# Innovation
# and the Marginalization of Research

Benoît Godin

Project on the Intellectual History of Innovation
Working Paper No. 29

2017

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**Project on the Intellectual History of Innovation**
385 rue Sherbrooke Est, Montréal, Québec H2X 1E3
Telephone: (514) 499-4074; Facsimile: (514) 499-4065
**www.csiic.ca**

# Innovation

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*Research*, particularly basic research, is certainly one of the central social and cultural values of the twentieth century. Whereas science as a body of knowledge (natural and social) and as a method (experimental and hermeneutic) have been discussed for centuries among philosophers and 'men of science' (scientists), research as a scientific activity or practice, conducted at the level of individuals or organizations, became an object of public discourses in the twentieth century. Industrialists espoused research as a source of industrial progress, and governments as a source of national economic growth.

Today, basic research is relatively absent from the vocabulary of governments and industry compared to the 1960s-70s. Policy documents are few, and come mainly from scientists' representative organizations, like the National Science Foundation and the National Academy of Sciences in the United States and the European Research Council in Europe. Government white papers concern innovation, and generally include only a couple of paragraphs on basic research. Departments or administrative units in charge of research policy now define their fields of responsibility as "research and innovation". The EU commission, for example, has established a Directorate-General for Research and Innovation (formerly DG Research). EU member states have meanwhile adopted the label "research and innovation" for funding programs and directives. In the United Kingdom the government set up the UK-IRC recently, merging research and innovation in a single agency. In sum, research has disappeared as an autonomous object. Innovation is the keyword. Research is discussed, when it is, as part of the rhetoric on technological innovation.

This chapter documents a key moment in history, responsible for the marginalization of research in scholarly and public discourses. Beginning in the 1960s, a diversity of scholars and practitioners (engineers and managers) began to question the role of research in contributing to socioeconomic progress. They did so by electing *innovation* as a key concept. Innovation is a social or holistic process that includes far more than research, when it includes it at all.

In a recent article, I documented how research came to be talked of in public discourse as not being the province of universities alone (Godin and Schauz, 2016). In this chapter, I turn to another discourse of the twentieth century that marginalized research, at least in social scientists' and governments' discourses: the discourse on technological innovation. The first part of the chapter discusses engineers', managers', policy-makers' and scholars' discourses of the 1960s on why "research is not enough" for progress. These discourses are generally not part of the scholarly literature on the history of science and science policy. The study of science and the study of innovation are two distinct fields, although research is postulated, on faith, as being at the origin of innovation. There is "historical blindness", or "hegemony of the distorted picture of science", as Ann Johnson put it in her review *What If We Wrote the History of Science from the*

*Perspective of Applied Science?*, "overemphasizing the academy" and "overlooking, for a variety of reasons, the private sector and applied science" (Johnson, 2008: 612).

I here give social existence to a discourse of the 1960s-70s, now forgotten but influential in the intervening decades, that marginalized research as a source of socioeconomic progress. [1] I also highlight the key concepts that serve this discourse: innovation, (experimental) development, adoption, need, coupling, process and system. The chapter shows that the current demands made on universities to contribute directly to the market have deep roots in history.

## 1. In the Name of Innovation

There have been two discourses on technological innovation in the twentieth century. One comes from policy-makers, natural scientists, and science and technology theorists. Innovation results from the application of science to industry. The issue discussed is research and development (R&D) and qualified human resources – as assets to a country's competitiveness. Here, innovation is an article of faith (the ultimate outcome coming out of basic research), not really theorized about (e.g.: Pavitt, 1963). The other discourse comes from practitioners. Innovation is a complex activity that includes research, when it does, as only one part of a whole process. The most important part or step is not research, but the development of inventions and their commercialization.

### *1.1 Research is not Enough*

"Research is not enough" was a key phrase of the 1960s. "Research", stated sociologist Everett Rogers, "is an unrealized public investment until the resulting innovations are diffused to and adopted by the intended audience….Research alone is not enough to solve most problems; the research results must be diffused and adopted before their advantage can be realized" (Rogers, 1962: 2-3). Jack Morton, an engineer at Bell Telephone Laboratories who brought the transistor from invention to market, and author of numerous articles and a book on innovation, concurred: "By themselves R&D are not enough to yield new social benefits. They, along with capital resources, must be effectively coupled to manufacturing, marketing, sales, and service" (Morton, 1971: 3). Ronald Havelock, a prolific author on knowledge transfer or dissemination of knowledge from the University of Michigan, thought similarly: "The 1960's saw the emergence of a new awareness that research by itself does not provide direct answers to the problems faced in the practical world" (Havelock and Havelock, 1973: 1). Donald Schon, a philosopher who worked at Arthur D. Little Inc. and the US Department of Commerce and produced an early book on "models" of technological innovation, agreed: "Scientific research is only one route to technological innovation" (Schon, 1967: 114). Finally, governments, public organizations and their representatives espoused the view: "Invention without innovation may be intellectually satisfying, but it does nothing to promote the general welfare….As far as society is concerned,

