Models of Innvoation:
Why Models of Innovation are Models,
or What Work is Being Done in Calling Them Models?

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Abstract

Models abound in the literature on science, technology and society (STS). They are continuously being invented and succeed one after the other. At the same time, models are regularly criticized. This paper looks at models of innovation and conducts a conceptual analysis of what a model is. To the producers and users of models of innovation, a model has at least five different meanings: conceptualization, narrative, figure, tool and perspective

Why so many things are called model? Model has both a scientific and a rhetorical function. Model is a symbol of scientificity and travels easily between scholars and between the latter and policy-makers. Calling a conceptualization or narrative or tool model facilitate its propagation.

Keywords

Innovation; process; models; linear model of innovation.

One of the problems in this area of research has been the need to develop consistent definitions, measurements, and a model of the process of innovation (James Utterback, *The Process of Technological Innovation Within the Firm*, 1971).

Models are … a series of verbal formulations, or a vocabulary, which scientists use in special social contexts – particularly … when they are engaged in describing or justifying pure research to outsiders (Michael Mulkay, *Three Models of Scientific Development*, 1975).

In a paper from 1959, May Brodbeck, chemist and philosopher at the University of Minnesota, suggests that “the term ‘model’ appears with increasing frequency in recent social-science literature … The term has … a decided halo effect. Models are Good Things … ‘Mathematical models’, needless to say, are even better. Yet, what exactly is a model and what purposes does it serve? I venture to suggest that ten model builders will give at least five different or, apparently different answers to this question” (Brodbeck, 1959: 373). To Brodbeck, models have several meanings, most of them “unnecessary”. One is “various kinds of verbal or symbolic systems”. Another is “diagrams and pictorial devices”. Still another is a synonym for “theory”, particularly arithmetical or quantified theories, including formalization. To Brodbeck, the one and true meaning of model is isomorphism: “the similarity between a thing and a model”. [1]

Models abound in the literature on science, technology and society (STS). They are continuously being invented and succeed one after the other – one author developing many versions of the same one over time. At the same time, models are regularly criticized. This paper looks at the semantic of models, through a study of models of innovation. [2]

There exist two kinds of models of innovation: analytical and mathematical. The first type is sometimes accompanied with measurement, but is more conceptual in nature. The latter type is grounded in arithmetical formulas and simulations. This paper is concerned with *analytical* models. [3] Before the late 1960s-early 1970s, the term “model” rarely appeared in literature on innovation. Theorists study innovation in terms of a process composed of “sequences” and “stages”. Such a view is not called model, but rather “framework”, “paradigm” or “conceptualization”. In a matter of a few years, the “linear

[1] “If the laws of one theory have the same form as the laws of another theory, then one may be said to be a model for the other … An area, either part of all of it, can be a fruitful model for another if corresponding concepts can be found and if at least some of the laws connecting the concepts of the model can be shown to connect their corresponding concepts” (Brodbeck, 1959: 379, 380).

[2] The study of innovation is a very large specialty. I limit myself mainly but not exclusively to the theorists who use the concept “innovation”. Not included here, with a few exceptions, are models of “change” (e.g. management; sociology), of invention, of discovery, of creativity, etc., whose semantic of model is, nevertheless, similar to that studied here.

[3] On the diversity of meanings of the term model, see Muller (2004).

sequence" became the linear model, and the alternative perspective, the "coupling process", became the coupling model. Is model just a semantic convention? Or does model include more than a "framework" or "paradigm" suggests?

This paper looks at the emergence of a vocabulary on (analytical) models of innovation and covers the period from c.1940 to c.1980s. The hypothesis made here is that models of innovation arose during this period and that the semantic remained similar in form during later decades. The source material is a collection of over 500 works on innovation produced over the period c.1900-c.1980 (Godin, 2015b). The first part of the paper looks at the idea of innovation as a process, above all among sociologists, for it is there that the semantic of model emerged. The second part asks what a model is, from the perspective of those who use the term. To theorists of innovation, model has at least five different meanings: conceptualization, narrative, figure, tool and perspective. Why so many things are called model? In conclusion, I suggest that model has a rhetorical function. First, model is a symbol of 'scientificity. Second, a model travels easily between scholars and across the latter and policy-makers. Calling a conceptualization model facilitate its propagation.

A Rhetoric of Model

The linear model of innovation – the most influential, and criticied, framework to the study of innovation – "has not been made explicit as a diagrammatic model in any publication the writer has been able to find", states Stephen Kline, inventor of the model that actually defines innovation, the "chain-linked" or interactive or system model. The literature by engineering designers "has discussed models of innovation that look very much like the chain-linked model for a long time [c.1965]. However, these models usually exclude economic considerations, are often rather complex in details, and typically are couched in jargon that only engineers understand" (Kline, 1985: 36, 43).

The history of models of innovation is one of mythic stories, such as Kline is. The origin of the "linear model of innovation", is attributed to different authors. According to the writers, it is chiefly attributed to Vannevar Bush or to policy-makers, [4] despite research to the contrary (Godin, 2006). To others, the model is said to have never existed but in the critics' mind (Edgerton, 2004). [5] In fact, the model has existed for decades, under different names. [6] The story of the "need or demand-pull model", as alternative to the linear model of innovation, is as speculative. The economist Jacob Schmookler is often credited as being its inventor (e.g. Scherer, 1982; Walsh, 1984). In fact, the model does not come from Schmookler, or from any particular theorist. The theorists of the 1960s were simply studying other factors than research (need) as the source of innovation. They never talk of models, with a few exceptions (e.g. Baker et al., 1967; Price and Bass, 1969). It is rather the reviewers who formalized these ideas into a model (Godin and Lane, 2013). A story as mythic is told about a third model. Some attribute the "linguistic origin" of the "tripartite model" (invention, innovation, diffusion) to economic theory (Staudenmaier, 1985), and still others attribute it to Joseph Schumpeter (Mansfield, 1968a; Stoneman and Diederen, 1994). Again, this is a false attribution (Godin, 2014). Finally, the "stage model" of sociologists, or phase theorem as some others call it (Witte, 1972), is certainly an influential model, as we will see below, but rarely part of typologies, stories and reviews of models of innovation.

When did models of innovation come to life, and why has the word model entered the vocabulary of STS? This section offers a genealogy of the idea of and vocabulary of models of innovation back to rural sociology.

