National Innovation System (II):
Industrialists and the Origins of an Idea

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Abstract

It is common today to view science and technology as a research or innovation system composed of institutional sectors in relation to each other: universities, industries, governments and non-profit. Where did this approach or framework come from? This paper develops the thesis that the emergence of industrial research was a key factor in the emergence of a system approach: universities were no longer alone in conducting research; there was a more complex "system" composed of universities, industries, governments and private foundations.

This paper analyzes the early industrial discourses held in the name of a system approach to research, or "scientific whole", following World War I. To industry, a system approach would put industrial research on the national research map, contributing to public recognition of the phenomenon. This would help make the case for universities contributing to industries' needs, and industries benefiting from the government's research efforts.

National Innovation System (II):
Industrialists and the Origins of an Idea [1]

It is common today to look at science and technology as a research or innovation system. This system is said to be composed of four main elements or sectors – universities, governments, industry and non-profit – and their interrelationships. The concepts of the Triple Helix and National Innovation System have become popular frameworks in the literature for discussing such a system approach.

Where did the frameworks come from? C. Freeman and B.-A. Lundvall, as prolific writers on National Innovation System, have suggested that F. List (*Das Nationale System des Politischen Okonomie*, 1841) was a pioneer of the approach. However, one would have difficulty documenting a tradition of theoretical research on the system approach arising out of List's work. It is one thing to resuscitate a forgotten author who held "similar" ideas over 150 years ago, and another to document the rise of a research tradition from that author. Positioning List as a spiritual forefather is rather like looking for a symbolic figure as a father figure after the fact. List is really an isolated case. The development of the National Innovation System concept owes to something else. [2]

In a recent paper, Godin has documented what the system approach in science studies owes to national policy and the discussions conducted on this matter in industrialized countries beginning in the early 1960s, above all at the OECD. Over the same period, the system approach found its way into official statistics, which helped solidify the concept (Godin, 2009a). However, we can go further back in time. And here national science policy is really at the heart of the matter again. The experience of World War I led to mobilization of the totality of scientific resources on a nationwide basis, what the American historian A. H. Dupree called the "great estates" of science in the country

[1] I want to thank Linda Joly who has search for obtaining copies of most of the documents used in this paper, as well as Jim Ferrier for linguistic revision.
[2] To be honest, Freeman uses List to build an argument on National Innovation System, while Lundvall and his colleagues argue for a linear descent.

(Dupree, 1957), and to the demand to link universities (science) with industry (applications).

In Great Britain, this started with efforts by the Board of Education (1915) to strengthen and redirect educational resources toward industry’s needs. The belief in shortages of research scientists, particularly scientists with expertise in both pure and applied science, and specifically industrial scientists, gave rise to the Department of Scientific and Industrial Research (Macleod and Andrews, 1970; Varcoe, 1979; Hull, 1999).

While the British Department became an active supporter of industrial cooperative organizations, the United States explicitly developed a different approach. In 1916, the US National Academy of Science offered to bring into cooperation government, education, industry and other organizations for the war effort. A National Research Council was to serve as vehicle to this end. It would rely primarily on private sources, among them the great foundations (Kevles, 1971).

From that time on, one observes regular speeches by the Council’s leaders and members of government, among them the US Secretary of Commerce H. Hoover, on what Dupree describes as "the beginning of a realization that the nation's scientific program was a single interrelated whole (...)" (Dupree, 1957: 340). The Council and its initiatives were "a pioneer effort to deal with the whole pattern of science as a single unit (…) [and] the beginning of a recognition that the estates of science - government, universities, foundations and industry - were closely interrelated" (Dupree, 1957: 343).

This paper focuses on analyzing the industrial discourses held in the name of a system approach or “scientific whole” following World War I. The emergence of large-scale industrial research was a key factor in the development of a system approach: universities were no longer alone in conducting research; there was a more complex system composed of universities, government, industry and what was called “benevolence” (private philanthropy).

Many universities had little interest in a system approach: according to scientists, all progress starts with basic research. University research constitutes the whole, and is the only research deserving of the name. In the first decades of the twentieth century, universities were still struggling for funds for basic research. The entry or recognition of a new research player on the scene would only make it harder to get funds from the government, which would have to distribute funding based on other criteria than science alone. However, to industry it was another matter. A system approach would put industry on the map, and contribute to public recognition of industrial research. It would also help make a case for universities contributing to industries' needs, and industries benefiting from the government's research efforts.