[1] That science is disruptive of the natural environment and the social world and the crisis of confidence in science are the main arguments studied in the literature. But it was only part of the argumentation that contributed to the contestation of science in the 1960s.

invention without innovation is an unwritten poem, an unpainted picture, an unplayed symphony" (Simone, 1965: 1095-96). [2]

Why is research not enough? Research has to be useful to society, and it is through innovation that this occurs. Economists, sociologists, historians, management schools, practitioners, governments, international organizations and their consultants all agree on four things. First, innovation includes far more than research. "There appears to be general agreement that the process of successful technological innovation depends on many more factors than the mere generation of scientific and engineering information" (US National Academy of Engineering, 1968: Foreword, no page number). As economic historian Rupert Maclaurin put it, "Advances in science are not automatically translated into advances in the practical arts" (Maclaurin, 1949: xiii). Between fundamental research and its applications, there is a "continuum" or "sequence" of activities, called "stages": fundamental research, applied research, engineering development, production engineering and service engineering.

With this sequential or linear model, a very influential model but also a much criticized one, Maclaurin was trying to explain how research transforms itself into technological innovation. This is not automatic. There are many activities necessary to turn research into useful applications. This gave rise to what is known as the linear model of innovation (Godin, 2017). Critics of the linear model of innovation usually stress that basic research is not the starting point of technological innovation, or that technological innovation is not a linear sequence beginning with basic research. Yet what is missing in the criticisms is a historical perspective that takes the inventor of the model (economic historian Rupert Maclaurin) seriously (Godin, 2008). Maclaurin was broadening the discourse of the time, on (basic) research leading automatically to technological innovation. Using the radio industry as a case study, he illustrated "the steps which are required to bring a new scientific concept from the theoretical stage to a successful commercial product" (Maclaurin, 1946: 426). Technological innovation is not only the affair of scientists: "The innovator as an individual takes his place with the pure scientist and the inventor as a key figure in material progress" (Maclaurin, 1953: 105). Innovation includes activities other than basic research as necessary stages. In the decades following Maclaurin, linear sequences multiplied in the literature.

Research amounts to a very small percentage of innovation activities, so measurements showed. In line with Maclaurin, economist Yale Brozen from Northwestern University suggested that basic research "does not automatically produce technical advance. Additional work must be done after the discovery of basic knowledge or the development of a technique to make use of research results….Beyond the stage of applied research, a technique must go through engineering development, production engineering, and service engineering….The effort required

[2] "The factors involved are by no means all, or mainly scientific; some of the most important are indeed sociological" (UK Advisory Council on Scientific Policy, 1964: 8); "a high level of R and D is far from being the main key to successful innovation….Government support should be given to the whole process of technological innovation, in contrast to its present overwhelming emphasis on the opening phases of research and development….The most difficult and complex problems in the process of technological innovation generally lie in this final phase [of marketable products which the customer wants and the producer can make at profit], the phase which includes aggressive and sophisticated marketing" (UK Advisory Council for Science and Technology, 1968: 9, 15). "Scientific and technological capacity is clearly a prerequisite but it is not a sufficient basis for success" (OECD, 1968: 23).

to bring a device to the point of commercial usefulness amounts to four to ten times the effort required to develop it….Development laboratories are an essential link" (Brozen, 1951: 27-28).

Such was the message of an influential report from the US Department of Commerce. In 1964, the US President asked the Department to explore new ways of "speeding the development and spread of new technology". To this end, Herbert Hollomon, as Secretary for Science and Technology, [3] set up a panel on invention and innovation, whose Chairman was Robert Charpie and whose executive secretary was Daniel de Simone. [4] The report was published in 1967 as *Technological Innovation: Its Environment and Management*. The report begins by making a distinction between invention and innovation as a difference between the verbs "to conceive" and "to use". To the Department, innovation is a "complex process by which an invention is brought to commercial reality" (US Department of Commerce, 1967: 8). R&D is only one phase or step of this process. Innovation includes R&D, engineering, tooling, manufacturing and marketing. Using "rule of thumb" figures from "personal experience and knowledge" of the members of the panel, the Department reported that R&D corresponds to only 5-10% of innovation costs. "It is obvious that research and development is by no means synonymous with innovation" (US Department of Commerce, 1967: 9).

The numbers paved the way for an influential representation of technological innovation in the following decades. Policy-makers, managers, engineers and social theorists embraced the representation without reservation. Scholars began to study *development*, a very central activity to innovation. Development should be assigned a functional "status equal to that of invention, innovation and investment", stated economist Frederic Scherer (Scherer, 1965: **XX**), because "inventors, engineers, appliers of science, and entrepreneurs give much of their time and resources to an activity that they label development" (Hughes, 1976: 424; see also Rosenberg, 1976). The merging of research with development in the phrase *research and development* (R&D) is witness to this consideration (Godin, 2005).