Prehistory

The origin of models of innovation is the study of innovation as a process. Beginning in the 1940s, rural sociologists began theorizing about the diffusion of new practices in

[4] I myself attributed the model to Bush several years ago.
[5] In the face of criticisms, David Edgerton has changed his thesis more recently: the linear model has simply never been *used* (Edgerton, 2010; see also Clarke, 2010).
[6] Research cycle (Holland, 1928), flow of ideas (Machlup, 1962), linear sequence or formulation or scheme (Allen, 1967a; 1967b), chain or spectrum (Goldsmith, 1970; Blackett, 1968), assembly line (Wise, 1985), rational model (Schon, 1967), hierarchical model (Barnes, 1982), pipeline model (Schmidt-Tiedeman, 1982), stage model (Saren, 1984; Forrest, 1995). "Linear model" began to be used in the late 1960s (Allen, 1967a; Price and Bass, 1969; Langrish *et al.*, 1972).

farming. To this end, and following the anthropologists (Godin, 2014), they imagined sequences and stages through which an innovation is adopted and diffuses over time, from an individual or innovator to the rest of a community (for a detailed history, see Godin, 2015a). [7] As Herbert Lionberger, professor of rural sociology at the University of Missouri put it in 1965 (Lionberger, 1965 31):

> Time and sequence considerations inherent in the process concept offer important suggestions for change agents. The time idea implies the need for sustained effort over an extended period of time before action results can be expected; and the "sequence of influence" idea implies the need for proper ordering of many educational efforts to achieve action ends.

Rural sociologists George Beal and Joe Bohlen's, Iowa State College, Ames, five-stage sequence of the mid-1950s has been influential here. The adoption of innovation goes thought a mental process composed of five stages: awareness, interest, evaluation, trial, adoption (Beal and Bohlen, 1955; 1957). The sequence culminated in Everett Rogers' classical formulation (Rogers, 1962).

At about the same time, economic historian Rupert Maclaurin and his colleagues at MIT also began theorizing about the process of technological innovation in terms of sequence and stages (Maclaurin, 1949). To Maclaurin, technological innovation is 1) a process, 2) a sequential process in time, 3) a process that starts with science (basic research), and 4) whose ultimate stage is commercialization. An idea that has lately come to be called "linear model of innovation" (Godin, 2008). Thereafter, technological innovation is theorized as a process with stages in every discipline, from management [8] and marketing [9] to sociology, [10] history, [11] economics, [12] policy [13] and others. [14]

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[7] Stages have a long history in the literature, e.g. philosophy/Scot enlightenment (Meek, 1976), economic/German school (Hoselitz, 1960) and social evolutionism (Nisbet, 1969). Stages abound in psychology, education, policy, decision-making and communication too.

[8] Carter and Williams (1957), Myers and Marquis (1969), Utterback (1971a; 1971b), Morton (1971), Zaltman (1973).

[9] Robertson (1971).

[10] Langrish et al., (1972), Mulkay (1975), Barnes (1982), Pinch and Bijker (1987).

[11] Kelly and Kranzberg (1975), Staudenmaier (1985).

[12] Mansfield (1968), Freeman (1974).

[13] For sources, see Godin (2015a).

[14] Tornatzky et al. (1983), Rothwell and Zegveld (1985).

Defining innovation as a process is a Twentieth century ‘innovation’. Herein lies a semantic ‘innovation’, an ‘innovation’ that has had a major impact on the modern representation of innovation (Godin, 2015b). Until then, innovation as a concept is either a substantive (novelty) or a verb (introduction, adoption), an end or a means. Sometimes it is also discussed in terms of a faculty (combination, creativity), an attitude (radicalism) or aptitude (skill) or quality (creativity, originality, departure, difference):

> Substantive: novelties (new ideas, behaviours, objects)
>
> Action: introducing (or bringing in) something new
>
> Process: a sequence of activities from generating ideas to their use in practice

Since the 1950s, innovation has been studied as a “process”, a sequential process in time. Innovation is not (just) a thing or a single act but a series of activies or a sequence of events. The nuance between innovation as a verb and innovation as a process is not as clear-cut as it might appear at first sight. This is not unlike innovation as substantive or verb. In fact, innovation is an abstract word that admits of two meanings: action (introduction of a novelty) and result/outcome (the novelty itself). For example, sociologists use innovation as a substantive but focus on the verb (diffusion). Similarly, economists stress the verb form (commercialization). Be that as it may, innovation as a process contributed to giving the concept of innovation a very large function: innovation encompasses *every* dimension of an invention, from generation to diffusion (Godin, 2015c).

It is precisely the view of innovation as a (sequential) process that gave rise to analytical models of innovation. However, before the 1960s, there was little talk of “models”. The terms used to talk of the innovation process were theory, pattern, approach, scheme, paradigm, framework, representation, perspective, notion, hypothesis, schema, figure, and diagram. Similarly, sequence and stages were talked about using terms like period, phase, step, cycle, flow, chain, spectrum and continuum.

A few exceptions deserve mention. In 1957, George Beal published a paper titled *How Does Social Change Occur?* To answer these questions, Beal offers a “construct” or “framework” for the analysis of social action”, or “model” as he calls it, “whose proper use … increases the chances of reaching the social action desired most effectively” (Beal, 1957: 18). The model is a time “sequence”, a “flow of actions or a process from the inception of an idea to final implementation”. Beal’s model, pictured graphically on two pages, is composed of thirty one “stages”. The year later, at a symposium on decision-making, Beal made a call to “develop our theoretical models [of stages of adoption] and define our concepts” better (Beal, 1958: 51).

That same after, Frederick Emery and Oscar Oeser develop a “model … stated diagrammatically” of factors influencing the adoption of new farming techniques and composed of four steps: present situational supports for motivation, receptivity to new ideas, communication behaviour (exposure), adoption (Emery and Oeser, 1958: 11-12). The entire book is concerned with measuring these factors. A year later again, in a critical note on the rural sociologists’ five-stage process of innovation, Edward Hassinger, University of Misssouri, criticizes the emphasis put on the first stage – awareness – to the detriment of later diffusion. Hassinger talks of the “stages of adoption” as a “useful model” and “the stage model” as an effective teaching device (Hassinger, 1959: 52). To another sociologist, James Coop, a model – never defined – is nothing else than a series of explanations or hypotheses, tested empirically, on the information sources available at different stages of the five-stage “conceptual framework” (Copp et al., 1958).

One use of the term that preceeded the above socologists is that of economist Yale Brozen. In a review of studies of “technological change”, Brozen summarizes the results of studies on the employment consequences of technological change. To Brozen, “Schumpeter’s model is the most complete we have for studying the determinants of the rate of technological change” (Brozen, 1951b: 449). [15] However, Brozen argues for multiple models rather than one complex model: “no model will readily serve all

[15] To the best of my knowledge, Joseph Schumpeter was the first to have used the term model in the literature covered here (Schumpeter, 1939: 130-38).

purposes unless it is complicated to the point of incomprehensibility" (Brozen, 1951b: 450). In conclusion, Brozen announces a model of his own. His paper *Invention, Innovation and Imitation* of the same year is that analytical model (Brozen, 1951a), what came to be called "tripartite model" later on. [16]

Yet, in general, the theorists' conceptualization of the innovation process in terms of stages is not a model. Beal and Bohlen's theory or approach by stages is called alternatively a "framework" (Beal and Bohlen, 1957: 2) and a "theoretical construct" (Beal, Rogers and Bohlen, 1957: 166). Before that, Eugene Wilkening, from the University of Wisconsin, Madison, reported the results of a five years study on the "process" of acceptance of new technology among farmers. To Wilkening, adoption is a process of "decision-making". This process is "composed of learning, decision and action over a period of time" that "may be broken down into four main stages": initial knowledge, acceptance (of the idea), trial, adoption (Wilkening, 1953: 9). Then Wilkening offers a "framework", not a model, put in the form of a figure or "schematic diagram" of the four stages and factors that influence the process of acceptance. To the best of my knowledge, Wilkening's is the first schematic representation of the sequence of diffusion (Table 1).