It is not my intention to offer a complete and definitive history of the era discussed here. This short paper is rather an addendum to Godin (2009a). First, this paper is limited to the United States. Second, I do not look at the actual experiences of system relations, like the contribution of research scientists to World War I, or the emergence of university-government-industry complexes in the interwar years. As witness that scientists, or at least university managers, were beginning to accept a system approach to research, (some) scientists and universities got involved increasingly in industrial research from World War I. This phenomenon reached its climax during World War II, when the US Office of Scientific Research and Development was set up with a provision to mobilize American science as a whole. Rather, I look in this paper at early representations and discourses of industrialists on a systemic view of research (as published in the journal *Science* and the *Bulletin of the US National Research Council*). Some scientists and their representatives may have held a system view of research at the time, but here I look at "men of action", namely industrialists. [3]

A Dichotomy

To scientists, the value of science has always been explainable in very simple terms. The spontaneous philosophy of scientists, from F. Bacon onward, is that there are two kinds

[3] On the rudiments of a system approach from an early sociologist of technology, see Godin (2009b).

of research – basic research and applied research – and that basic research gives rise to applied science and applications (Godin, 2003; Kline, 1995). Certainly there is a relationship between basic research and applied research, but it is a one-way relationship: from basic research to applied research. The first is the task of the university sector, while the second is that of industry. As J. D. Bernal put it, the idea of pure science is that "of the scientist's responsibility being limited to carrying out his own work, and leaving the results to an ideal economic system" (Bernal, 1939: 29).

The identity of university research as so conceived is well represented in an address delivered in 1909 by the retiring president of the US American Association for the Advancement of Science (AAAS). To R. I. Nichols, the United States was full of ingenious people. However, "although we in this country have had a hand in the development of the art of generating power nearly every important step in the use of steam originated in Europe, as did most of the devices pertaining to boilers and engines" (Nichols, 1909: 4). What was missing was scientists:

> A country that has many investigators will have many inventors also (...). Communities having the most thorough fundamental knowledge of pure science will show the greatest output of really practical inventions. Peoples who get their knowledge at second-hand must be content to follow (…). European practice is confidently based on theory, but in America men of affairs habitually use the word theoretical as synonymous with impractical, unworkable and not in accordance with fact (…). We have less than our share of men of science because we have not, as yet, universities that sufficiently foster and encourage research (…). A true university from the standpoint of productiveness is a body of scholars; that is to say, of men devoting themselves solely to the advancement of learning. Every one in it from top to bottom should be an investigator (…). We need not merely research in the universities but universities for research (…).

There is no need here to cite multiple references to this spontaneous philosophy of scientists. A discourse on gaps with Europe to justify university research and public funding, and basic research as source of progress, was held by many scientists at the time, like S. Newcomb (1874; 1902), H.A. Rowland (1902), R. A. Millikan (1919), J. M. Cattell (1922) and V. Bush (1945), and is well documented in the literature. However, what was the view of industrialists on the idea of a classification of research as either basic science or applied? Was there a strict division of labor between universities and industry?

As to scientists, industrialists believed in basic science as the source of industrial development. In 1924, speaking before the US Chamber of Commerce, J. J. Carty, Vice-president at ATT and a member of the US National Research Council, proclaimed: "The future of American business and commerce and industry is dependent upon the progress of science" (Carty, 1924: 1). To Carty, the pure scientists were "the advance guard of civilization. By their discoveries, they furnish to the engineer and the industrial chemist and other workers in applied science the raw material to be elaborated into manifold agencies for the amelioration of mankind, for the advancement of our business, the improvement of our industries, and the extension of our commerce" (Carty, 1924: 1-2).

To Carty, science was composed of two kinds: pure and applied. However, he explicitly refused to debate the contested terms "pure" and "applied": "the two researches are conducted in exactly the same manner" (Carty, 1924: 7). To Carty, the distinction was one of motives. Carty simply wanted to direct "attention to certain important relations between purely scientific research and industrial research which are not yet sufficiently understood" (Carty, 1924: 1).