A second reason why research is not enough is that it requires use or adoption or application in a practical context to be beneficial. "There is a growing feeling that *new* knowledge and especially new *scientific knowledge* must be put to good use" (Havelock, 1967: 47). The message has an old origin. Discovery or invention "is without result and sterile unless it is adopted", stated anthropologist Roland Dixon in 1928. "Without its diffusion beyond the discoverer or inventor, the new trait remains merely a personal eccentricity, interesting or amusing perhaps, but not significant" (Dixon, 1928: 59). Innovation is use or adoption, i.e.: action rather than contemplation or speculation.

A related argument is that innovation is a managerial problem or even a social problem, not a scientific or technical problem. [5] As Hollomon put it, "We are limited not by our inability

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[3] Successively head of General Electric Engineering Laboratory, first Assistant Secretary for Science and Technology at the US Department of Commerce, founder of the US National Academy of Engineering, then professor of engineering at MIT.

[4] Charpie was Director of Technology at Union Carbide Corporation, and Simone, an electrical engineer, was Director of the Office of Invention and Innovation at the US National Bureau of Standards.

[5] Similarly, the external or contextual turn in the history of *technology* is a crucial and well-studied moment.

to apply science or by a dearth of technical possibilities, but by social, political, and economic considerations….[Innovation] requires a group of people with a deep understanding of economics, politics and social science" (Hollomon, 1965b: 124, 131). [6] To most scholars, use or application means by the market. [7] Such was the understanding of officials too. [8]

*1.2 The Key Factor is Need*

Research is not enough for a third reason: need – often called demand – determines innovation. Beginning in the 1960s, practitioners and scholars from different fields began to look at technological innovation from a demand rather than a supply perspective, arguing that the most critical element in technological innovation is need-pull forces (opportunities *pulling* from peoples' needs and the market) rather than by supply-push forces (technological opportunities *pushing* forward from scientific discoveries).

These studies had no theoretical aim; they were conducted by governments and their consultants to get more out of research activities – and out of public funding for research. The messages of these studies were twofold. First, *need* is what drives technological innovation. "Nearly 95 percent [of innovations in weapons systems] were motivated by a recognized Defense *need*", stated the famous US Department of Defense's report known as *Project Hindsight*. "Only 0.3 percent came from undirected science" (Sherwin and Isenson, 1969: 1577). This message emerged in similar studies as well. The National Academy of Sciences stated that

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6 "Advocates [of creativity] have generally failed to distinguish between the relatively easy process of being creative in the abstract and the infinitely more difficult process of being innovationist in the concrete….What is often lacking is not creativity…but innovation…i.e. putting ideas to work. All in all, ideation is relatively abundant. It is its implementation that is more scarce" (Levitt, 1963: 72-73). "Ideas are useless unless used. The proof of the value is their implementation" (Levitt, 1963: 79). "The challenge to industry and government…is to organize not only the search for knowledge through R&D as we are already doing, but – equally vigorously – the use of that knowledge….The problems of innovation are not primarily technical. They are managerial problems" (Michaelis, 1964: 45-46). "Creative, innovative researchers are not enough in themselves. What is needed…is an organization which provides collaboration between scientific innovators and sales and production specialists" (Lorsch and Lawrence, 1965: 109). "The limitations to the application of science and technology in civilian areas are not so much technical as social….The problem is one of dealing with technical and social factors together" (Warner, 1965: 209).

7 "Innovation requires not only the inventor who conceives a product or service to meet a customer's needs, but also the entrepreneur who underwrites and markets the new product" (Warner, 1965: 211). "A great deal of technology" does "not depend on science…[but] draws on it incidentally….Most of inventions were not made by scientists….Invention is still the basic ingredient of innovation" (Wiesner, 1966: 11-12). "Having a new idea and demonstrating its feasibility is the easiest part of introducing a new product. Designing a satisfactory product, getting it into production, and building a market for it are much more difficult problems" (Wiesner, 1966: 15). "The technical innovators are men who not only have some scientific knowledge but who are also inspired to put it to work on every new idea that comes their way" (Wiesner, 1966: 17). "Innovation is the process of carrying an idea – perhaps an old, well known idea – through the laboratory, development, production and then on to successfully marketing of a product….The technical contribution does not have a dominant position" (Research Management, 1970: 435).

8 "Technical innovation depends not only on R and D, but also on the capacity of firms to use its results" (OECD, 1966: 11). "It is not enough for the inventor to invent; he must also bring his idea for a new product or process to market" (US Advisory Committee on Industrial Innovation, 1979: 6). "The most intractable problems lie not in the potential of science and technology as such, but rather in the capacity of our economic systems to make satisfactory use of this potential" (OECD, 1980: 93).