[16] To Brozen, there are three "levels" or roles of technological change in economic growth, all interrelated (the "movement" of one is reflected in the others): what is technologically possible (invention), what is possible with techniques currently used (innovation) and what is occurring in the economy as a whole (imitation).

Table 1.

Eugene Wilkening's Process of Innovation

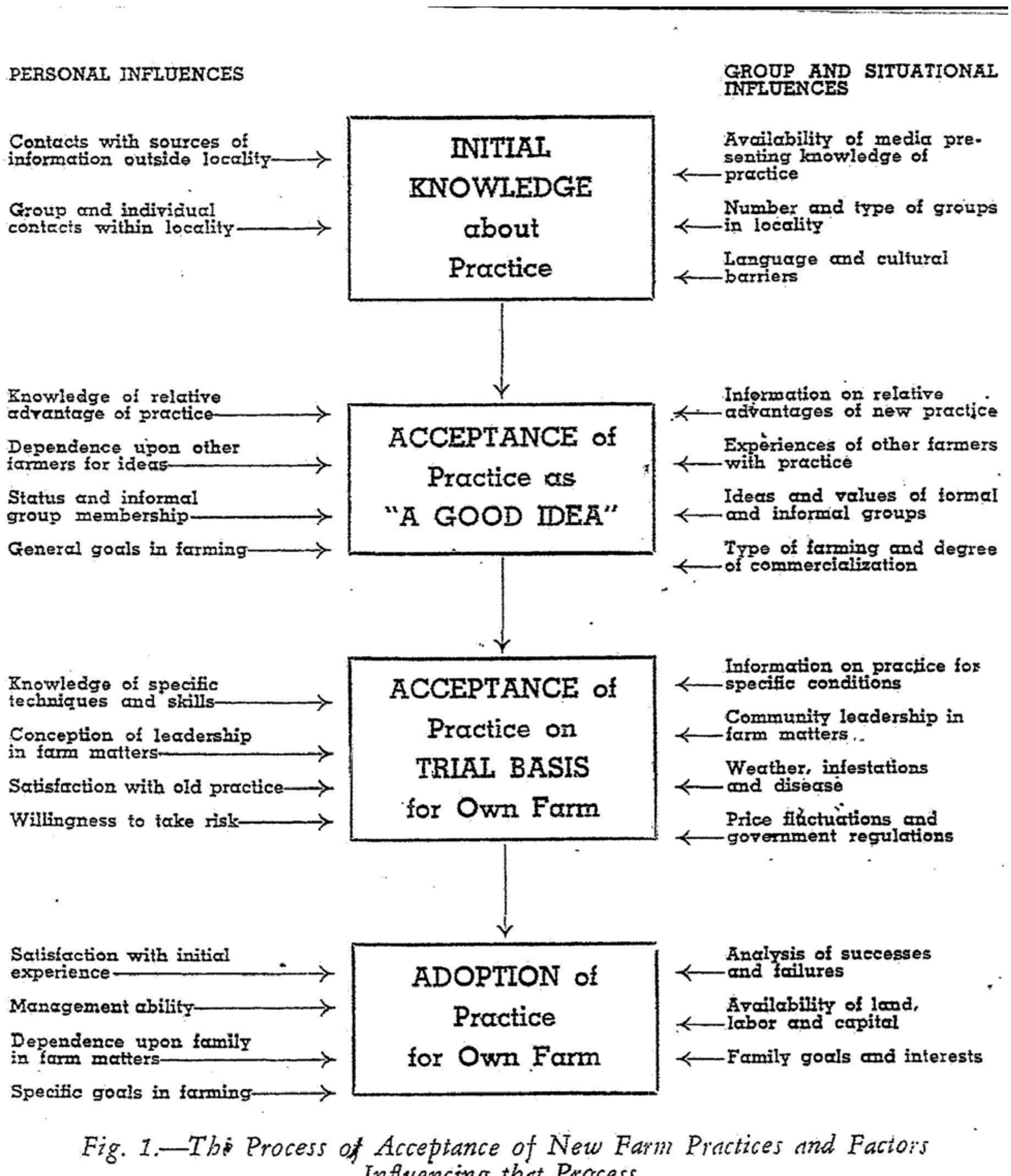

Fig. 1.—The Process of Acceptance of New Farm Practices and Factors Influencing that Process.

In the same vein, in 1962, Rogers did not use the term model for his approach – neither in his empirical papers of the 1950s. He offers a "paradigm" (antecedents, process, results), put into schematic form, that "owes certain ideas … to [previous] models" (Rogers, 1962: 305, footnote; 306). [17] The term paradigm shares a place with "framework" and "approach" to a theory (Rogers, 1962: 308). To Rogers, the "framework suggests (1) generalizations that have been tested in previous research and summarized here, or (2) hypotheses capable of being tested by empirical means" (Rogers, 1962: 308). In the chapter with Eugene Havens on predicting innovativeness, the term appears several times and stands for statistical models, such as multiple correlation. The authors suggest that "it is now time to set forth a model to explain theoretically how the adoption of an innovation takes place in a social system" (Rogers, 1962: 296).

Rogers introduced the term model for his own conceptualization in 1971, with no explicit definition. First, he discusses the "conceptualization" of the adoption process in five stages as a "model", then introduces his own "model" or "conceptualization" composed of four "functions or stages", [18] "depicted in a figure" titled "Paradigm of the innovation-decision process" (Rogers and Shoemaker, 1971: 100f). Second, Rogers discusses existing "conceptualizations" of the mass communication process, under what he calls "models of mass communication flows" (Rogers and Shoemaker, 1971: 203-209). [19] Rogers' first explicit definition of model was in 1977, together with theoretical discussions on models as such (Rogers, Eveland and Klepper, 1977: 61f).

> Models are sets of symbols, of concepts abstracted from the real world, which are organized together to represent a problem. Any interaction of concepts can be represented as a model … Models are never true or false – rather they are simply more or less useful.

Another influential sociologist, Elihu Katz, talks of the "elements" that composed the diffusion process as a "conception", "a kind of 'accounting scheme'", not model (Katz, Levin and Hamilton, 1963: 240). Overall, there is no difference between a study on the

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[17] What does model mean to Rogers here? Rogers' cited references are unpublished material, but two: the analytical model of Emery and Oeser (1958) and the statitiscal model of Milton Counghenour (1960).

[18] Knowledge, persuation, decision, confirmation. Also discussed in terms of antecedents, process, and consequences.

[19] Hypodermic needle model, two step flow model, one step flow model, multi-step flow model.

stage "process" and a study on the stage "model". Both include a sequence, a set of variables responsible for the sequence and a figure.