In an article published in *Science* in 1916, Carty developed the first full-length rationale for public support for pure research. His rationale is not very far from that offered by W. von Humboldt, founder of the modern university, in his memorandum of 1809 (Humboldt, 1809). To Carty, "pure" science was "the seed of future great inventions which will increase the comfort and convenience and alleviate the sufferings of mankind". But because the "practical benefits, though certain, are usually indirect, intangible or remote" (Carty, 1916: 8), Carty thought the "natural home of pure science and of pure scientific research is to be found in the university" (Carty, 1916: 9), where each master scientist "should be provided with all of the resources and facilities and assistants that he can effectively employ, so that the range of his genius will in no way be restricted for the want of anything which money can provide. Every reasonable and even generous provision should be made for all workers in pure science" (Carty, 1916: 12).

But "where are the universities to obtain the money necessary for the carrying out of a grand scheme of scientific research?" Carty's answer was: "It should come from those generous and public-spirited men" [philanthropists and, much later, the State] and "from the industries" (Carty, 1916: 14-15).

Without doubt, to Carty, the universities should be supported by industry: "pure science cannot support itself, it must depend upon contributions of money from the public, from far-sighted patriotic citizens and men of affairs; from business and commerce and the industries" (Carty, 1929: 7). It is necessary to "encourage those engaged in the industries and in the practical arts and in commerce to make contributions to the support of scientific discovery in the universities and other institutions" (Carty, 1920: 13).

F. B. Jewett, from Bell Laboratories and also a member of the US National Research Council, held similar discourses on many aspects. To Jewett, science is the source of industrial progress: industrial applications have their origins in pure science, "like the connecting links of an intricate chain network" (Jewett, 1924: 3). "We must in consequence provide adequately for a continuous supply of well trained workers" (Jewett, 1918: 6).

Jewett emphasized a division of labor between universities and industry. He objects to the proposition of "having the colleges, universities and technical schools undertake industrial research" (Jewett, 1918: 12). "The agency for producing the trained investigator must be outside and distinct from the industrial research field (…). It must be in some way intimately associated with the field of so-called pure scientific research" (Jewett, 1918: 7). Jewett recommends that we "insure that pressure from the industries will never be so great as to withdraw those men who can render the greatest service by continuing as investigators in the field of pure research and the training of younger men" (Jewett, 1918: 14). Similarly, industrial research "must be intimately along the lines of the business", and be of a utilitarian character (Jewett, 1918: 7). However, Jewett suggests the "stimulation of scientific research in a more diverse fashion through the universities and higher educational institutions" with professorships and fellowships from the US National Research Council, and cooperation between industry and universities (Jewett, 1918: 8).

In summary, industrialists accept a division of labor between universities and industry, as do scientists, but at the same time urge greater relations, above all for the purpose of funding basic research as a source of industrial applications and to secure enough human resources for industry. Although limited to two sectors – universities and industry – there is here the seed and emergence of a "systemic" or relational view that was absent from the dominant scientific discourse of the time.

A Spectrum of Institutions

In the view of some other industrialists, the research system was more complex. A research system encompasses different kinds of research agencies, or institutions with complementary tasks: university, government, industry and philanthropy. In the addresses of industrialists, a national perspective is often adopted as *rationale*: such a diversity, or research system, is a source of national strength, or "greatness" and progress.

Such a view began to emerge shortly before World War I. In many of his discourses, A. D. Little, the chemist who gave his name to a well-known firm of consultants, compared the United States to Europe, as did many scientists. For example, in 1913, he discussed how "Germany has long been recognized as preeminently the country of organized research" (Little, 1913). However, in the United States, there is a "disdain of scientific teaching". Little then discussed recent advances in agriculture, the telephone, the automobile, chemistry, iron and oil, and how these discoveries depend upon what he called different kinds of **research agencies**: government, where the research "results are immediately made available to the whole people" (such as agriculture, roads, forestry, fisheries, geology, mining and standards); industry, representing at least 50 laboratories each with over $300,000 in research expenditures per year; and university. In the latter case, however, “our own institutions of learning have, speaking generally, failed to seize or realize the great opportunity confronting them. They have, almost universally, neglected to provide adequate equipment for industrial research and (…) have rarely acquired that close touch with industry essential for familiarity and appreciation of its immediate and pressing needs”, with a few exceptions like MIT (Little, 1913: 651). To Little, the issue was not better university funding in recognition of their central place in the research system, but the need for more relevant university research.

