A century of scientific research and innovation in Romania

Steliana SANDU[1]

Abstract: *The purpose of this paper is to analyze the scientific research and innovation in Romania during 1918-2018, the conditions and stimulating factors, as well as the obstacles that characterized different historical periods in the development of Romanian science and technology. Emphasis was placed on the analysis of: legislation, organization and funding; patent; number and quality of workforce; evaluation of results, national and international harness of Romanian discoveries and inventions, as well as on their propagated effects over time. Although they were founded in certain historical periods, the major scientific research schools in Romania had been a valuable legacy over time. Many of the inventions of Romanian scholars had revolutionized the technical applications of their time, as well as the methods and processing of the natural resources in Romania and in many other countries. Through their results, both in the field of fundamental and applied research, they had influenced so far the development of science and technology in various fields. It was highlighted that, despite the difficulties of different historical periods, generation after generation of researchers had contributed, through valuable results, to enriching the scientific heritage of their predecessors.*

Keywords*: history of scientific research and innovation in Romania, management of S&T, evolution of patent activity, science and technology policies.*

JEL Classification*: N01, N74, O33, O34*

1. Introduction

The current scientific potential of Romania is due to the numerous contributions of the past generations of researchers, as well as to the research schools created and developed by them in Romania. Romanian scientists from various fields (mathematics, physics, chemistry, engineering, medicine, biology, geology, agronomy, economics, etc.) have raised the international prestige of Romanian research and innovation. At the

[1] SR I, Institute of National Economy, Bucharest, Romania, e-mail: sandu.steliana55@yahoo.com

turn of a century after the Great Union in 1918, we should present important achievements of Romanian science, and also the general economic and social framework in which these achievements took place, the factors that stimulated or slowed them, the meritorious results obtained by the Romanian authors in the field of discoveries and innovations.

he limited space of this work does not allow us to refer to all those who have made significant contributions in their research fields. I opted for the analysis of the technical sciences field, starting from the premise that the applicability of the results is more direct and their contribution to the development of the national economy, especially the industry, is more visible. The technical researches undertaken by the scholars of the interwar period covered both theoretical and practical applications, aiming in particular at the development of the technical creativity for Romania's economic growth. These researches led to the discovery of new natural riches and also to the increase of the efficiency of feedstock capitalization and the technical performance of built machines.

2. Literature Review

There are few works on the history of science in a whole century, 1918-2018. So, in the Romanian literature, this study is a pioneering work. The specialized literature includes aspects of subperiods, such as the interwar period (Iancu St, 2003), and the period 1948-1989 (Milea, 201 Draganescu).

The most numerous studies on this subject have been published since 1990, even within the Competitiveness and Technical Progress Department, established in 1990 within the Institute of National Economy. The researchers of this department approached very different issues included in the Annual Research Plans of the Romanian Academy. The results were capitalized through studies and articles published in international databases reviews and also, in the books published in Romania and abroad. Some of the main papers and most cited which are addressed within this department are reffering to: Innovation, Technological Competence and Economic Growth (2002); The obstacles encountered by small firms regarding the technology transfer process in Romania (2004); Impact of R&D investment on productivity (2008); The interaction of policy mixed instruments conducive the increase of R&D investment in Romania (2010); Main Issues of R&D Financing in Romania (2010); The optimal rate of R&D expenditures in GDP – between theory and practice (2010); Assessing the possibilities of filling the gap between Romania and the EU in the RDI field (2010); Challenges of increase in the economic and social relevance of Romanian Innovation (2010); Evaluation the Romanian National Capacity to absorb scientific results (2011); Improving collaboration between universities and industry, a major challenge for Romania (2012); Smart specialization concept and the status of its implementation in

Romania (2012); The visibility and performance of the Romanian Scientific research (2013); Impact of R&D and Innovation on high tech export (2014); Market of R&D results in Romania (2014); How soon could Romania close the R&D gap against EU-28? (2015); The impact of economic crisis on R&D convergence in Romania (2016); The resilience of the Romanian R&D system (2016).

3. Methodology

This study was based on a laborious historical documentation, through the study of monographs which included information about the Romanian scientists from different periods of the last hundred years. Based on the documents and databases, the analysis was performed for the following subperiods: 1918-1945; 1948-1989; 1990-1995; 2000-2005; 2007-2018. A special effort has been made to provide statistical, relevant and consistent data, to harmonize them and to build long-term statistical series. The replacement of the institutional structures within the Romanian scientific research system at different historical stages, as well as the methodologies for statistical evaluation of relevant indicators, has created great difficulties in carrying out long-term analysis. That's why we chose those series of data to ensure comparability over subperiods.

The great scholars and inventors of Romania, the most representative personalities in science and technology, have been grouped, as far as possible, according to: the historical stages in which they done research works and contributed with their scientific results to enrich the literature or to increase performance of different technologies. The chronology of information regarding the development of science and technology in Romania took into account the cyclicality and characteristics of the stages regarding the economic and social evolution of our country.

We sought to identify the factors that allowed the outstanding results of research in the development period of Great Romania, as well as the interwar period, the negative effects on the Romanian scientific research in the world crisis from 1929-1933, as well as the progresses during 1934-1940. The period of the Second World War, 1940-1944, also had bad consequences in the field of science. A series of information has been gathered from the 10 volumes of the Romanian Academy Reception Speeches. The data from the Communist regime, during 1946-1989 were gathered from the Romanian Statistical Yearbooks of every year. More statistical data, from Romania' transition to the market economy and its integration within North Atlantic structures and full membership of the European Union, have enabled us more robust statistical analysis, as well as international comparisons, taking into account EUROSTAT's longer term harmonized data at European level.

4. Results

4.1. Science and technology during 1918-1947

Despite the difficulties inherent in the interwar period, Romanian science had made major progress, both in terms of various fields specialization, and the development of experimental methods also, which have allowed the industrial application of research and innovation results. During this period, the number of scientific societies, such as Romanian scientific schools and scientific units related to universities or Romanian Academy, laboratories and specialized reviews in the main cities of the country (Bucharest, Iasi, Cluj, Timisoara, and Brasov), increased significantly.