Inventing Models

With time, models took a fundamental place in the vocabulary of social theorists (Heyck, 2014), and the theorists of innovation are no exception. The process of innovation in terms of stages came to be called "model" (Bohlen, 1964; 1967; Havens, 1965; Lionberger, 1965; Campbell, 1966; Rogers and Shoemaker, 1970). "I do not claim", states Bohlen in a paper on *Needed Research on Adoption Models*, "that this model [the five-stage process] is the final answer for the understanding of the adoption process. [However], it appears to be consistent with some theories of learning and the way in which man thinks" (Bohlen, 1964: 271).

From the 1960s onward, the theorists of innovation gradually began to produce models, using the term as such (Table 1), some producing many versions of the same model over time (Rupert Maclaurin, Everett Rogers, James Allen, Richard Daft). Sociologists have continued to be productive, but management and business schools have joined the efforts of sociologists early on. In fact, sociology and management are the most productive of models over the period studied herein.

A special issue of *Journal of Business*, published in 1967, has two papers that develop models. Kenneth Knight, School of Business, Stanford University, reviews studies on innovation in sociology, psychology and economics and develops a typology of "types of search" (strategies of innovation) that he combines into a "general model of organizational search" as a "framework that describes the organizational environment" (Knight, 1967: 486). The model is put into a figure (boxes and arrows: three strategies leading to different types of innovation and radicalness). The other article is from two colleagues of Knight from the same department. Selvin Becker and Thomas Whistler developed an analytical model of the innovation process in organizations according to the type of search, such as Knight had done: routine or programmed innovation, non-routine innovation – slack (successful) or distress (unsuccessful) innovation. The model "serves as a framework that describes the organizational environment", and is pictured graphically (Becker and Whistler, 1967: 487).

Table 1.

Early Models (called as such)

1950s	1960s	1970s
Bohlen, 1957	Coughenour, 1960	Becker, 1970
Copp et al., 1958	Rubenstein, 1962, 1969	Slevin, 1971; 1973
Emery and Oeser, 1958	Morton, 1964; 1967, 1968	Utterback, 1971
	Campbell, 1966	Morton, 1971
	Becker and Whistler, 1967	Robertson, 1971
	Allen, 1967	Crane, 1972
	Knight, 1967	Burt, 1973
	Baker et al., 1967	Zaltman et al., 1973
	Gellman, 1967	Haeffner, 1973
	Havelock, 1967	Rothwell and Robertson, 1973
	Robertson, 1968a; 1968b	Ross, 1974
	Mason and Halter, 1968	Mulkay, 1975
	Clark, 1968	Burns, 1975
	Gruber and Marquis, 1969	Bingham, 1975; 1976
	Havelock, 1969	Ettlie, 1976
	Becker, 1970	Daft, 1978

Echoing Sumner Myers on the need to "construct a theoretical model" (Myers, 1967: I-2), a study produced by the National Planning Association and funded by the US National Science Foundation talks of "patterns" or kinds of information acquisition or transfer, not of models (National Science Foundation, 1967). Yet the report includes two chapters on "models" as such. The first is from Jack Morton, father of the transistor, who suggests a model of the innovation process that helps you "think about the parts in relation to each other and to the whole" (Morton, 1967: 23). In 1964, Morton began discussing models in several papers. Morton's model, whose exemplar (model) is the Bell

System, is “ecological” or “systemic”, “a model of a total process, all parts of which are related” (Morton, 1964: 82), from basic research to commercialization (Morton, 1967: 26), namely “the totality of human acts by which new ideas are conceived, developed and introduced” (Morton, 1971: 3). Morton introduces a new kind of model here, different from the stage model of sociologists. Morton’s model is a system and its constituents, rather than a sequence, whose essential part is the linkages between the components (input, organization, output). The other chapter is from another practitioner, Aaron Gellman, Vice president, North American Car Company, who develops the idea of an indicator on the “propensity to innovate”. To Gellman, model refers to a perspective on the role of individuals in low innovative firms, as contrasted to more ‘advanced’ organizations (Gellman, 1967).

Another management study of the time includes several discussions of models as “attempts to provide a framework for further analysis” (Gruber and Marquis, 1969). The introduction discusses technology transfer in terms of three alternative “models”: communication paths or flows (from science to technology to use), sequence of events (stages from idea to production), transfer process (a set of factors). In a subsequent chapter, philosopher Stephen Toulmin discusses the process of innovation (defined largely) in analogy to the biological model: mutation, selection, diffusion. William Gruber and Donald Marquis conclude the book with a four-stage model or “diagram” fusing technical feasibility and demand.

At about the same time, model also entered governmental organizations. In *The Management of Innovation in Education*, the OECD offers a “model approach for the process of innovation in education” (OECD, 1969: 20-25). The organization discusses “innovation as a five-phased sequence … from planning to diffusion”. To the organization, this sequence is “a working-model which may serve as a check list for innovators”. To the OECD, the idea of phases serves to plan innovation.

From the 1970s, models began multiplying in literature. Most, if not all, analytical models are alternatives to the linear model of innovation. Secondly, a new type of models appeared: system models replaced sequential models (Table 2). System models, as Jack Morton puts it, look at the whole and parts, or the constituents of a system, their relationships and the factors as causes, rather than sequence in time. [20] They are a kind of model that became commonplace among writers on industrial innovation and national systems of innovation in subsequent decades.

Table 2.

Types of Models

Historical or developmental (a sequence of events)
Functional or managerial (a sequence of activities in decision-making)
Causal (a system, its components and their relationships)

Giving Life to Models

Two factors contributed to give social existence to models. The first was reviews. By the 1960s, models had been developed to a point that a series of reviews appeared in literature (Table 3). In fact, reviews appeared a few years only after the first models, labeled as such. One of the first reviews, if not the first, was from Robert Chin on models of "human events", in a book on planned change (Chin, 1961). Chin looks at analytical models in vogue in psychology, sociology, anthropology, economics and political science, that he sums up to two – and to which he adds his own:

Developmental models
System models (and intersystem models)
Model for changing

Development models stress change (growth and decay) and system model stability (equilibrium). Chin summarizes critically the assumptions and concepts used in the models (like stage and feedback). To Chin, "an analytical model is a constructed

[20] See also Schon (1971), Burns (1975).

simplification of some part of reality that retains only those factors regarded as essential for relating similar processes" (Chin, 1962: 202).

The next review comes from the consultant firm Arthur D. Little, in a study on educational innovation conducted for the US Office of Education, Department of Health, Education and Welfare (Arthur D. Little, 1968). The report surveys six "prototypical models" of the adoption process which "all fail to qualify as a general model":

Rational change process model
Response to a need model
Internal change agent model
Lighthouse model
Outside agent model
Incentives for change model

To the consulting firm, the sources or inventors of the models reviewed are not mentioned. Model is an anonymous beast, like it is to Chin. Yet, like Chin again, the report brings forth a definition of model, one of the few definitions at that time. A model is a "description of the way things actually happen, as concepts of the way things are thought or believed to happen, as descriptions of the way adoptions ought to happen, or as descriptions of what should be done to increase the rate of innovation adoption" (Arthur D. Little, 1968: 8).