"the recognition of an important *need* was most frequently the principal factor in stimulating research-engineering interactions" (National Academy of Sciences, 1966: viii; 15-16). The message was also emphasized in early reviews of "models" of innovation (Price and Bass, 1969; Rothwell and Robertson, 1973; Utterback, 1974): "the majority of successful innovations", summed up Roy Rothwell from the Science Policy Research Unit (SPRU) in Brighton, England, "arise in response to a specific *need*" (Rothwell and Robertson, 1973: 213). In a study on "educational innovation" for the Office of Education (US Department of Health, Education and Welfare), the consultants from Arthur D. Little Inc. review six "models of innovation", among them the "rational change process model" (linear model) and the "response to a *need* model" (Arthur D. Little Inc., 1968). At about the same time, Havelock identified three models of change in the literature, two of which are the "R, D & D model" (research as first mover) and the "problem-solver model", which he discusses in terms of the "*needs*" of the client (Havelock, 1969). Then in 1972, researchers from Manchester gave what became a standardized label to these models: the linear or "discovery-push" model, and the demand or "*need*-pull" model (Langrish *et al.*, 1972: 72-73).

Most studies agreed that the need model is emblematic of technological innovation. Technological innovation is the use of an invention "to satisfy a demand or *need*" (Gruber and Marquis, 1969: 256). The process of invention behind technological innovation is an "oscillation between *need* and technology" (Schon, 1967: 16). "The recognition of a [market] *need* at the distribution end and the prospect of exploiting it is probably the most powerful driving force for the total process" of technological innovation (Allen, 1967: 23). Hollomon is a perfect example of the rhetoric of the time. "Most technological change, most innovation, most invention, and most diffusion of technology are stimulated by demand…and [are] only indirectly science-created" (Hollomon, 1967: 34). Hollomon summarized his idea in his speech to a conference on the *Economics of Research and Development* held at Ohio State University in 1962 (Hollomon, 1965a: 253):

> The sequence – new science from research, application of new science, development, prototype manufacturing, and sales – is not the usual way innovation occurs. The majority of new processes which increase our ability to turn out products and services efficiently, broaden our economic life, and widen our variety of choice take place as a result of a process that involves the recognition of a *need*, by people who are knowledgeable about science and technology. The sequence – perceived *need*, invention, innovation (limited by political, social, or economic forces), and diffusion or adaptation (determined by the organizational character and incentives of industry) – is the one most often met in the regular civilian economy.

To be sure, need as the source of technological innovation did not remain uncontested. But the argument opened the door to the study of multiple factors responsible for technological innovation (Godin and Lane, 2013). Technological innovation is a matter of fusion or *coupling*, a key word of the 1960s. It may be "an orderly process" composed of (linear) stages – a process "starting with the discovery of new knowledge, moving through various stages of development, and eventually emerging in final, viable form", stated William Price and Lawrence Bass, formerly from the US Department of Defense and Arthur D. Little Inc. respectively – but basic research does not necessarily initiate the process. There is no linear sequence from basic research to invention to technological innovation. "There is a complex interplay of concepts and people" with dialogue and feedback (Price and Bass, 1969).

In the mid-1960s, the idea of coupling was everywhere in the literature. Coupling became "a word of fashion", as the organizers of a conference on *Coupling Research and Production* put it (Martin and Willens, 1967: 1; see also Rubenstein and Douds, 1969), along with various other terms or synonyms: interface, transfer, liaison, diffusion, interaction, communication and fusion. Coupling refers to the various people and activities involved in technological innovation. There is need to couple basic research to development and to couple development to production (Martin and Willens, 1967: 3), to couple the technological, economic and human factors together (Gruber and Marquis, 1969: 4), to couple the technical opportunity with market demand recognition (Myers and Marquis, 1969: 5) and to couple the laboratory with the factory (Gruber and Marquis, 1969: vii). There is a need for interaction between science and technology, and between technology and production (Toulmin, 1969: 35).

The idea and semantics of coupling from the 1960s is present in every subsequent study, and new terms make their appearance: interaction, combination, symbiosis, synthesis and complexity. John Langrish and his colleagues suggested a "complex process involving the interaction of many factors" (Langrish *et al.*, 1972). Project SAPPHO called it a "complex sequence of events" (SPRU, 1972). Chris Freeman called it a "combination": "almost any of the innovation which has been discussed" could be cited in support of this "creative and imaginative matching" or "combination" of ideas (Freeman, 1974: 167-69).

