appeals for a review. The petition succeeded, and on July 2, 1940, the slow neutron patent was issued. It differed significantly from the Italian and British ones in providing detailed experimental results on all 92 chemical elements. It claimed rights only on the process of generating slow neutrons probably to conform with U.S. patent legislation that distinguishes between controlling a process and a product. The second patent failed; the Board of Appeals rejected it on May 12, 1941.[98] The patent on β-emissive elements, however, succeeded with the Canadian patent office.[99]

That is not the end of the story. The nuclear pile, designed by Fermi in 1942 became the model for the chief instrument for the production of radio-elements and nuclear power after World War II. The principle of slowing neutrons was essential to the functioning of piles. This gave Fermi and his ex-associates a possible claim for license fees for the slow neutron process. Because of the secrecy of the Manhattan Project, however, Fermi had to sell all the patents relative to nuclear piles for one dollar each. He and Segrè continued to claim compensation for the use of the slow neutron patent. Despite an initial promise of a fee of $900,000, negotiations with military officers failed. In 1946 Fermi et al. put forward a new claim on the transfer of the assets of the Manhattan District to the U.S. Atomic Energy Commission (USAEC) . Eventually the parties settled, in 1953, for a third of the amount initially promised: $300,000.[100] Thanks to this agreement, companies associated with the USAEC had a free license to produce radioisotopes. As Westinghouse and General Electric were among these companies, they can be considered the only winners in this history, since they could now sell radioisotopes in a fast-developing market without paying fees to the inventors of the processes they used.

97. Giannini to Segrè, 18 Apr 1939, box 13, folder 4, EFP.

98. U.S. Patent Office, Board of Appeals, Appeal No. 32,841 (copy in box 19, folder 2, EFP).

99. Enrico Fermi, "Radio-active isotope production," CA patent n. 407559, issued on 22 Oct 1942.

100. Simone Turchetti, "For slow neutrons, slow pay" (forthcoming).

SIMONE TURCHETTI

**The invisible businessman: Nuclear physics, patenting practices, and trading activities in the 1930s**

ABSTRACT

In the 1930s the production of patents for the protection of intellectual rights became central to the research activities of Enrico Fermi and his group, consistently with a research policy emerging within the Italian Fascist Regime. Behind their work was an international network consisting of businessmen, industrialists, and multinationals who helped them patent their method for the production of artificial radioactive elements and to promote its industrial exploitation. The lack of research funding combined with a more aggressive foreign policy of the regime made it impossible for the group to continue these activities in Rome, and in 1938 the promulgation of racial laws forced them to migrate abroad.

KEY WORDS: nuclear physics, intellectual property, fascism, radioactive elements, international business, industrial processes, medical treatments