The following years, Ronald Havelock, University of Michigan, a prolific writer on knowledge transfer, offered a review of existing models of change – called models of innovation in a later talk (Havelock, 1974) – that he sums up to three (Havelock, 1969: 2.40-2.43): [21]

Social interaction model (diffusion)

[21] In 1967, Havelock surveyed the models of factors involved in knowledge utilization as composed of two types: system model and process model (Havelock and Benne, 1967).

R, D and D model (research)
Problem-solver model (needs of clients)

To Havelock, models are "points of view". "We have identified three distinct points of view toward D&U [dissemination-utilization] represented in the models, theories and analyzes of different authors. We are going to use the word 'model' for each of these points of view because each designates a complete conceptual system within all of the facts pertinent to D&U can be ordered" (Havelock, 1969: 2-40). In contrast to Arthur D. Little, Havelock studies the several authors responsible for the three models at length (mainly from psychology and sociology).

Table 3.

Reviews of Models

1960s
Chin, 1961; Allen, 1967; Arthur D. Little, 1968; Havelock, 1969

1970s
Robertson, 1971; Langrish et al., 1972; Chakrabarti, 1973; Roberts and Romine, 1974; Rogers et al., 1977

1980s
Tornatzky, 1983; Sarren, 1985; van de Ven, 1989

1990s
Forrest, 1991; Rothwell, 1992

Arthur D. Little and Havelock were preceeded by James Allen, professor of Chemistry, University of Newcastle, Australia. On a leave from Newcastle to the University of Manchester, Center for Business Research, Allen produced two books (Allen, 1967a; 1967b). In *Scientific Innovation and Industrial Prosperity* Allen surveys current "models of innovation", that he sums up to the "linear model" or "scheme" ("the most commonly advanced scheme") that he calls the "Right to Left model". Like Arthur D. Little, Allen's models are anonymous. As an alternative to that model (e.g. "a straighforward time sequence"), Allen introduces the "Wheel, Hub and Axle model". The latter puts investment at the center of the model and involves multiple interactions between the components (Allen, 1967a: 19-30).

The above reviews deserve mention for several reasons. First, they indicate that (the idea or concept of) model was taken for granted by many in the 1960s, despite the limited number of models that existed. Second, the basic model is the linear model, under different names. The stage model of sociologists is rarely mentioned, even discussed, with the exception of Chin and Havelock, and would continue not to be mentioned in subsequent reviews. Third, the reviews are witness to a search, early on, for alternatives to the linear model. For example, by the late 1960s "need" rather than research as a factor responsible for technological innovation was taken for granted by many, particularly in management, evaluation studies and studies of knowledge transfer (Godin and Lane, 2013).

Reviews continued to appear in the 1970s and 1980s, of which those from John Langrish et al. and Roy Rothwell have been influential. Langrish et al. define a less refined typology than Arthur D. Little and Havelock do – a dichotomy: discovery-push model and demand-pull model. The authors never define explicitly what a model is. One may infer from their few remarks that a model is "a neat order of conceptual scheme [placed] on the chaos of observation" (Langrish et al., 1972: 2) that serves as "assumptions" for policies (Langrish et al., 1972: 72). In the years that followed, every theorist who developed a model developed a typology of models (Table 5). The epitome model, presented as if definitive, is always the more recent one or one's theorist model, and is labeled with as many different names as there are theorists. Most authors agree on the absence of a definitive or generalized model. Rothwell was witness to the lack of consensus. He developed a typology composed of five "generations" of models (Table 4) – that culminates with the current representation of innovation: a system model

(Rothwell, 1992). Rothwell’s typology was regularly reproduced in the following years (Senker, 1995; Marinova and Phillimore, 2003; Tidd, 2006).

Table 4

Rothwell’s Generations of

Models of Innovation

First generation
Technology-push: Simple linear sequential process. Emphasis on R&D. The market is a receptacle for the fruits of R&D.

Second generation
Need-pull: Simple linear sequential process. Emphasis on marketing. The market is the source of ideas for directing R&D. R&D has creative role.

Third generation
Coupling model: Sequential, but with feedback loops. Push or pull or push/pull combinations. R&D and marketing more in balance. Emphasis on integration at the R&D/marketing interface.

Fourth generation
Integrated model: Parallel development with integrated development teams. Strong upstream supplier linkages. Close coupling with leading-edge customers. Emphasis on integration between R&D and manufacturing (design for easy manufacturing). Horizontal collaboration (joint ventures, etc.).

Fifth generation
System Integration and Networking models (SIN): Fully-integrated parallel development. Use of expert systems and simulation modeling in R&D. Strong linkage with leading-edge customers (customer focus at the forefront of strategy). Strategic integration with primary suppliers including co-development of new products and linked CAD systems. Horizontal linkages: joint ventures, collaborative research groupings, collaborative marketing arrangements, etc. Emphasis on corporate flexibility and speed of development (time-based strategy). Increased focus on quality and other non-price factors.

A second factor contributed to give life to models: attribution. Model is so important an idea (and term) that theorists began attributing models restrospectively to some who had never used the term. For example, in 1964, Max Heirich analyzed theories of social change and their concern with time: evolutionism, diffusionism, social history, Marxism, functionalism and historical philosophy. In retrospect, Heirich talks of those theories as “models” (Heirich, 1964). Others attribute a model, together with a figure, to anthropologist Homer Barnett for his much cited theory of innovation (Barnett, 1953) – a term Barnett never uses and a figure he did not produce (Chakrabarti, 1973: 113-14) –, or to Rogers' book in 1962, which does not use the term for analytical models (Larsen, 1962: 20; Engel, 1968: 550, 553; Ozanne and Churchill, 1971: 322; Chakrabarti, 1973: 115; Ettlie, 1976: 62,66), or to the National Academy of Sciences' seven stages of the research and development (R&D) process (Layton, 1977).

Philosopher John Dewey receives the same kind of attribution from sociologists for his stages of reflexive thinking (e.g. Hassinger, 1959; Lionberger, 1960; Rogers, 1962), as does Sumner Myers and Donald Marquis' (1969) figure of the process of innovation from management (Chakrabarti, 1973). [22] "All tend to agree", believe many theorists, "on some version of the [Myers-Marquis] model" (Goldhar et al., 1976: 52). Rothwell's own model, put into a figure, is more or less a *replica* of Myers and Marquis (Rothwell and Robertson, 1973). [23]

One more attribution that deserves mention is Richard Nelson's much cited theory of innovation (Chakrabarti and Rubenstein, 1976; Coombs et al., 1987). Rod Coombs and his colleagues construct a schematic model of Richard Nelson and Sidney Winter's theory (1974; 1982), a picture that is absent from the book (Coombs *et al.*, 1987: 117). To be sure, Nelson and Winter's work is situated entirely within the vocabulary of models, including the authors' own theory: an "evolutionary model" of economic growth. Yet, to Nelson and Winter, a model is a "style" one may unearth from a certain number of theories. According to them, a model is a conceptual scheme embodied in a simulation equation program, not a schema.