In 1918, the research activity was carried out in four universities established before 1900, in Iasi (1860), Bucharest (1864), Cluj (1872), and Cernauti (1875). These universities, in addition to the Romanian Academy, have become the main core of scientific and technical creativity in the United Romania. Most of their professors were already trained in the scientific laboratories in Germany, France, Austria, England, etc. They combined the teachings with research activities and created teams and research schools, as well as associations or scientific societies, in order to support their work.

In the new historical and cultural context after the Great Union, it became imperative both to improve and also unify the organizational framework of scientific and technical creativity throughout Romania. The development of scientific schools has been differentiated, depending on the existing potential and the specificity of the research field. In some disciplines, the university chairs have become the second core of research. During the process of development of the scientific schools, a distinction was made in some of them, by specialization (Ştefan, 1981).

The Romanian Academy, which had more than 50 years of experience in the year of the Great Union, exercising its role as a catalyst of Romanian scientific life, established itself as the highest national science and culture forum during the interwar period. On June 1, 1920, the Romanian Academy approved the request of the Scientific Section to join the International Research Committee in Brussels. The National Research Council established on May 29, 1937, was the "advisory and consultative body of the state in all matters, having authoritative role in pure or applied science pure, following the example of similar institutions in the Western and Trans-European countries of Europe." The Romanian Academy held the most important scientific library in the country, and the Annals of the Romanian Academy (its main publication, whose memories appeared on sections), systematically published the research results of the Academy members and representatives of the scientific schools (Rusu DN, 1997).

The Royal Foundations ("Prince Carol" - 1921, "King Ferdinand I" - 1925, "Charles II Literature and Art Foundation" - 1933) had an important contribution to the development and spread of science. One of the collections of books, edited by the "Charles II Literature and Art Foundation" was the "Enciclopedic Library", which aimed to provide the general public with knowledge and information of high popularization of science. On the 10th anniversary of the inauguration of the "Higher Industrial School" in Cluj (1920), King Carol II set up in this city the Institute of Scientific Research "Charles II", an institute which targeted experiments and inventions with immediate applicability (Iancu St, 2003).

Scientists such as Emil Racovita, Elie Carafoli, Henri Coanda, and many others, who understood the necessity of developing national scientific activity, returned to Romania from the developed countries in which they attended university and / or doctoral studies, in order to lay the foundations for some new research schools. At the same time, they were also concerned about the passing of the acquired knowledge to the next generations. In his report of September 1925, Prof. Al. Savulescu, the provost of the University of Iasi, wrote that "... the success of a national culture lies in the earnestness and superiority of its scientific activity, compared to the cultures it competes with", while stressing the need to integrate the latest scientific knowledge into university studies.

The growth in the number of university graduates and doctors in science has contributed to the permanent enrichment of the human potential, capable of sustaining the scientific and technological activity of that period.

Table 1. Number of doctors, university graduates, diplomats and graduates of special schools

Years	1933/1934	1934/1935	1935/1936	1936/1937
Total	4829	3707	4673	5073
Romania	2710	2710	3765	4041

Source: Statistical Yearbook of Romania, 1939-1940, p. 294

The special achievements of the Romanian scholars in the interwar period are due to their passion for scientific research, manifested since the time of their university studies. The great Romanian scholar, Ştefan Procopiu, who made a special contribution to the development of magnetism, said in a lecture delivered in 1939 that "progress is achieved by those perseviring" (Tanăsescu, 2015).

Years after the achievement of the Great Union are also characterized by the acknowledgment of the importance of upgrading the economy on strong industrial basis,

where innovation and patents played a very important role. In this context, it was necessary to harmonize the legislative framework of the field, while Bukovina was governed by Austrian laws, Bessarabia of Russian laws, and Banat and Transylvania were subject to Hungarian laws.

Between 1920 and 1921, the first package of three legal drafts was drawn up: separately covering patents, trade marks and industrial designs, as well the organization of the Industrial Property Office. At the same time, the first regulations regarding the "mandators" and the "industrial property consultants" were established. These head officers had to be "persons with academic degrees, engineers or similar specialists and to be authorized by Royal Decree from the Ministry of Industry and Commerce, following the opinion of the Industrial Property Office" (Bădărău, 2005).

After the completion of the first phase in the post-World War II reconstruction, generally speaking, Romania was in line with the economic and internationalization trend, and made substantial advance in patent applications.

Table 2. The number of patents applications in the period 1923-1938, total and of those originating from Romania

Years	1923	1924	1925	1926	1927	1928	1929	1930
Total	928	1186	1271	1141	1283	1436	1546	1311
From Romania	264	340	457	390	421	436	485	325
Years	**1931**	**1932**	**1933**	**1934**	**1935**	**1936**	**1937**	**1938**
Total	1129	848	1005	1059	1050	1107	1312	1430
From Romania	357	296	351	461	423	406	443	526

Source: Statistical Yearbook of Romania from 1937-1938, p. 757

Table 2 shows an increase in both the total number of patents and those coming from Romania, with some oscillations in some years.

In terms of branch distribution, the prevalence of inventive patents is highlighted in the branches of: machinery, chemical industry, precision and electricity tools, mines and metallurgy. By countries of origin, we can see a prevalence of the claims and patents granted to the inventors from Romania, Germany, France, Austria, England, and America.

Since 1920, an important role in patenting activity was the accession of Romania into The Paris Convention on Industrial Property Rights, which provided the extension of the legislative scope in the field of industrial property, in order to uniformly regulate the

rights of inventors in all countries of the world, by gradual unification of all national laws, aiming to obtain a unique international patent.

In order to harness the inventions on an industrial scale, on January 20, 1931, a leaflet of an initiative Committee, consisting of three engineers, was published for the establishment of a joint stock company called INVENTA, whose stated purpose was "putting into production" of an invention that promised to revolutionize the industrial technique of engines and many technical devices.

Many of Romanian scientists' contributions have registered notable achievements recognized worldwide. In the first place, there were the discoveries in the fields of oil exploitation (Lazăr Edeleanu, Ion Şt. Bazgân, Petre Oteteleşanu), and chemistry (Petru Poni, Costin D. Nenițescu, Negoiță Dănăilă, Gheorghe Spacu). The Romanian scientists have contributed internationally to the fields of sonicity (Gogu Constantinescu), aviation industry (Henri Coanda, Traian Vuia, and Elie Carafoli), and astronomy (Hermann Oberth). Romanian scientists Spiru Haret, Stefan Odobleja, Danielopolu became precursors of cybernetics worldwide.