### *1.2 Innovation is a Holistic Process*

In the end, and this is a fourth argument, research is not enough because innovation is an inclusive process, which research is not. Innovation is not the result of a single act, the act of a genius. Technological innovation is "the *total* process of translating scientific discovery into wealth or social benefit" (Cade, 1971: 7, footnote). The vocabulary used to describe this process is composed of a series of action-related terms. Innovation is a process from adoption to diffusion (sociology), from invention to commercialization (economics), from (product) development to manufacturing (management) (Godin, 2015):

> *Introduction*: introducing something new to the world. This concept first appeared among anthropologists and sociologists, but is most popular among economists and management.
>
> *Application*, assimilation, transformation, exploitation, translation, implementation: applying (new) knowledge in a practical context. Innovation is the application of ideas, inventions and science.
>
> *Adoption*, acceptance, utilization, diffusion, transfer: adoption of a new behaviour or practice. These concepts are mainly used by sociologists.
>
> *Commercialization*: bringing a new good to the market. Used concurrently with introduction or application, this concept applies to industrial innovation.

(Invention and) innovation as a process is an old story (William Ogburn, Colum Gilfillan, Robert Merton, Abbott Usher, Epstein). "A great invention is not the completed result of a single man", claimed Maurice Holland, Director of Engineering and Industrial Research Division at the US National Research Council in 1928. "It is the resultant of many inventions, the composite of a number of realized ideas merged into a workable *whole*" (my italics) (Holland, 1928: 332). [9] The most ardent publicist of the idea was Jack Morton. Starting in 1964, Morton defined innovation as a *total* process. [10] Then, in 1971, he produced *Organizing for Innovation*, and summed up his idea as follows (Morton, 1971: 3-4):

> Innovation is not just one single act. It is not just a new understanding or the discovery of a new phenomenon, not just a flash of creative invention, not just the development of a new product or manufacturing process; nor is it simply the creation of new capital and consumer markets. Rather, innovation involves related creative activity in *all* [Morton's italics] these areas. It is a connected process in which many and sufficient creative acts, from research through service, couple together in an integrated way for a common goal….By themselves R&D are not enough to yield new social

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[9] "The individual act of invention is not an isolated item, nor does any one invention make possible the full achievement of the potentialities implicit in the general concept or principle….Inventions form part of an orderly sequence, which embraces in its entirety the full records of the steps by which we achieve the complete realization of our ends". There is "interdependence of individual inventions…"a long series of inventions accumulated". The purpose of the inventor "requires several related inventions and discoveries, and not merely a single innovation. [It] "involves ultimately the organization of research laboratories" (Usher, 1929: 19-21). The adoption process "is not a unit act, but rather a series of complex unit acts – a mental process" by stages (Beal and Bohlen, 1957: 2). Innovation "is not a single action but a total process of interrelated subprocesses….A technical innovation is a complex activity which proceeds from the conception of a new idea to a solution of the problem and then to the actual utilization of a new item of economic or social value" (Myers and Marquis, 1969: 1). "Research and development is only a part of the spectrum of technological progress….Innovation [ranges] from idea conception, through development, on to implementation and finally to the diffusion of the technology into the economy" (Roberts and Romine, 1974: 1 of Research Summary). "Innovation is not really a single action, but a total process of interrelated subprocesses. It is not just the conception of a new idea, nor the invention of a new device, nor the development of a new market. The process is all these things acting in an integrated way toward a common objective – which is technological change….The management of technical innovation is far more than the maintenance of a technically productive R&D laboratory" (Marquis, 1969: 31, 36). Innovation is the "total process by which companies translate a technical advance, an idea, or an invention into products, processes, or services" (Schoen, 1969: 156).

[10] The "process of converting relevant research to new technology…is not just a flash of genius, not just the discovery of a new piece of understanding, not just the development of a new product or a new piece of manufacturing equipment. Rather, it is all these things, acting together in an integrated way" (Morton, 1964: 82). "By putting these steps in sequence [statement of objectives, list of alternative solutions, models and experiments, applied research, manufacturing], we can begin to isolate specialized functions which are part of this total process" (Morton, 1964: 84). "Technological innovation is a total process….Innovation does not involve a single act. It is not just a flash of inventive genius, it is not just the development of a new gadget, a new system, a new manufacturing technique, or the development of a new market or a new way of raising capital. Rather it is all these things acting together, in some related way" (Morton, 1966: 21). Innovation "is not a single action but a total process of interrelated parts. It is not just the discovery of new knowledge, not just the development of a new product, manufacturing technique, or service, nor the creation of a new market. Rather, it is *all* [my italics] these things: a process in which all of these creative acts, from research to service, are present, acting together in an integrated way toward a common goal" (Morton, 1968: 57). "Innovation is not a single, simple act. It is not just the discovery of new understanding, not just the development of a new product or process, nor is it simply the creation of new capital and consumer markets. Rather, innovation involves creative activity in *all* these areas. It is a connected process in which the necessary and sufficient creative acts, from research to service, couple together in an integrated way for a common goal….By themselves, R&D are not enough….They must be effectively coupled to manufacturing, marketing, sales, and service. When we couple all these activities together, we have the connected elements of a total innovation process" (Morton, 1969: 40).

> benefits. They, along with capital resources, must be effectively coupled to manufacturing, marketing, sales, and service. When we couple all these activities together, we have the connected specialized elements of a *total* [my italics] innovation process.