[22] Chkrabarti also attributes a model to many others: Gruber and Marquis and March and Simon (Chakrabarti, 1973) and Nelson, Peck and Kalachek (Chakrabarti and Rubenstein, 1976).

[23] Rothwell's study is an ideal article for the study of how ideas travel (anonymously) between disciplines. First, Rothwell offers a figure as model, a figure which is a replica of Myers and Marquis (1969)'s figure, without mentioning the source. Second, Rothwell studies the sources of ideas in technological innovation – *sources of ideas* being here analogical to *sources of information* in diffusion studies from sociologists, again with no reference to that literature.

Table 5.
Typologies of Models

1960s	1970s	1980s	1990s	2000s
Developmental model System model Model for changing Chin, 1961	Simple reflex model Rational problem solving model Havelock, 1970	Hierarchical model Interactive (or symmetrical) model Barnes and Edge, 1982	Stage model Conversion model Technology push/Msarket pull model Integrative model Decision model Forrest, 1991	Linear model Interactive model System model Evolutionary model Marinova and Phillimore, 2003
Left to Right model Whell, Hub and Axle model Allen, 1967	Adoption process model Hierarchy to effects model AIDA model [24] Robertson, 1971	Pipeline model Systemic model Combined model Concomitance model Schmidt-Tiedeman, 1982	Linear model Cyclic model Neural net model Ziman, 1991	Institutional design model Institutional adaptation model Institutional diffusion model Collective action model Poole and van de Ven, 2004; Hargrave and van de Ven, 2006
System model Process model Havelock and Benne, 1967	Center/periphery model (Learning) system model Schon, 1971 Rational/experimental model Projective model Schon, 1971	Technology source-centered model Technology user-centered model Tornatzky, 1983	Linear model Interactive model Newby, 1992	Linear model Chain-linked model Multi-channel interactive learning Caraça et al., 2009

[24] AIDA: Attention, interest, desire, action.

Organic growth model Differentiation model Diffusion model Combined-process model Clark, 1968	Cumulative (sequential) model Random model Logistic curve model [25] Crane, 1972	Department-stage model Activity-stage model Decision-stage model Conversion process model Response model Saren, 1985	Technology-push model Market-pull model Coupling model Integrated model Strategic integration and networking model Rothwell, 1992	
Rational change process model Response to a need model Internal change agent model Lighthouse model Outside agent model Incentives for change model Arthur D. Little, 1968	Discovery-push model [26] Demand-pull model [27] Langrish et al., 1972	Linear model Chain-linked model Kline, 1985; Kline and Rosenberg, 1986	Linear model Systemic model Freeman, 1996	
Social interaction model R, D and D model Problem solver model Havelock, 1969	Individual oriented model Organization oriented model Zaltman, 1973	Linear model Evolutionary model Epidemic model Coombs et al., 1987	Linear model Linear-plus model Tait and Williams, 1999	
Rational model Nonrational model Schon, 1969	Decision chain model Development stage model Functional model Department model R&D model Roberts and Romine, 1974	Linear model Multidimensional model Pinch and Bijker, 1987		

[25] This label is mine.
[26] Two types: "science discovers, technology applies" and"technological discovery"
[27] Two types: "customer need" and "management by objectives"

	Process-phase model Flow model Kelly and Kranzberg, 1975	Group development model Decision process model Organizational planning model Organizational change and development model Innovation process model van de Ven et al., 1989		
	Bureaucratic model Management model System model Burns, 1975	Historical model Functional model (Emergent) Process model van de Ven et al., 1989		
	Model of openness Model of closure Model of branching Mulkay, 1975			
	Static model Process model Rogers et al., 1977			
	Manufacturer-active model Customer-active model von Hippel, 1979			

The Thing in the Model

From the above survey, model has a diversity of meanings and functions and no theorist agrees on a specific definition, as Brodbeck stated in 1959. Model is a beast not easy to define. More often than not, a writer takes what a model is for granted. Eugene Havens, who collaborated to a chapter in Rogers' *The Diffusion of Innovation* in 1962, is an exception. [28] Bohlen never defines explicitly what he means by model – certainly not a mathematical or empirical model. In fact, that "the basic model is still valid" (Bohlen, 1967: 123) refers to the theory or approach by stages, rarely called a model until that time.

In the literature studied here, a model is talked of or 'defined' according to several dimensions:

Concretely: an equation, a figure.
Abstractly: a theory, an approach.
Functionally: a heuristic, an ideal-type.

This section tries to make sense of the vocabulary of model, and suggests five meanings of model as they exist in the literature on innovation.

A Conceptualization

The standard view of what a model is is a set of variables and their relationships. A model is a representation that abstracts some essential explanatory factors of a phenomenon and depicts their relationships, a representation of reality – in a simplified form. As Roland Mueller, on the history of the concept, summarizes it: "A model is a

[28] "A model serves several basic functions. It clarifies the main concepts, defines the dimensions and limits of the research area, sets forth crucial assumptions, and states the theoretical propositions and their operational hypotheses to be tested. A model "provides a frame of reference and a directive for the collection and analysis of data to answer research questions" (Havens, 1965: 151). To Havens, models are statistical models or models for measurement, as his "prediction model" is. For some early statistical "models" on diffusion of innovation from sociology, using the term model as such and put into a schematic figure, see Dodd (1955), Coughenour (1960), Mason and Halter (1968), Burt (1973).

simplified part of reality or potentiality. It can be material or materialistic, graphic or abstract" (Muller, 2004: 241). STS scholars share this view. Models are "complex patterns of relationships among a large number of key variables" (Corwin, 1974; see also Chin, 1961). But this is exactly what a theory is, as Brodbeck suggested in 1959. [29] In a recent survey Gabriel Abend identifies several meanings of theory – every one applies to model, as we will see below: a general proposition, or logically-connected system of general propositions, which establishes a relationship between two or more variables; an explanation of a particular phenomenon, with factors or conditions as causal; an interpretation, reading or way of making sense; the writings of some emblematic authors; an overall perspective or framework form which one sees and interprets the world (Abend, 2008).

Why call a theory a model? To many, a model does not have the same scientific status or rigor as a theory. Qualifications are always added. Such was the case with sequences and stages in rural sociology, which were criticized on two grounds from the start – the initiating factor or stage and the linearity of the sequence –, exactly as models were criticized in subsequent years. An early qualification on sequence and stages comes from James Green and Selz Mayo, North Carolina State College, on the posited stages of the sociologists' innovation process sequence. Green and Mayo claim that "in practice their order is not invariant and the distinctions between them are not always recognizable" (Green and Mayo, 1954: 323). Herbert Lionberger's *Adoption of New Ideas and Practices*' aim is to summarize the research done on diffusion. Lionberger starts with the idea of diffusion as a process over time, composed of "a series of distinguishable stages" – "operating through time rather than an abrupt metamorphosis", those of Beal and Bohlen. The stages, according to Lionberger, "are not necessarily a rigid pattern which people follow" but "represent five sequences that can be clearly identified very frequently" (Lionberger, 1960: 4), a statement that recurs again and again in subsequent literature. The stages are "a rough general approximation of the typical decision pattern" (Lionberger, 1960). According to Lionberger (Lionberger, 1960: 23-24), stages:

[29] To Brodbeck, model is used for theories that are 1. uncertain (untested), 2. selective (equivocal or partial), 3. ideal and 4. quantified. All characteristics apply to a theory (Brodbeck, 1959: 381-83).