C E. K. Mees of Kodak, author of a classic book on the management of research (Mees, 1920), is also critical of universities. “It is generally assumed that research is the proper home of the university. However, very few universities devote a large portion of their energies to research work. In fact, history shows that “so far as research work has been associated with **institutions** [my emphasis], it has always been because those institutions required the results of research for the effective performance of their own essential duties”: first ecclesiastics using knowledge to support religious belief, then teachers using research results in their teaching (Mees, 1914: 618).

However, to Mees, with the growing specialization and complexity of science, there is an increasing distance between teaching and research. “Our energies should, therefore, be directed towards the development of [new forms of] institutions which will prosecute scientific research (…) because it is of use to them”: “It is to the industrial research laboratories that we must look in the future for progress in all branches of science” (Mees, 1914: 619). And the research required in industry “is not merely an improvement in processes or a cheapening in the costs of manufacture, but fundamental development (…). The work of the research laboratory must be directed primarily toward the fundamental theory of the subject” (Mees, 1920: 9) because “it is almost impossible to name any class of physical or chemical scientific work, from the physics of the atom to structural organic chemistry, which may not sooner or later have a direct application and importance for the industries” (Mees, 1920: 11).

As for universities, Mees objected to the use of university facilities to fulfill industrial needs. "The primary function of the university is education and training" (Mees, 1920: 15), among these training in research by professors themselves engaged in research. It is therefore "vital to the future of research that the universities should be strengthened and supported for their own work, and that any diversion of their energies should be resisted" (Mees, 1920: 21).

Apart from university and industry, there is a third kind of institution. According to Mees (1914), special provision must be made for "non-paying" branches of science, where benefits accrue to the welfare of the people as a whole: government and private philanthropy. Although private philanthropy has been welcomed as a source of funding for individual researchers for some time (Kohler, 1991), Mees, as with most US industrialists, is skeptical of government support for industrial research, like that of the UK Department of Scientific and Industrial Research: government support generally degenerates into a control mechanism.

A Classification and its Diffusion

From industrialists like Carty and Jewett to Little and Mees, we can see that a "system approach" was slowly taking form in industrialists' minds. Still more explicit statements are to be found among other authors, and classifications developed. To C. E. Skinner of Westinghouse (Research Division), research covers an extremely wide field of activities, from pure science to applied research. Both are "so closely interlinked that it is impossible to say where the one ends and the other begins" (Skinner, 1917: 871). Skinner suggests dividing research into four **classes**, depending on the agencies involved and the purposes for which the work is done. Although "no sharp lines can be drawn between these classes", states Skinner, the classification is based on the primary function of each class and their distinctive fields. However, Skinner suggests we also look at the relationships among them:

- Universities, where the primary function is pure science and the training of "research men".
- Industry, with its own laboratories and men familiar with all phases of research, but where closer relationships with university are needed for better training.
- Government, where research results are directly available to all people, but where there is a "desirability of increased cooperation between all the forces having to do with research, both at home and abroad" (Skinner, 1917: 877).
- Philanthropy.

Similarly, in an address delivered to the Associated Engineering Societies of Worcester in 1917, P. G. Nutting (1917) from Eastman Kodak suggested that different **types** of research made up the scientific landscape. He starts by adopting a national perspective: "A nation is great according to its resources and according to its development of these resources. And the development of those resources may be accomplished only through organized knowledge". To Nutting, "a nation will advance to leadership in which the increase in organized knowledge and the application of that knowledge are greatest (…). For this reason, interest in research should be as wide as the nation and should cover the whole gamut of problems from administration to agriculture, from medicine to manufacture" (Nutting, 1917: 247-248).

To Nutting, there are "three distinct types of research organizations": government or national (for the "solution of such problems as concern the national as a whole"), universities (devoted to the "advancement of the various sciences as such"), and industry (focused on "practical commercial application"). [4] In the latter case, he says "we need more teaching and instructors in closer touch with industrial problems" (Nutting, 1917: 251). To Nutting, "another great need is cooperation among the various branches of research: university, national and industrial. There should be a free interchange of men between such laboratories, and each should be thoroughly familiar with the needs and problems of the other" (Nutting, 1917: 251).

[4] To these Nutting adds the following, but without discussion: privately endowed research organizations and private cooperative research laboratories.