The research has been deepened, followed by practical actions in the fields of electricity (Dimitrie Leonida), electrical networks (Constantin Budeanu), construction (Nicolae Porfiri), and automobile industry (Aurel Persu). Electrification plans were developed (Belis, Emil Prager, Constantin C. Teodorescu), also the hydraulics (Dionisie Ghermani), the soil and agriculture (Ion Ionescu from Brad, Gheorghe Munteanu-Murgoci, Gheorghe Ionescu-Sisesti), medicine (Teodor Seidel, Ioan Cantacuzino, Gheorghe Marinescu, Constantin I. Angelescu, Constantin I. Parhon, Daniel Danieloplu), works in the Danube area of Iron Gates and internal rivers (see: Frangopol, 2002, Millea, 2017, Iancu Şt., 2003, Rusu, 2006).

The beginning of the Second World War marks an important moment, both in the field legislation and also in the way of registering patent applications. From September 1940 to August 1944, two Decrees - Laws on Patent Granting were signed. In 1942, the Industrial Property Service was subordinated to the General Directorate of Industry. In the same year, 99 invention patents, 11 improvement patents and 2 import patents were granted, and in 1944, 103 invention patents. The existence of a patent application form, prior to the start of the war, or during the war, ensured the right of the depositor to submit a new application form, no later than 12 months after the commencement of the Peace Treaty, and granted priority based on the previous application.

From August 1944 to December 1947, 14 royal decrees were signed and 334 invention patents, 11 improvement patents, and 2 import patents were granted, with a total of 1,088 patent applications (Iancu St, 2003).

4.2. Development of science and technology during 1948-1989

The nationalization of the main means of production in 1948 produced effects that came to support the changes envisaged by the new regime. In order to achieve important economic objectives, large research institutes such as: Institute of Studies and Power Engineering (1949), Institute of Electrotechnical Research and Design (1950), Institute for Studies and Hydropower Design, Institute of Energy Research and Modernization (1974) have been established (Millea, 2017).

After 1965, the scientific research, technological development and technical progress plans included large-scale themes focused on the priority areas, specific to each stage of "multilateral development" of the branches: electronics, petrochemistry, physics and nuclear energy, computer science, numerically controlled machines, pharmaceutical industry, etc.

Some of the Romanian scholars from the interwar period, as well as other younger researchers, left the country because of the communist regime's pressure. Those who continued their activity in Romania were joined by prestigious scholars and inventors, such as Gheorghe Cartianu Popescu, Ion I. Agârbiceanu, Justin Capra, Vitalie Belousov, Horia Hulubei, and Ştefan Procopiu.

With new patents, products and technologies, scientific creation in Romania was supposed to contribute to the major national investments. Based on purchased licenses and their subsequent changes, Romanian research and technology have contributed to the development of "medium-high-tech" branches. The Romanian researchers also participated and were awarded at international invention exhibitions in 1968, 1969, 1970 (Sonea, 2007).

During this period, the number of patent applications of Romanian applicants increased from 1,348 in 1965 to 2,570 in 1980 and 5,615 in 1988. The number of patents granted increased more than 11 times in 1989 compared to 1939.

“The Research and Development Program for the 1976-1980 Five-Year Plan and the Guidelines for the Period 1981-1990” as well as the "Scientific Research, Technological Development and Technological Development Programming Directive for the period 1981-1990, and the main directions until 2000“ focused scientific research in Romania towards its applicative aspects, forcing it to replace, in increased proportions, the import of new technologies, in order to save the foreign currency for paying off the external debts.

Achieving the objectives of these programs has been difficult, on the one hand, because the economic crisis became acute in the 1980s, and the restrictions on external debt, which has generated multiple problems for scientific research, in general, and for the transfer of results to industry, in particular. On the other hand, due to the isolation of the Romanian scientific community from that belonging to developed countries. The

Romanian researchers did not benefit from equipment, scientific literature, participation in international meetings, being limited to scientific research centered on the maintenance of large industrial complexes; the import of spare parts necessary for equipment purchased from developed countries was forbidden.

The institutional structure of scientific research of this period was pyramid type, centralized and politicized, under the direction and control of the National Scientific Research Council (CNCS). This coordination forum was established on January 19, 1945 and became the National Council for Science and Technology (NSCT) in 1973. The central research institutes, focused almost exclusively on applied research, as well as the numerous scientific research units created in the main provincial cities after 1969 were subordinated to its authority.

In the 1960s and early 1970s, Academy coordinated a number of 60 research institutes and centers from the most diverse areas in which research was predominantly fundamental. But, the research network of the Romanian Academy was abolished in the 1970s, in 1974 and 1975, by the transfer of all institutes and research centers to various ministries and central institutions.

The Academy of Agricultural and Forestry Sciences (subordinated to the Ministry of Agriculture and Food Industry) and the Academy of Medical Sciences (subordinated to the Ministry of Health) continued to coordinate their own network of institutes. Institutional structure of the scientific research, comprised also The Romanian Institute for Standardization, The State Office for Inventions and Trademarks and the National Institute for Information and Documentation.

The pyramid structure, based on large research institutes affiliated with industrial companies, distorted the role of industrial scientific research and diminished the fundamental research activity, especially through the abolition of the network of Romanian Academy institutes. The R & D plans of the major industrial research institutes have been correlated with the "accelerated development" objectives of the national economy, especially in the areas that were supposed to introduce new technologies, according to the objectives of the five-years plans.

Strategic development areas such as nuclear physics and energy, computer science, petrochemistry, etc. have benefited from substantial investments at that time, scientific research being involved in achieving its goals. The research and development infrastructure had gradually become obsolete due to the policy of restricting imports, including scientific literature acquisitions, and Romanian science has been almost completely isolated from the international scientific community. "The phrase: Research – Development - Production" has become more a slogan than a reality (Iancu A., 2005; Sandu, 1998).

Table 3. The network of scientific research, engineering and design units in Romania

Years	1985	1986	1987	1988	1989
Total, out of which	332	336	341	341	343
Scientific research units	62	62	63	63	63
Mixed units, scientific research, technological engineering and design	74	76	78	79	83
Agricultural stations	92	92	92	92	93

Source: Statistical Yearbook of Romania, 1991, p. 190.