Engineers and managers in general held the same view. A symposium sponsored by the US National Academy of Engineering in 1968 concluded, "There appears to be general agreement that the process of successful technological innovation depends on many more factors than the mere generation of scientific and engineering information". Technological innovation is a process that includes "research, development, design, manufacturing or processing, marketing, customer service after sale, and the relation of these to the total environment" (US National Academy of Engineering, 1968: Foreword, no page number). To managers too, innovation is a process. The summary statement of the annual meeting of the Industrial Research Institute (IRI) on innovation, where over one hundred research managers gathered in April 1970, begins with the following "authoritative picture" of innovation: "Innovation is the process of carrying an idea – perhaps an old, well known idea – through the laboratory, development, production and then on to successfully marketing of a product….The technical contribution does not have a dominant position" (*Research Management*, 1970: 435).

Like managers, governments were not unaware of the idea of innovation as a holistic process. Technological innovation as a phrase entered government discourse in the 1960s in the context of debates on industrial competition and competitiveness between nations. There are "technological gaps" between countries, it was said, due largely to time lags between invention and the commercialization of invention ("time lag" was a key phrase in the 1960s) – hence the idea of espousing the concept of innovation as a process over time, from invention to commercialization. Governments and international organizations produced some of the first titles on technological innovation: the UK Advisory Council for Science and Technology, the US Department of Commerce, and the OECD. The US National Science Foundation was also a major funder of studies – the organization appropriates a concept instrumental to document the idea that basic research is useful to society. As to scholars, to policy-makers, technological innovation is process, from basic research to the exploitation of research results. [11] Innovation a "total process", an "entire venture", embedded in a "total environment" (US Department of Commerce, 1967: 2, 8, 11, 14): [12]

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[11] Technological innovation is a "complex subject" that involves "not only pioneering by means of research and invention but also the diffusion of improved design and manufacturing practices" (UK Advisory Council on Scientific Policy, 1964: 8); technological innovation is a "process by which an invention or idea is translated into the economy…a complex process by which an idea is brought to commercial reality" (US Department of Commerce, 1967: 2, 8); "technical innovation is the introduction into a firm, for civilian purposes, of worthwhile new or improved production processes, products or services which have been made possible by the use of scientific or technical knowledge". This "innovation process" is composed of "three parts": invention, (initial) innovation ("when a firm introduces a new or improved product into the economy for the first time") and (innovation by) imitation (diffusion) (OECD, 1966: 9); technological innovation is "the technical, industrial and commercial steps which lead to the marketing of new manufactured products and to the commercial use of new industrial processes and equipment" (UK Advisory Council for Science and Technology, 1968: 1).

[12] In terms of government action, total means the "co-ordinated and concerted action" of several ministries (OECD, 1966: 7), and the combination of direct (funding) and indirect (climate) measures (OECD, 1966: 10).

> The term 'technological innovation' can be defined in several ….At one extreme, innovation can imply simple investments in new manufacturing equipment or any technical measures to improve methods of production; at the other it might mean the *whole* [my italics] sequence of scientific research, market research, invention, development, design, tooling, first production and marketing of a new product (UK Advisory Council for Science and Technology, 1968: 1).

> Invention and innovation encompass the *totality* [my italics] of processes by which new ideas are conceived, nurtured, developed and finally introduced into the economy as new products and processes; or into an organization to change its internal and external relationships; or into a society to provide for its social needs and to adapt itself to the world or the world to itself (US Department of Commerce, 1967: 2).

## 2. The System Approach

The above ideas coalesced into a system approach to innovation. Innovation is a *system* that includes multiple organizations, and whose ultimate function is the commercialization of invention. The idea of system encompasses the idea of a holistic process. Research is not only a stage or the initiating stage in the innovation process. A system is composed of many organizations and functions acting in interaction. "There is no single institution or set of institutions to turn to. There is only the *whole* [my italics] complex of institutions: companies, industry associations at varying levels, universities, research institutes and governments – municipal, state and federal" (Schon, 1967: 173).

Again, Morton was part of thinking that changed the way innovation was understood, both at the time and in subsequent decades. "It is relatively straightforward, though difficult, to acquire and develop high levels of creative specialization, but it is a much more subtle and complex task to couple them together for the overall purpose of the system" (Morton, 1971: 62). Morton developed a "system model of innovation", as he calls it (Morton, 1964; 1966; 1968; 1969; 1971). "The essential virtue in the systems approach to innovation", claims Morton, "lies in the parts of the process and their linkages with one another, *not in the sequence* [my italics] in which such linkages are performed" (Morton, 1971: 19).