> do not necessarily represent discrete, or distinctly separate stages … Nor is it implied that that they are universally followed by all people in all of the decisions they make, or that these are the most appropriate stages to use. What these stages do represent is a useful way of describing a relatively continuous sequence of action, events, and influences … Not all decisions involve a clear-cut 5-stages sequence.

This is quite a different statement than that from Beal and Bohlen, to whom the five stages "are not merely theoretical, but actually are real in the minds of farm people" (Beal and Bohlen, 1957: 3). To Lionberger, the idea of a five-stage process has two aims: theoretical (it gives "depth and meaning to research and permit generalizations") and practical (it makes "possible more effective and efficient actions"). It provides "a framework for defining sequences of influences" (Lionberger, 1965: 32-33).

To Rogers, "the stages are arbitrarily broken down … for conceptual purposes" or "ease of conceptualization … and for practical applications … More or fewer stages might be postulated" (Rogers, 1962: 79). Like discrete "adopters categories" in terms of time of adoption (Rogers, 1958a: 346; 1958b: 331), [30] Rogers' five-stage process is a "heuristic" device. Rogers made qualifications again in the 1970s, on the number and the linearity of stages (Rogers and Shoemaker, 1971: 101; Rogers, 1976: 164; Rogers, Eveland and Klepper, 1977: 64-65). [31] To rural sociologist Rex Campbell, University of Missouri, Columbia, and his "model or paradigm", put into a figure and developed in reaction to the limitations of the "rational traditional model" (the sequence or adoption process in five stages), namely the lack of variability in decision-making or irrational adoptions, a model is a "heuristic device" [in terms of explanation] from which to measure actual decisions" (Campbell, 1966). To Bohlen too, in contrast to his claim made ten years earlier, the adoption process is not one composed of "stages through which the adopter passes in an irrevocable manner … The process is portrayed in stages for heuristic purposes" (Bohlen, 1967: 118). Bohlen adds that "the exact lines of demarcation between

[30] Categories are "a "heuristic device" because of the "ease with which the concept of time of adoption may be communicated to lay audiences and 'action' agents" (Rogers, 1958a: 346).

[31] Yet, at the same time Rogers claims that "the essential sequence cannot be short-circuited" (Rogers, Eveland and Klepper, 1977: 17).

the stages of the process are not nearly so amenable to empirical verification … Any given individual may, in this manner, go back and forth …" (Bohlen, 1967: 119).

Such criticisms continued repeatedly concerning the "rational" or "simple", as it is regularly called, linear model of innovation – even starting decades before the use of the phrase "linear model". [32] The "widespread belief" that more research ensures more innovation, claims Bruce Williams, is "based on a simple model of the innovation process": research, development (invention), investment, new products/processes (Williams, 1967: 57). "The 'linear model' is not typical", state William Price and Lawrence Bass. "One appreciates the nonrational nature of the innovative process when one notes that the more novel the invention is, the less orderly … is the process" (Price and Bass, 1969: 803).

To some, the linear model of innovation is just an approximation. To others it is an idealized representation. To still others it is arbitrary and unrealistic, oversimplified, extreme and untypical, even harmful: [33] "Most researchers identify a series of stages … an ordered and rational process … [This] indicates more about the limitation of researchers that about the particular phenomenon of interest" (Kimberly, 1981: 91). Yet,

[32] "There is no exact order for the appearance of discovery and invention. They may be made simultaneously or they may precede or follow each other in any order" (Rossman, 1931). On the stages from research to adption of results by industry: "the line of demarcation … is seldom clearly defined" (Stevens, 1941). On the "continuous spectrum" from pure science to practical arts: it is "difficult to draw the line" – although "only by a continuous development of pure science can the practical arts advance" (Conant, 1948).

[33] The most well known critiques are from Price and Bass (1969), Langrish et al. (1972) and Kline (1985). Some others are: "The sequence … is not the usual way that innovation occurs": needs rather than research drives innovation (Hollomon, 1965). Stages are "in reality a series of approximations, with feedback" (O'Brien, 1962). "Interaction among the leading entities often provides a sounder first approximation that does linear causation" (Siegel, 1962). Innovation does not "proceed in a simple time sequence" (Allen, 1967a: 19). The rational model or view "function[s] as a device … an idealized after-the-fact view … as we would like [invention and innovation] to be so that they can be controlled, managed, justified" (Schon, 1969: 37). "It is useful when treated as something from which to deviate. It is false and harmful when treated as a hard-and-fast methodology or an accurate description of the process of innovation" (Schon, 1969: 41). Stages do "not always occur in the linear sequence …" (Myers and Marquis, 1969). "Not necessarily linear and unidimensional" (Robertson, 1971: 67). Not "necessary or invariant order of events" (Zaltman, 1973: 70). "Oversimplified early 'models' of innovation"; "extreme and untypical examples" (Rothwell and Zegveld, 1987).

the critics forget that every user of the model, with a few exceptions, [34] admits of qualifications. As Jack Morton put it: "It is useful to talk of the innovation process as it were an orderly sequence, always remembering that the ordering and timing of the various parts are neither rigid nor done only once" (Morton, 1971: 19-20).

Given the qualifications, what a model refers to? One common view, to repeat, is a representation [35] or rather a simplified representation of reality. [36] Such a definition of models is a *reliqua* of the old debate or speculative thoughts on realism from analytical philosophy, and before. [37] The diverse definitions of models from the theorists of innovation, both producers and users, rather sum up to a conceptualization. As Robert Roberts and Charles Romine put it in an early review of models: models are "conceptual structure or pattern … segregating the process [of innovation] into clearly defined segments and applying … descriptive labels that are meaningful" (Roberts and Romine, 1974). A few years before, Donald Schon offered a similar interpretation: a "conceptual picture of descriptions [of a "sequence of events"] which relate characteristics of action, situation and outcome at some level of generality" (Schon, 1971: 233).

A Narrative

Models as a set of variables and relationships do not tell the whole story. What about sequences and stages? These are not variables in this sense, but a conceptualization, a story, an order constructed or put over a sequence of events by the theorist.