The analysis of the share of total expenditure on R & D and the introduction of the technical process (CIS-DT-IPT) into the global product between 1976 and 1989, during the three cycles that made up this period, reveals an insufficient growth in terms of needs and tasks, from 1.09% between 1976 and 1980, to 1.12% for 1981-1985 and 1.19% for 1986-1989. The evolution of the number of staff employed in scientific activities describes an upward trend in the period 1950-1989 (Table 4)

Table 4. Evolution of staff employed in scientific activities

Years	1950	1960	1970	1980	1985	1989
Totally, thousands of people	19,1	37,8	46,2	77,3	134,8	141,2
Dynamics%	100	198	242	405	706	739

Source: Romanian Statistical Yearbook 1980 and 1990, pp. 112 and 245

In 1965, out of 4,305,300 employees, 59,147 were employed in R & D and related activities, accounting for 1.37% of all employees, organized in 261 research units (institutes / centers). In 1989, of the total of 8,023,800 employees, 270,421 were involved in research (of which 111,738 were undergraduates), representing 3,37% of the total, organized in 503 units (Sonea G., 2007).

The analysis of employees in the R&D sectors highlights (Table 5) that the fundamental and applied research institutes held only 34.42% of the total number of the research units, but the technological engineering and investment design, as well as micromanufacturing units, held 60.39%. Micromanufacturing has been at that time a source of the research funding. These activities were predominant in the total labor force engaged in research in 1989.

Table 5. The structure R&D personnel by sectors of activity in 1989

Activity sector	Total		Higher education	
Total R&D, out of which	270.421	Percentage %	111.738	Percentage %
Fundamental and Applied Research	93.084	34,42	31.636	23,83
Technological Engineering	58.225	21,53	39.426	35,28
Investment Design	74.210	27,44	24.648	22,05
Micromanufacturing	30.866	11,42	7.743	6,90
Other activities	14.036	5,19	7.283	6,51

Source: Romanian Statistical Yearbook, 1990.

According to some experts (Millea, 2017), the funds allocated to research in 1989 were 18.449 billion lei (the equivalent of 1.154 billion dollars – with rate exchange 1 $ = 16 lei), representing 2.92% of the Gross National Product.

National scientific and technical creation activity were usually completed with investment projects, invention patents and / or licenses, know-how, homologated prototypes and manufacturing files for new products and technologies, benefiting, in particular, the national industry, which was in the process of development.

The ideas embodied in invention patents had also contributed to economic development and enabled Romania to take part in international specialized exhibitions. In the years 1968, 1969, 1970, for example, of the 45 Romanian inventions presented at the international exhibitions in Brussels, Vienna, Nancy, London, Nurenberg, and Oberhausen, a total of 43 were awarded, of which 31 were awarded gold medals (1st place) and 12 were awarded silver medals (2nd place), (Marinete, 1971).

Table 6 shows that patent applications and patents granted to OSIM had an increasing trend during the years 1985-1989.

Table 6. Patent and patent applications granted (total and national) between 1985 and 1989

Years	1985	1986	1987	1988	1989
	Patent applications				
Total	4580	4680	5195	5880	6137
National	4201	4394	4821	5615	5875
	Patents granted				
Total	2452	2550	2688	2878	3086
National	1981	2215	2383	2589	2900

Source: Statistical Yearbook of Romania, 1991, p. 191

The development of the complex institutional system of scientific research and technological innovation in Romania from 1945-1990 was accompanied by extensive changes in the dimensions of human scientific and technical potential, and in its quality and distribution in sectors of economic and social activity.

During this period, pioneering activity in the field of radioelectronics took place, through the organization of research in the field of electronics, the elaboration of scientific papers in the field of electronic circuits, industrial electronics and nuclear electronics. Also, the "Automatic and Electronic" magazines were created, as well as the "Telecommunications" magazine. In 1960, enterprise Automatica was established, a complex research, design and assembly profile, from which the Institute of Automation Designs (IPA) was detached.

Based on research in this field, since 1957, the first electronic computer has been built in Romania. Professors of higher education, like Alexandru Rogojan, Adrian Petrescu, Marius Guran, Dan Tonceanu, had an important contribution. Through its own efforts, Romanian research and electronics industry has developed and introduced in 1978 a modern family of micro and minicomputers.

Academician Mihai Drăgănescu, the creator of the Romanian school of semiconductor devices and microelectronics, and also the leader of the national economic computerization program, contributed to the development of informatics in Romania by conceptualizing this field, publishing papers and elaborating a new theory on Computer Society in Romania, between 1980 -1985.

Mihai Drăgănescu has also contributed to the development of electronic field in our country. Furthermore, he has formed a large number of specialists and promoted them in his capacity as professor and head of the specialized department, through the courses taught at the Faculty of Electronics in the Politechnica University of Bucharest. His conception about the institutionalisation of the national information system was presented in the papers published after 1967. He created the theoretical framework and set the directions of action and management for the development of informatics in Romania.

In the last years of the period, scientific research has suffered both because of the reduction of funds for the acquisition of scientific equipment and literature, and also, above all, due to its isolation from the international scientific community. This limitation has been felt more acutely in the field of social sciences.

4.3. Changes in Romanian science and technology system after 1990

The transition period to the market economy represented a major transformation stage in the research, development and innovation system, or RDI, in order to became

compatible with the R&D systems in the developed countries and, to be in accordance with international trends in science and technology. Between 1990-1995, the RDI system faced the greatest challenges, accompanied by big difficulties (Sandu, Dachin, Toia, and Zaman, 1995).

The shift from a hyper-centralized, politicized and bureaucratic system to a decentralized one, based on the competitive allocation of public funds according to national priorities and also on stimulating the private sector to invest in RDI, was a complex, iterative process with inevitable errors (Iancu A, 2005; Agachi et al., 2006).

Compatibility of RDI statistics with those of Eurostat, avoidance of institutional dissolution, danger induced by Law 31 of 1990, transformation of industrial research institutes into commercial companies, creation of an institutional framework favorable to an innovative environment, and transfer of research results to the business environment, undergoing profound transformation, all these have been major concerns of decision makers between 1990-1995. The RDI reform had to find solutions for a whole series of major shortcomings of the centralized economy system (Eisemon et al., 1996).

The radical institutional changes in the period 1990-1995 have led to the creation of the premises for the decentralization and flexibility of the RDI system and the emergence of several actors with roles and skills which were, unfortunately, not enough clearly defined and operationalized.