The “system approach” reached the national planning agenda in the hands of H. Hoover, US Secretary of Commerce. According to Hoover, pure scientific research is the most precious asset of the country. “It is in the soil of pure science that are found the origins of all our modern industry and commerce. In fact, our civilization and our large populations are wholly builded upon our scientific discoveries” (Hoover, 1927: 27). However, Hoover calculated that **the nation** was not spending enough on this kind of research, in contrast to applied research. To Hoover, “there is no price that the world could not afford to pay these men” (Hoover, 1927: 27): “The wealth of the country has multiplied far faster than the funds we have given for those purposes. And the funds administered in the nation today for it are but a triviality compared to the vast amount that a single discovery places in our hands. We spend more on cosmetics than we do upon safeguarding this mainspring of our future progress” (Hoover, 1927: 29).

“How are we to secure the much wider and more liberal support to pure science research” (Hoover, 1927: 28)? Hoover considered that this support should be in three directions: government (more pure research in national laboratories), industry (entrust the National Academy of Sciences with a fund to support research), and philanthropy. “A nation with an output of fifty billion [dollars] annually in commodities which could not be produced but for the discoveries of pure science could well afford, it would seem, to put back a hundredth of one percent as an assurance of further progress” (Hoover, 1927: 28).

From that time on, the national organization of science would be increasingly well understood, after some controversy about matters of scientific freedom *versus* planning certainly, as being carried out in three main “administrative spheres [5] – not independent of one another”, and contrasted to an era (the nineteenth century) in which independent scientists depended on sporadic benefactors (Bernal, 1939: 35). It would not take long for a “**national** science budget” to be constructed for policy purposes, representing the sum of expenditures devoted to research by government, universities, industry and

[5] Philanthropy, or non-profit, is more often than not a residual in “modern” versions of the system approach.

philanthropy. Until the 1940s, these sectors were measured separately, as in surveys of government expenditures (Rosa, 1920; 1921; US National Resources Committee, 1938), or industrial research (US National Research Council, 1920) (see Appendix 1). Subsequently, the sectoral data were aggregated into a "national research budget" (and a matrix showing the flows of money between sectors was constructed), beginning with the British scientist J.D. Bernal (1939) and followed by V. Bush (1945), the US President's Scientific Research Board (1947), the US Department of Defense (1953), the US National Science Foundation (1956), the UK Advisory Committee on Science Policy (1956), and the OECD Fracsati manual (1962) (Godin, 2008b) (see Appendix 2).

Then, the system approach got into policy. From the early 1960s, the OECD has been an ardent and influential promoter of a system approach to science policy: policy-makers must address the problems of each of the four economic sectors composing a research system (now called innovation system), and work for the development of relationships between the sectors, particularly with the industrial sector (Godin, 2009a).

Conclusion

The system approach has deep roots in history. These roots are not theoretical (like F. List).[6] The system approach was first discussed systematically (I mean regularly) among "men of action": industrialists beginning in the 1910s, as discussed here, then policy-makers in the 1960s and subsequently. Then, and only then, the National Innovation System tradition developed among academics, adding new dimensions to the analysis.

A system approach to understanding the organization of research evolved gradually. At the very beginning, there was only one component in the system, or in fact there was no system at all. University research was the basis of all progress, and pure research was contrasted with applied research, which is derived from pure research. The interest of academics here was to preserve a division of labor. This understanding is what we have

[6] To what extent the literature on National Innovation System itself is really theoretical, as opposed to merely descriptive, is a matter of debate in science policy studies.

called above the spontaneous philosophy of scientists. It was shared also among non-scientists very early on. [7] As W. R. Whitney from General Electric put it in 1934, the "principle of discovery first and utilization after is the oldest thing in man's history" (Whitney, 1934: 74).

Then industrialists added their voice to a national view of research, first suggested by governments due to the need to mobilize the scientific "estates" of the nation for the war. Research, while still discussed as a sequence from basic to applied research (then development), had obvious and necessary relationships between its components. The interest of industrialists was manifold. One was convincing more firms to invest in research and thus accelerate industrial development. Another was to get support from universities and to participate in and benefit from the government effort during the war and subsequently.

Then, the system approach found its way into policy, first among planning institutions, [8] and later into science policy. Two factors contributed to this move. First, a budget (statistics) came to be constructed to measure the national volume of research and to provide information for public decisions on scientific matters. Second, but much later, theories developed and "enlightened" the policy actions.