In *Organizing for Innovation*, Morton starts by defining two functions of organizations, as Jay Lorsch and Paul Lawrence did before him. To Lorsch and Lawrence, the two functions are specialization and coordination. An organization divides its "total" task into specialized pieces, and coordinates the activities of the different parts to come out with a "unified effort" (Lorsch and Lawrence, 1965: 109). To Morton, these two functions are named specialization and coupling. As regard coupling, Lorsch and Lawrence talked of coordination, others of transfer (Myers and Marquis, 1969), still others of communications (Rothwell and Robertson, 1973). *Coupling* is Morton's keyword – together with *system* (systems approach) and *total* (the total innovation process). "A system is an integrated assembly of specialized parts acting together for a common purpose…a group of entities, each having a specialized, essential function. Each is dependent for its system effectiveness upon its coupling to the system's other parts and the external world….*Parts*, *couplings*, and *purpose* are the three characteristics which define every system" (Morton, 1971: 12-13).

To Morton, innovation is "teamwork between science, engineering, and industry….But our understanding of the innovation process is still incomplete and not widely diffused….What I hope for is that our understanding of technological innovation will be broadened to include the *totality* [my italics] of human acts by which new ideas are conceived, developed, and introduced" (Morton, 1971: 2-3). To understand this process, Morton uses the "systems approach" of engineers, as he calls it. To Morton, the system approach is similar to the scientific method ("analysis into components and the synthesis into a system structure"). "The innovation process consists in the application of the scientific-systems method in coupled specialized sub-processes…basic or applied research, development and design, or manufacturing, sales and service" (Morton, 1971: 21-22).

This view still constitutes a stage model or linear model, but with feedback; an interactive model as some call it. Yet Morton combines this view with that of a system or organizations and institutions, including the external environment: firm, funding institutions, regulatory agencies, government departments and the world (see Figure 1). Morton's exemplar (model) is "the Bell System, whose "flow charts of the innovation process" evolved from organizational separation of entities and activities to coupling between 1925 and post-World War II". Bell Labs provides "a good case history for the application of the systems approach to the total innovation process" (Morton, 1971: 34).

Morton made a second analogy to science here, namely to biological ecology – and contrasts it to two other "viewpoints, models or schools of thought": the bureaucratic approach to organization (Max Weber and Frederick Taylor) and the human-relations approach or participative-management (Fritz Roethlisberger and William Dickson; Douglas McGregor, and Harold Leavitt). Like the human being, the innovative organization is a living organism and the manager is an agent of change, the "Maxwell's demon". "He must be alert and sensitive to changes both in his organism and its ecosystem" (Morton, 1971: 99). "Managers must understand the *total* innovation process from an ecological systems view" (Morton, 1971: 147). The task of the manager is to make this system work as unified whole.

Morton' system model was followed by many others, including governments and international organizations. [13] For example, from 1972 to 1978, the OECD conducted an analysis of national policies for stimulating technological innovation. The exercise was conducted using two conceptual frameworks. One was according to *time*, as the organization called it, or stages of

[13] Morton was preceded by Ellis Mottur. Mottur graduated in Business Administration in 1954 (Masters degree from Harvard Business School). He worked at the National Science Foundation in the 1960s, then became Assistant Director of the Office of Technology Assessment in the 1970s, and thereafter worked as Deputy Assistant Secretary for Technology and Aerospace at the Department of Commerce until 2001. While he was senior staff scientist at the Program of Policy Studies in Science and Technology at George Washington University, Mottur produced a report for the Office of Invention and Innovation, Department of Commerce, at the instigation of its Director, Simone, and as a follow-up to *Technological Innovation: Its Environment and Management* (US Department of Commerce, 1967). Mottur's system model is "a flow system in which goals, resources, technological knowledge, and related information flow through varying networks of institutions, organizations, groups, and individuals…to produce the technological innovations that enter the socio-economic system" (Mottur, 1968: 168-69). The model "provides a powerful synthetizing mechanism which society can use to accomplish this objective" (Mottur, 1968: 193). It "can assist in predicting those aspects of innovation that are predictable, in directing those sequences of events that are subject to direction, and in structuring strategic elements of the socio-economic environment along lines designed to facilitate the flow of innovation" (Mottur, 1968: 191). Echoing the Department of Commerce report from 1967, Mottur claims that the model allows actors "to become more widely acquainted with the 'language' and 'world' of innovation".

the innovation process (the linear model of innovation), and the other according to *space*, or the institutions involved in the process of innovation. To each framework a figure was attached, that on institutions being similar to those used today to visualize national innovation systems (OECD 1972a, 12; 1978, 142) (see Figure 2). In the following decades, a voluminous literature on *national innovation system* ensued that put the firm at the center of the system and universities in the environment as one, and only one, institution contributing to technological innovation.

**Conclusion**

That research is not enough for progress is an old discourse. Between research and progress there must be innovation, so it was said in the 1960s. Innovation is the adoption of research results. Without use, research is sterile. Innovation includes far more activities than just research, all necessary to make of research a useful thing. Innovation is a holistic process. It is not a single act, but a social process and includes diverse sorts of peoples, functions and organizations. Above all, research does not start the innovation process. It is (social and market) needs that are fundamental. The concept of system of innovation encompasses all these ideas.