The abolition of the CNST in 1990 by a governmental decision was followed by the creation of the Ministry of Education and Science, whose role and functionality supported the principles of decentralization, increased autonomy of R & D units, staff selection and promotion based on competence. In 1994, the Ministry of Research and Technology was created by reorganizing the Department of Science and the National University Research Council, subordinated to the Ministry of Education.

Under law no. 4 of 1990, the Romanian Academy was reorganized as the highest scientific forum in Romania, a promoter of fundamental and advanced research; its network of institutes was re-established. The Romanian Academy, along with the specialized commissions of the Parliament and, respectively, the representative bodies of the Romanian Government (Ministry of Research and Technology, and the Ministry of National Education), formed the central decisional level in the new configuration of the national RDI system. Other two consultative bodies were created in 1991 to serve this level, namely the Science and Technology Council, and the Consultative College for Research, Development and Innovation. The responsibility of these institutions was to elaborate the National Development Research Program and to pursue the achievement of its objectives.

Several stages can be identified in the transformations that took place in the Romanian R & D system after 1990, each with its specific features. In the 1990-1995 period, most changes occurred at the institutional, legislative level, staff dynamics and funding mechanisms (Zaman et al., 1995).

By Government Decision no. 1284 of 1990 and Law no. 31 of 1990, scientific research units acquired, according to their options, the status of commercial companies, autonomous administrations or units subordinated to autonomous administrations. These entities had to operate on a commercial basis, developing new profit-making activities, such as business assistance or consultancy services.

Under the decreasing demand for research results, slow pace privatization and lack of incentives for investments in modernization of production, the technological research institutes, that became trading companies, have been confronted with a brutal process of acquiring autonomy, being unprepared to adapt to the new conditions and requirements of the market economy, in general, and to the field of scientific research, in particular. Consequently, most of the R & D institutes have been threatened with liquidation (Sandu S., 1998). In 1995, the share of the private sector in the R&D was still modest, accounting for 14.9% of the number of units, 5.9% as the number of employees and 6.1% as contribution to the research funding. Private research units were small in size, with a small number of researchers and, the main activity of the most of them (53%) was designing for investment. Those with effective research activity represented only 10% of the number of units and 2.2% of the number of employees.

The failure of the RDI unit privatization policy is explained by a combination of factors, among which the most important are: the lack of a clear methodology for assessing the patrimony, the disagreement between the privatization offer (very high) and the relatively low demand; lack of managerial experience under the new conditions; failure to meet the commitments of strategic investors wishing to use the assets of research institutions for other purposes than research.

Paradoxically, the spectacular increase - by fragmentation and privatization - of the number of research institutes has been accompanied by a drastic decrease in the number of employees in all areas of R & D and innovation, with considerable economic and social effects. While the number of units increased from 382 in 1991, to 569 in 1995, mainly in the manufacturing and other branches, the number of employees decreased with 20%, from 132,635 to 105,038, the most affected being buildings, mining, public services and manufacturing areas, accounting for 45%, 40%, 37%, and 28% reductions in research staff. In 1995, the employees from public sector formed 92% of all R & D personnel, and those with higher education accounted for only 3.6%.

Table 7. The number of R & D units and the number of R & D employees in 1991-1995

Year	1991	1992	1993	1994	1995
Total number of units	382	423	571	545	569
Total number of employees	132635	123064	118372	117089	105038

Source: Statistical Yearbook of Romania, 1995, pages 312-313 and 1996 pages 304-350.

The establishment of new private institutes for research, development and innovation was at an early stage and extremely modest, due to the lack of risk capital and practical experience. The insufficient financing of research and development activities due to the reduction of investments has been a permanent feature since 1990, which led to a sharp decrease in the number of employees in R&D by 1995 (Russu C, Sandu S., 1999).

The acute shortage of funds has been accompanied by the emergence of hybrid forms of so-called "survival" funding, especially in the industrial research units. The institutes of the Romanian Academy got minimum funding in most cases, from budgetary funds, which represented a very small part of GDP, covering only salaries. Industrial research institutes, at the pressure of trade unions and research employers, have forced the government to set up the "1% Fund" (from the turnover of public and private firms) which effectively failed and has been disolved. That is why the institutes that have transformed into commercial companies have looked for forms of minimum funding insurance, often diverting research activity into other activities in order to get extra-budgetary funds.

Since 1992, in Romania, through a combination of top-down and bottom-up initiatives and strategies, a network of research transferring units to the business sector (business incubators, technology transfer centers, etc.) have been established under the umbrella of universities or research institutes. The stated goal was to stimulate the relationship between research and the economic environment. These new units aiming to encourage academic-industry relations were funded for three years from the public budget. Subsequently, when they were left without funding, some of them disappeared.

As a general feature of this period, RDI funding has been dominated by government funds, pointing to the low demand for industry contracts that went through deep recession and destruction (Sandu S., 2010). Most of the funds for research and development were carried out through the Ministry of Research and Technology.

Despite political rhetoric, the R & D role was neglected in the measures and policies implemented between 1990 and 1995. Consequently, its involvement in solving Romania's social and economic problems was marginal. Policymakers have adopted

very liberal measures, insufficiently substantiated, which has contributed to the disorganization of the activity, with unfavorable effects on the number and quality of research potential over a long period of time.

In terms of preparation for integration in European Union, the period 1995-2000 is characterized by transformations that are compatible with the similar institutions and the mechanisms of management and financing of R & D and innovation in the European Union. In particular, funding has been channeled through national priorities and access has been provided to competition-based funding through national programs and all categories of operational research units.

Following the model of some developed countries, in Romania, institutions were set up to formulate the priorities of scientific research at national level, in consultation with the ministries of economy (Inter-Ministerial Council for Research, Technology and Innovation, 1997), or state institutions for stimulating the transfer of the research results to economy (National Agency for Technology Transfer, within the Ministry of Research and Technology, 1996). The establishment of the Research and Development Advisory Board and its specialized commissions aimed at setting the thematic priorities for the 22 large areas covering the whole spectrum of research and the allocation of financial resources in a competitive system.