Industrialists have been far more influential on the organization of science and the development of theories than is usually imagined. The idea that research is organized (as the industrial laboratory is) and systematic (unlike the work of the individual researcher) gave rise to our contemporary definition of what research is and to its measurement (Bud, 1978; Godin, 2007). Similarly, our concept and measurement of research as being

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[7] See Alexis de Tocqueville's "trichotomy" in *Democracy in America* (Volume 2, Chapter 10: Why the Americans are More Addicted to Practical than to Theoretical Science): "The mind may, as it appears to me, divide science into three parts. The first comprises the most theoretical principles, and those more abstract notions whose application is either unknown or very remote. The second is composed of those general truths which still belong to pure theory, but lead, nevertheless, by a straight and short road to practical results. Methods of application and means of execution make up the third. Each of these different portions of science may be separately cultivated, although reason and experience show that none of them can prosper long, if it be absolutely cut off from the two others". I owe this reference to Jan Kozlowski.

[8] Like the US National Resources Committee, the US National Resources Planning Board and the US President's Scientific Research Board.

research and development (R&D) owes its existence to the importance of the D (development) in industrial (and government) research (Godin, 2006a). The influence of industrialists does not stop here. They have also contributed significantly to current conceptual frameworks used in science policy and science studies. Godin has shown what the linear model of innovation owes to industrialists, first among them the industrial partners of the US National Research Council (Godin, 2008a; 2006b). What we have discussed here is how industrialists have contributed to the origins of another framework: a system approach to science. From the 1910s, US industrialists have discussed research in terms of a national system – without the term –, and the relations between the elements of the system. Their contribution, although not theoretical, is certainly one step toward the development of National Innovation System theory.

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Appendix 1.
Coverage of Official Surveys of Research
by Economic Sector

(Year of first edition)

	Sector				
	Industry	Govt.	Univ.	Others	All
United States					
National Research Council	1933				
Works Progress Administration	1940				
National Resources Committee	1941		1938		
Bush (Bowman report)					1945
Senator Kilgore		1945			
Office of Scientific Research and Development		1947			
President's Scientific Research Board					1947
Bureau of Budget		1950			
Department of Defense	1952				
	1953		1953		
Bureau of Labor Statistics	1953			1950	
				1951	
National Science Foundation	1956	1953	1956		1956
Canada					
National Research Council	1941				
Department of Reconstruction		1947			
Dominion Bureau of Statistics	1956		1960		
United Kingdom					
Advisory Committee on Science Policy					1956
Department of Scientific and Industrial Research	1958				

Appendix 2.
A Statistical Approach to the Research System

The construction of statistics is an important step toward the construction of a system approach to research. In turn, the statistics has contributed to the crystallization of the approach: the statistics have helped to "objectify" the system approach in policy matters.

The first exercise in measuring a national research system came from the British scientist J. D. Bernal. Bernal was one of the first to figure out how much was spent nationally on R&D – the **budget of science**, as he called it. [9] In *The Social Function of Science* (1939), Bernal estimated the money devoted to science in the United Kingdom using existing sources of data: government budgets, industrial data (from the Association of Scientific Workers) and University Grants Committee reports. The national science budget was nevertheless estimated at about four million pounds for 1934 (Bernal, 1939: 64).

The next experiment toward estimating a national budget was conducted in the United States by V. Bush in his well-known report to the President titled *Science: The Endless Frontier* (1945). Primarily using existing data sources, the Bowman committee – one of the four committees involved in the report – estimated the **national research budget** at $345 million (1940). The committee showed that industry contributed by far the largest portion of the national expenditure, but calculated that the government's expenditure expanded from $69 million in 1940 to $720 million in 1944.

Bush was only the first to compute such statistics in the United States. In 1947, at the request of the US President, the Scientific Research Board published its report *Science and Public Policy*, which estimated, for the second time in as many years, a **national R&D budget**. With the help of a questionnaire it sent to 70 industrial laboratories and 50 universities and foundations, the Board in fact conducted the first survey of resources devoted to R&D using precise categories, although these did not make it "possible to arrive at precisely accurate research expenditures" because of the different definitions

[9] One exception is Hoover (1927). However, the source of the numbers he used is unknown to me.

and accounting practices employed by institutions (US President's Scientific Research Board, 1947: 73). The Board estimated the US budget at $600 million (annually) on average for the period 1941-45. For 1947, the budget was estimated at $1.16 billion. The federal government was responsible for 54% of total R&D expenditures, followed by industry (39%), and universities (4%).