Innovation is an inclusive concept (Godin, 2016). It sums up to a desire to enlarge the dominant cultural discourse on science and scientists. Innovation is action contributing to the practical, while science is strictly mental. Over time, the cultural power of the concept of innovation is threefold. First, the concept gave social existence to engineers and managers. "It is esteemed a kind of dishonour upon learning for learned men", stated Francis Bacon, "to descend to inquiry or meditation upon matters mechanical" (Bacon, 1623: 383). Such was the culture or attitude that engineers and managers wanted to change. [14] Second, the concept, particularly the phrase *technological innovation*, participates in the market ideology. Third, innovation serves national policy and, because of this, achieved legitimacy among the public at large.

Over the twentieth century, innovation has given rise to a new semantic pair. The century-old basic research/applied research dichotomy is concerned with or internal to science. It contrasts two types of scientific research. The twentieth century brought in a new pair or dichotomy: (basic) research/innovation. Technological innovation sprang from a tension between science (for its own sake) and society, or aspiration to action. The contrast is no longer internal to science, one between types of research, but between research and society. Innovation is contrasted to research, particularly basic research, in society's name. Research has to be useful to society – through the market.

[14] "The pure scientist appears to be held in higher esteem than the engineer and technologist....[There is] lack of status of the professional engineer as compared with the scientist….Inventions and innovations are not necessarily meritorious in themselves, but only in so far as they contribute to higher efficiency and enable us to compete more effectively in world markets" (Duckworth, 1965: 186, 188). "Engineering is a profession, an art of action and synthesis and not a simply body of knowledge….Engineering is the extension of man's capabilities – no less noble an object than the extension of his knowledge" (Simone, 1968: 1-2, 7).

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**Figure 1**

Jack Morton's Model of the Bell System

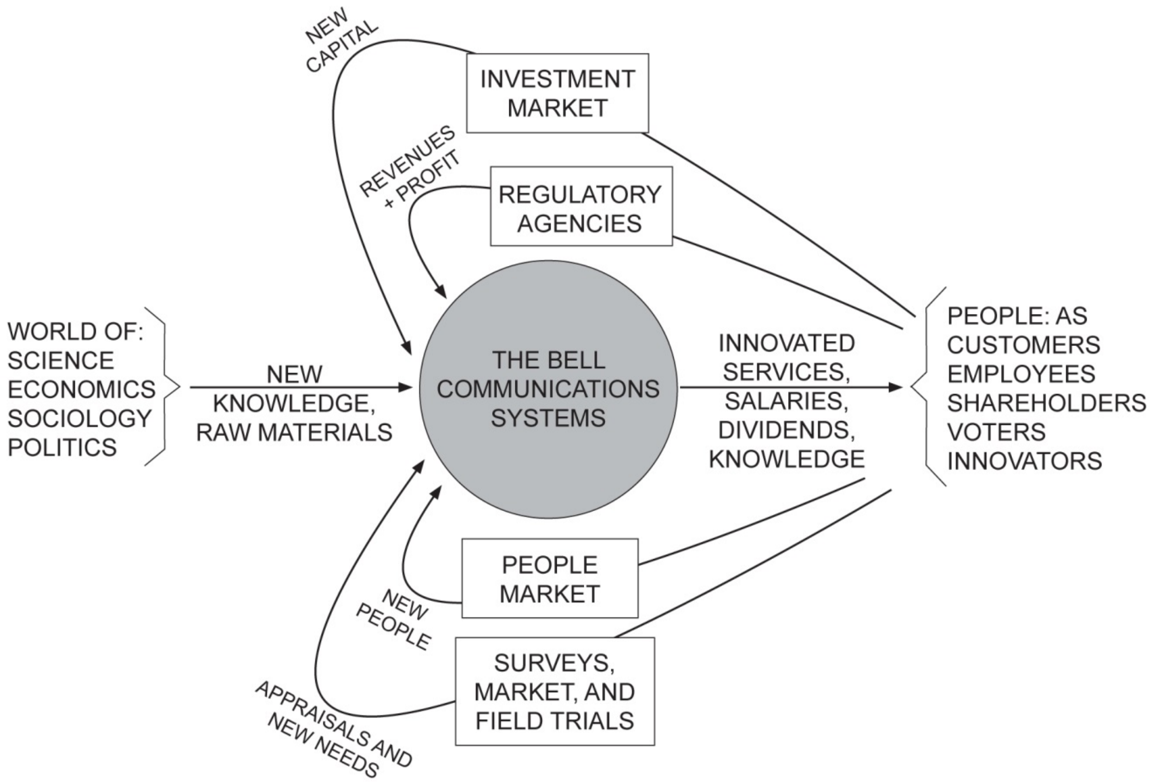

**Figure 2**

OECD