At the same time, there is a positive and promising trend towards the development of in-house industrial research and the development of departments within viable businesses, as well as the creation of new, small private and independent institutes. While in 1995 there were 473 industrial R&D units, of which 74 were private owned, in 1999 there were 626 industrial R&D units, of which 179 were mostly private owned. Mainly small businesses with interest in R&D activity have been involved in the consulting and service sector. Some of the managers of these firms have previously been researchers in public research and development institutes, in which they have maintained formal employment (Sandu, 2002).

Between 1995 and 2000, the share of RDI staff employed in public research units continued to decline, decreasing from 89.1% to 70.92% of total RDI employees. In contrast, R & D personnel from integral private or mix public-private companies increased (from 8.6% to 29.07%). While, in some areas of social science, the number of researchers has increased, in technological research, which can be directly capitalized in the economic development, the employment has declined sharply. According to the Statistical Yearbooks from 1996-2000, the number of researchers decreased by 32% overall.

The main reforming trend in funding research and innovation activity between 1995 and 2000 consisted in introducing the principle of competitiveness into the fund allocation

system, based on specific assesment and selection procedures. In this regard, in 1995, the National Program ORIZONT 2000 was launched, whereby the total R&D proposals were ex-ante and ex-post evaluated.

Thus, through the 22 specialized committees, in 1998, about 8,886 themes, operational programs, regional and interdisciplinary programs coming from the national institutes, institutes of the Romanian Academy, units of university education, non- governmental organizations, as well as in public and private commercial companies were selected by open competition and funded from public funds (Agachi S et al., 2006).

A first step in defining priorities, in line with the major economic and social development objectives, was recorded in 1997 when the national priority programs RELANSIN, CALIST, INFRAS and CORINT were launched. Subsequently, another 10 national programs funded under the competition system were added. Their purpose was to increase the impact of R & D activities on the economy and society in the perspective of the revival and sustainable development of Romania.

While a wider access to competition can be considered an important step in the transformation of the Romanian funding system, the large number of Romanian research institutes and potential beneficiaries of research funding, combined with the very low level of financial resources, and their allocation which ignored the real priorities, led to the erosion of budget allocations and, consequently, to the inefficiency of the use of funds.

After 2000, RDI policy occupied a distinct place within the economic and social development strategies of Romania, in order to fulfill the essential conditions for the integration of Romania in the European Union in 2007 (Zaman, Sandu, 2005). One of the consequences was the increase, between 2003 and 2008, in the share of total R & D expenditures in GDP.

Table 10. Share of total R & D expenditure in GDP in %

Years	2003	2004	2005	2006	2007	2008
Total	0,33	0,39	0,41	0,46	0,52	0,58
Enterprises	0,18	0,17	0,15	0,19	0,14	0,13
Public funds	0,18	0,19	0,22	0,29	0,31	0,30
Higher education	0,01	0,01	0,02	0,01	0,01	0,02
Funds from abroad	0,02	0,02	0,02	0,02	0,02	0,02

Source: Statistical Yearbook of Romania, 2009, p. 617.

The harmonization of the functioning mechanisms of the Romanian R & D system with those of the European Union through the Community Aquis was carried out under the

direct supervision and monitoring of the European institutions. Romania has been obliged to gradually adapt its RDI objectives and instruments, in line with the European convergence criteria and the requirements of Lisbon and Barcelona (Fuerea et al, 2004).

The diminishing of the gap between Romania and the European Union regarding the performance, efficiency, good functioning of the RDI system and its integration into the dynamics of the national economy development, remains a long-term challenge, open to policymakers and RDI actors (Sandu, Paun, 2009). Effective integration of Romanian research and innovation into the European Research and Innovation Area involves reducing performance gaps. The analysis and the forecasts carried out in different studies reveled that it is difficult to reduce these disparities in short or medium-term. (Vlad V., 2015, 2016).

The mechanism of selecting priority programs and research themes has been refined gradually, notably through the National Plan for Research, Development and Innovation 2000-2006 (PNCDI1), PNCDI2 (2007-2013) and the Excellence Research Program (CEEX) 2005 - 2008, which promoted high-quality research and created the premises for a better integration of Romanian research into the European Research Area.

The European Framework Programs for Research and Development (FP4, FP5, FP6, FP7) have been an important impetus for the Romanian scientific community. Even if the success rate of funding applications for Romanian researchers was much lower than even in other new member countries, our country benefited from greater mobility of researchers, co-participation in international research programs and co-authoring of research papers, published in scientific reviews which were indexed in international databases.

A remarkable progress has been made in university research which, at least from an institutional point of view, has been relatively low before 1989. Participation in European programs, the benefit of foreign funds, the increased number of papers published in international journals, the improved relation with researchers from other countries under European funded programs, have boosted university research and have also led to an increase in the number of staff involved in scientific research.

After 2000, strategies to strengthen the links between universities, research institutes and industry have become more consistent and were supported by programs and funds specifically dedicated to this purpose. The INFRATECH program, established in 2004, was the main tool that provided financial support for the development of specialized technology transfer facilities, including scientific parks (Sandu F, Anghel I, 2010).

The INFRATECH Program stimulated the establishment and development of a network of technology transfer units. According to the strategic objectives specific to the RDI field, at present, there are 33 units of infrastructure for innovation and technological transfer based on accreditation in Romania. These are entities without legal personality, located in universities (Bacău, Braşov, Cluj, Craiova, Galati, Ordea), national research and development institutes (17), Chambers of Commerce and Industry, or foundations. Almost half of these innovation and technology transfer entities are Technology Transfer Centers (14), followed by Technology Information Centers (12) and Business Incubators (7).

The ambitious goal set by the Romanian Government in 2000 for a gradual increase of the public budget for RDI to 1% of GDP by 2010 has not been achieved, although total RDI expenditures have had an upward trend until 2008 when recorded the maximum of 0.58%. The financial and economic crisis has lowered the budget allocation for RDI in 2009 to almost half of 2008 (Sandu S., 2010).

The objective of allocating 2% of GDP to RDI activities by 2020, as set out in the Europe 2020 Strategy, is, in turn, a very big challenge for Romania. Private sector participation, which has to reach 1% in 2020, was only 0.27% of GDP in 2016.