The last exercise in constructing a total R&D figure, before the NSF entered the scene, came from the US Department of Defense in 1953 (US Department of Defense, 1953). Using many different sources, the Office of the Secretary of Defense for R&D estimated that $3.75 billion, or over 1% of the Gross National Product, was spent on **research funds** in the United States in 1952. The report presented data regarding both sources of expenditures and performers of work. The statistics showed that the federal government, as a source of funds, was responsible for 60% of the total, [10] industry 38% and non-profit institutions (including universities) 2%. With regard to the performers, industry conducted the majority of R&D (68%) – and half of this work was done for the federal government – followed by the federal government itself (21%) and non-profit institutions and universities (11%).

Then came the US National Science Foundation. According to its mandate, the organization started measuring R&D across all sectors of the economy with specific and separate surveys in 1953: government, industry, university and non-profit. Then, in 1956, it published its "first systematic effort to obtain a systematic across-the-board picture" (US National Science Foundation, 1956) – one year before Great Britain did (UK Advisory Council on Science Policy, 1957). It consisted of the sum of the results of the sectoral surveys for estimating **national funds**. [11] The organization calculated that the national budget amounted to $5.4 billion in 1953.

The US National Science Foundation's methodological guidelines became international standards with the adoption of the OECD methodological manual on surveying research

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[10] The Department of Defense and the Atomic Energy Commission were themselves responsible for 90% of the federal share.
[11] The term "national" appeared for the first time only in 1963. See: US NSF (1963).

and development (R&D) by member countries in Frascati (Italy) (OECD, 1962). The Frascati manual suggests collecting two types of statistics on research: the financial resources invested in R&D, and the human resources devoted to these activities. The main indicator to come out of the manual is **Gross Domestic Expenditures on R&D** (GERD) – the sum of R&D expenditures in the four main economic sectors: business, university, government and non-profit. GERD is the term invented by the OECD for measuring what was, before the 1960s, called national funds or budget.

Republican dominance over national policy and subsidization of business development during the Civil War and Reconstruction accelerated American industrialization. It was the railroads that signaled the new American order. The railroads created the first great concentrations of capital, spawned the first massive corporations, made the first of the vast fortunes that would define the â€œGilded Age,â€ unleashed labor demands that united thousands of farmers and immigrants, and linked many towns and cities.Â Educated employees swelled the ranks of an emerging commercial middle class. Industrialization remade much of American life. Rapidly growing industrialized cities knit together urban consumers and rural producers into a single, integrated national market. National Systems of Innovation presents a new perspective on the dynamics of the national and the global economy.Â Part II: A Closer Look at National Systems of Innovation. Chapter 5 WORK ORGANISATION AND THE INNOVATION DESIGN DILEMMA. Chapter 5 WORK ORGANISATION AND THE INNOVATION DESIGN DILEMMA.Â Chapter 13 NATIONAL SYSTEMS OF INNOVATION, FOREIGN DIRECT INVESTMENT AND THE OPERATIONS OF MULTINATIONAL ENTERPRISES. (pp. 259-292). FranÃ§ois Chesnais. The national innovation systems approach stresses that the flows of technology and information among people, enterprises and institutions are key to the innovative process. Innovation and technology development are the result of a complex set of relationships among actors in the system, which includes enterprises, universities and government research institutes. For policy-makers, an understanding of the national innovation system can help identify leverage points for enhancing innovative performance and overall competitiveness. It can assist in pinpointing mismatches within the system, both a... C. Freeman and B.-A. Lundvall, as prolific writers on National Innovation System, have suggested that F. List (Das Nationale System des Politischen Okonomie, 1841) was a pioneer of the approach. However, one would have difficulty documenting a tradition of theoretical research on the system approach arising out of Listâ€™s work.Â However, what was the view of industrialists on the idea of a classification of research as either. 7. basic science or applied?Â To Jewett, science is the source of industrial progress: industrial applications have their origins in pure science, â€œlike the connecting links of an intricate chain networkâ€ (Jewett, 1924: 3). â€œWe must in consequence provide adequately for a continuous supply of well trained workersâ€ (Jewett, 1918: 6).