Table 11. Share of R & D expenditure in GDP, by financing sectors in %

Sector	2011	2012	2013	2014	2015	2016
Business	0,18	0,19	0,12	0,16	0,22	0,27
Government	0,20	0,20	0,19	0,16	0,19	0,16
Higher education	0,11	0,09	0,08	0,06	0,08	0,05
Total	0,49	0,48	0,39	0,38	0,49	0,48

Source: Romanian Statistical Yearbook 2017, p. 467

Because the average EU 28 is 2.03% R&D in GDP, Romania has to recover a significant gap in order to overcome the current stage and reach the 2% target proposed for 2020. The private sector's contribution to support total spending is lower than in developed countries, and even than the EU 28 average; the increase of private investment in RDI could be a solution for the future.

During 1998-2015 there was a reduction in the share of research and development (R&D) staff in the total employed population, from 0.59% in 1998 to a minimum of 0.39% in 2000, then it increased to 0,53% in 2015. If the decrease in the business sector was drastic, from 0.40% in 1998 to 0.14% in 2015, there is a significant increase in the higher education sector and a moderate growth in the public sector.

Most researchers are involved in engineering and technology (39.7% in 2011 and 49.1% in 2016). The lowest share is in agricultural sciences, although agricultural research has a long-standing experience and the development of agriculture must be based in the future on the results of scientific research.

As a result of the decrease in RDI funds and systemic deficiencies, over the period 2007-2016, Romania's innovative performance expressed by the Synthetic Innovation Scoreboard is lower than the European average, according to the European Innovation Scoreboard 2018.

Table 15. Synthetic Innovation Scoreboard 2010-2017

Years	2010	2011	2012	2013	2014	2015	2016	2017
România	0,224	0,223	0,191	0,190	0,153	0,145	0,154	0,157
Compared to the EU	46,9	46,7	40,1	39,9	32,2	30,4	32,4	32,9

Source: European Innovation Scoreboard 2018, p. 98.

One of the indicators of the innovation activity results is the number of patents which were required and granted throughout 2011-2016. The statistical data shows that in the period of 2011-2016 it decreased by 28%. Most patent applications come from individuals (50%), the rest come from businesses (17%) and higher education institutions (12%).

Reducing the number of patent applications filed to OSIM, may be explained by the possibility for Romanian researchers to register with international patent offices (WIPO or EPO). Throuhh their efforts to engage in extra-budgetary projects funded by national and European funds, Romanian researchers have succeeded in contributing to the improvement of research infrastructure. The placement of the largest nuclear reactor in Europe at the National Institute for Research and Development for Physics and Nuclear Engineering from Magurele is a favorable prerequisite for the closer collaboration of Romanian researchers with those from advanced countries in a high-level field of science, with multiple applicability in the economy and society.

Choosing the Magurele Institute for Atomic Physics (IFA) for the Extreme Light Infrastructure (ELI) project in Nuclear Physics is a proof of the prestige that this institute enjoys in the international scientific community. Due to its long-lasting experience in Nuclear Physics (the institute was founded in 1949 by Horia Hulubei), Romania was selected by the ELI Consortium to build the first pillar of Nuclear Physics in the Lasers field. The other two pillars of the project will be built in the Czech Republic and Hungary. Extreme Light Infrastructure (Nuclear Physics) ELI-NP will use both high-intensity lasers and intense gamma bands, two manifestations of extreme light. ELI-NP will be the most

advanced research infrastructure in the world that focuses on the study of photonuclear physics and its applications and a pioneer in the field of nuclear physics and engineering, as well as in fundamental physics and its various applications.

Also, over the last ten years, the international visibility of Romanian research - indeed, very low before 1989 - has improved considerably. After 2007, the number of articles published by Romanian authors in foreign professional journals, the papers presented in the national and international scientific events, as well as the Romanian scientific journals indexed in international databases has increased considerably. There are 56 Romanian scientific publications indexed in ISI Thomson, while 388 reviews are indexed in international databases.

During the 27 years of participation at the International Exhibition of Inventions in Geneva, under the aegis of the ministries that coordinated the RDI field and also supported through funding, overwhelmingly, the Romanian booth won hundreds of gold, silver and bronze medals, as well as many other special prizes offered by jury or the representatives of the participant countries. At this event, considered to be of great international prestige for the invention field, the inventions of researchers from various fields, either from universities, national research institutes, research companies or individual have been rewarded.

In 2017, at the Geneva Exhibition of Inventions, Romania won 34 gold medals, 8 silver medals and 28 special awards. In the last Geneva Exhibition of Inventions in April 2018, the Romanian inventors received 19 gold medals, 16 silver medals, 1 bronze medal, and 31 special awards. Gold medals have been awarded for inventions in the fields of nanotechnologies, optoelectronics, chemico-pharmaceutical, aerospace, physics applied in medicine, textiles - leather, construction, food industry, mining.

The awarded inventors come from 5 universities (University "Lucian Blaga" Sibiu, Politehnica University of Bucharest, Technical University of Civil Engineering of Bucharest, "Stefan cel Mare" University of Suceava, "King of Romania" University of Agricultural Sciences and Veterinary Medicine, Timisoara), national research and development units, three companies with research profile, and one individual.

The substantial increase in the requirements regarding the scientific and creativity level in the doctoral and post-doctoral schools of the Romanian Academy and other higher education institutions is a favorable prerequisite for the fundamental change of reality and public image, in scientific research in Romania. This desideratum can be achieved only through an appropriate political decision, aiming at, among other things, the allocation of public and private funds according to performance criteria, and also according to scientific and technological priorities, or social-economic priorities as well.

The responsibility of Romanian researchers must be doubled by the institutional and legislative initiatives, which will stimulate the substantial participation of the business environment in the financing of Romanian research, especially in the field of applied research. The target group of these policies remains the small and medium-sized enterprises (SMEs), as multinationals, which hold the majority of the capital of major economic agents, grant financial support to research activity conducted predominantly in laboratories of the origin countries.

5. Conclusion

In the history of one century, science and technology in Romania has gone through three completely different stages, each one with specific achievements and difficulties. During the interwar period, although science was being organized according to the unitary principles of entities in the three historical provinces, the Romanian research has made major progress in various fields, such as the establishment of new institutions, scientific societies, laboratories, experimental stations, and specialized publications. Through a laborious activity, the outstanding representatives of Romanian science managed to impose remarkable results and also to enrich the national and world scientific heritage.

The period 1945-1989 represents the involvements of scientific research in achieving the multilateral development objectives of the industry. As a result, a particular emphasis was placed on industrial applicative research. The theoretical, fundamental research took place till 1975, especially in the institutes of the Romanian Academy and after this year in the institutes belonging to other three academies in the fields of medicine, agriculture, social sciences. During this period, the number of institutes, personnel, and the volume of investments dedicated to scientific research, technical development and introducing of technical progress (CSS-DT-IPT), increased significantly, which was also reflected in the patenting activity of the research results.

After 1990, the CDI system had undergone the most difficult period in its history. Essential transformations in the legislative and institutional framework and also in the financial system and the capitalization of the research results have been imposed; this fact has been accompanied by very high difficulties. Against the backdrop of market economy reforms, scientific research faced major financial constraints, drastic cuts in staff and faulty privatizations, especially between 1990 -1995. However, the RDI system has demonstrated great adaptability and resilience to the new conditions (Sandu S., 2016).

Starting with 2000, Romania's preparation for EU membership in 2007 required other legislative and institutional changes, in line with the requirements of the Community

Aquis. Progress has been made in funding competitive research through appropriate institutions, participation in the European Commission's Framework Programs for Scientific Research, increasing the number of scientific journals indexed in international databases, including ISI-Thomson.

Even if there are still gaps between Romania and the EU developed countries, it must be taken into account that the science and technology systems of the developed countries have formed and developed in hundreds of years of market economy, while in Romania, an appropriate market-economy, with a big influence on the R&D system was experienced in the last 28 years. In the future, Romania must increase the amount of R&D financing, also the improved management of funds, and must rise the responsibility of all persons involved in research activity.

Bibliography

Agachi S., Curaj A., Dumitrache I., Popa G., Szabo L., Stanciulescu I. (ed.), 2006, "The national RDI system in the context of integration in the European Research Area" Of the Romanian Academy, Bucharest.

Dingers M., Sandu S., 2010, "Main Issues of R & D Financing in Romania", in the Romanian Economy Review, XX, vol. 30, no.1, p.127-145, CNCSIS B + journal, indexed in international databases, RePec IDEAS.

Drăgănescu M, 1980, "Second Industrial Revolution, Microelectronics, Automation, Informatics, Determinants", Editura Tehnica, Bucureşti, 1980, p. 144.

Eisemon T.O., Ionescu Siseşti I., Davis C.H., Gaillard J., 1996, "Reforming Romania's National Research System", Research Policy, Vol 25, No 1.

European Commission (EC), 2018, European Innovation Scoreboard 2018.

Frangopol P. T., 2002, "Mediocrity and Excellence, a Radiography of Science and Education in Romania", Albatros Publishing House, Bucharest, 2002.

Fuerea A., Sandu S., Scarlat C., Hurduzeu Gh., Paun C., Popescu R., 2004, "Evaluation of the Complimentation between Romanian Legislation and the Acquis Communitaire according to the negotiation chapter", Infoeuropa web page.

Iancu A., 2005, "Transformations in the Institutional System of Romanian Research and Problems of International Documentation and Visibility", in Oeconomica, No 2, p.1-49.

Iancu Şt., 2003, "Development of science and technology in the interwar period", in NOEMA Vol. II, no. 2.

Institute of Industrial Economics (IEI), 1986, "Aspects of scientific research activities, technological development and introduction of technical progress in Romania compared to other countries", Industrial Economics Studies, pag. 72-75.

Marinete L., 1971, Movement of Inventions and Innovations in the Five-Year Plan 1966-1970, Journal of Inventions and Trademarks, No. 4, p. 286.

Millea N., 2017, Three centuries-old Romanian scientific research -1938-2015, in NOEMA XVI, 2017 http://noema.crifst.ro/ARHIVA/2017_05_02.pdf.

Nastase G., 2004, Ion St Bazgan, a novel inventor for eternity, Ion Bazgan Publishing House, Performantica.

Otiman Păun Ion, 2013, 1948. The Great Drama of the Romanian Academy, Romanian Academy Publishing House, p. 23

Russu C., Sandu S., 1999, "Report on the Financing of R & D Activity in Romania", in Romanian Economic Research Observer, no. 6-7-8, pp. 29-61.

Rusu D. N, 2006, Members of the Romanian Academy 1866-2006, Romanian Academy Publishing House.

Rusu D. N., 1997, "History of Romanian Academy in Data", Romanian Academy Publishing House, Bucharest;

Sandu S., 1998, "Industrial R & D Reform in Romania", in Meske W, Etzkowitz H editors, Transforming Science and Technology System - the endless transition? NATO Science Series, vol 23, IOS Press, pp. 244-253.

Sandu S., 2016, "The Experience of the Transition to the Market Economy in the Field of Research and Development and Innovation in Romania", in the journal of Studies of History and Economic Thought, Romanian Academy Publishing House, Vol. 18, pp. 189-212.

Sandu S., Anghel I., 2010, "An asset-based approach of the Romanian Research-Development and Innovation Systems", in the Journal of Research and Social Intervention, vol. 29, pp. 57-71.

Sandu S., Dachin A., Toia A, Zaman Gh, 1995, "Romanian Case", Transformation mittel-und ost-europaischer Wissenschafts-systeme, Landerberichte, Leske + Budrich.

Sandu S., Păun C., 2009, "Assessing the Possible of filling the gap between Romania and the EU in the R & D field." In volume Iancu A. coord. Economic Convergence, The Publishing House of the Romanian Academy, Bucharest, 2009, p. 80-101.

Sonea G, 2007, "Domestic Science and Technology in Romania's Development 1938-1989", AGIR Ed.

Ştefan I.M., 1981, "The Process of the Formation of the Romanian Scientific and Technical Schools", in the History Magazine no. 6/1981.

Tănăsescu F., 2015, 125 years since the birth of the Romanian scholar ŞTEFAN PROCOPIU http://www.icpe.ro/files/0/Stefan_Procopiu.pdf.

Zaman Gh. Et al., 1995, "Dynamic Changes in the Romanian Research and Development System", in Mayntz R, Schimanch, Weingart, Transformation Mittel - und ost-europaischer Wissenschafts - Systeme. Ed. Leske + Budrich, Opladen, p. 977-1044.

Zaman Gh., Sandu S., 2005, "European Research Area: Challenge for Romanian R & D and Innovation System", volume "Science and Technology Policy, Lessons for CEE countries", Annamaria Inzelt, Gh. Zaman, Steliana Sandu, Expert Publishing House, Bucharest.