[34] "The various phases of research and development fall into a logical and highly ordered sequence" (Scherer, 1959); "Innovation is a logically sequential, though not necessarily continuous, process, which can be subdivided into a series of functionally separate, but interacting and interdependent stages" (Rothwell and Robertson, 1973).
[35] "A model of R&D decision making in firm" put into a figure or "diagram", an "abstract representation of the major variables and relationships which constitute the framework for this study" (Rubenstein, 1962: 386). A "view" of the innovation process, a figure as an attempt at a "representation" of a complex process (Goldhar et al, 1976: 51, 57).
[36] Schumpeter's analytical "model" of economic change (also called "schema") is an "approximation", a "simplification", a "skeleton" (Schumpeter, 1939: 130). Models as simplifications of reality or ideal-types, "emphasizing a number of salient features" that one should not believe corresponds to reality: "models have some usefulness provided it is recognized at the outset that few, if any, are likely to be a fair representation in any universal sense" (Allen, 1967a: 27); a model "is unable to represent adequately more than a fraction of the kinds of cases which arise in every day experience" (Allen, 1967a: 22, 27).
[37] To artists and artisans of the previous centuries, a model is an imperfect imitation of something ideal, like nature.

Models are narratives. No one has put it better than Elting Morison, historian, founder of the MIT's program in STS (1976). In his study of the continuous-aim firing, Morison talks of the process of innovation in terms of a "chronological account" or narrative on a "sequence of events" (Morison, 1950: 599). In fact, this is how models of innovation began. Models of innovation are schematizations of stories or narratives on a sequence of events, what some call a "journey". [38]

It is rural sociologists Bryce Ryan and Neal Gross' and economic historian Rupert Maclaurin's stories that were lately put into schemas, retrospectively called models. In their influential paper of 1943 and those that followed, Ryan and Gross tell a story – together with numbers – along the lines of what is known, since the French sociologist Gabriel Tarde, as the geometric or diffusion curve with three "ages" or "phases": slow acceptance at first, followed by accelerated diffusion then stagnation or decline (Tarde, 1890: 182-86). The authors narrate the diffusion "process" (or "time pattern") in terms of the conditons and speed (or "time lag") with which the hybrid seed corn diffuses in two communities in central Iowa (Ryan and Gross, 1943). This allows them to make distinctions between first knowledge and first adoption of the new technique, between early and late adopters, between experimentation and complete adoption, distinctions that gave rise to time sequences, then stage models in sociology (Godin, 2015a).

Like Ryan and Gross, Maclaurin narrates a "historical account" of the "process of technological change" in the radio industry (Maclaurin, 1949; 1950). Maclaurin looks at how the scientists (M. Faraday, J. C. Maxwell, H. R. Hertz, J. J. Thomson, O. W. Richardson) were not consciously thinking about the commercial possibilities of their research, but how fundamental research was nonetheless vital to industrial development. Maclaurin then discusses the role of inventors (G. Marconi, R. A. Fessenden, L. De Forest) and the need for entrepreneurial skill, or the capacity to carry through a successful innovation, and for venture capital. To Maclaurin, history suggests a sequence in five

[38] The "innovation journey", whose stages are initiation, development and implementation/termination (van de Ven et al, 2008).

stages (fundamental research, applied research, engineering development, production engineering, service engineering), a sequence that later came to be called the linear model of innovation (Godin, 2008).

Such narratives are from from unique. Schumpeter's "pure model" is a "sequence of events" on the entrepreneurial activities, the followers and the effects on the industries. [39] Such narratives are far from being limited to early theorists. More recently, historian Thomas Hughes talks of "model" for (his narrative of evolution of) styles of electrical systems over time, whose phases are: invention, transfer, growth, momentum, quantitative change (Hughes, 1983).

A Figure

Conceptualizations, including narratives, are generally put into a figure: a set of boxes (variables) plus arrows (relationships between the variables), sometimes with numbers (correlations) added on the arrows. [40] Charts, diagrams and schemas have a long history in the literature on the management of R&D, starting with Kenneth Mees at the least, to whom industrial research "laboratories [are] organized into departments according to stages of application" (Mees, 1920: chapter 5; Mees and Leermakers, 1950: chapter 9), [41] Clifford Furnas' "flow diagram from research to sales" (Furnas, 1948: 4), Albert

[39] "The very sequence of events that we observe in the course of those fluctuations in economic life which have come to be called business cycles" (Schumpeter, 1939: 138).
[40] A "series of modules [boxes] of linked propositions", put in a pictorial form, or factors that influence innovation (Radnor and Rubenstein, 1970: 973, 975); a "modified model" (to the research tradition on diffusion of innovation that focuses on leaders (not marginals) as sources of innovation) put into a figure: four variables plus arrows plus correlation coefficients (Becker, 1970). A "conceptual model" of the innovation process in firms pictured in a figure (Rubenstein and Ettlie, 1979: 67, 75).
[41] "The increase in scientific knowledge can be divided into three steps: frist, the production of new knowledge by means of laboratory research; second, the publication of this knowledge in the form of papers and abstracts of papers; third, the digestion of the new knowledge and its absorption into general mass of information … The whole process, in fact, may be likened to the process of thought. We have first the perception by means of the senses. The percept is then stored in the memory and the mind is compared with other previously stored percepts, and finally forms with them a conception" (Mees, 1917: 519-20). The development department "develop [s] a new process or product to the stage where it is ready for manufacture on a large scale". It is "founded upon pure research done in the scientific department, which undertakes the necessary practical research on new products or processes as long as they are on the laboratory scale, and then transfers the work to special development departments which form an intermediate stage between the laboratory and the manufacturing department" (Mees, 1920: 79).

Rubenstein's "schematic diagram" of the R&D decision making (Rubenstein, 1962) and his "flow model representation" (Baker at al., 1967; Rubenstein, 1969), the product life-cycle and product development planning (Cox, 1967; Abernathy and Utterback, 1975). Figures have been produced and stand for models of innovation too – starting with Wilkening (1953), then National Science Foundation (1967), Allen (1967a; 1967b), Gruber and Marquis (1969), Myers and Marquis (1969), Rogers and Shoemaker (1971), Robertson (1971), Utterback (1971a; 1971b), Rothwell and Robertson (1973), Zaltman et al. (1973).

To many, a model is simply, as Jack Morton claims, "a picture of the process" of innovation (Morton, 1966: 23). Morton is right. Model is often a term introduced in the title of a figure or simply refers to a figure. The figure summarizes, and for this reason is more easily propagated among theorists. For example, a figure summarizes a mathematical model. Stuart Dodd's "general model" is "A [n algebraic] formula [or geometric curve] on six dimensions or classes of factors affecting diffusion (Dodd, 1955: 392, 397). Dodd concludes his paper with a figure summarizing the mathematical model ("Logistic Modeling [a curve] for Diffusion"). Milton Coughenour offers a statistical or "empirical model" (symbols with arrows) of information sources in the adoption process, measured, and "used to provide a more general interpretation of findings of other studies" (Coughenour, 1960: 283). Like Dodd, Coughenour ends his paper with an analytical model or figure that "presents graphically a summary of the theoretical relationships among these variables". Robert Mason and Albert Halter propose a mathematical model of diffusion, "not only a vehicle for illustrating the estimation procedure, but also illustrates how a system of interdependent equations can be justified and tested" (Mason and Halter, 1968: 185). The authors end the paper with a figure titled "Diagram of the Innovation Diffusion Model" (Mason and Halter, 1968: 193).

Yet, the theorists most productive of figures are the inventors of analytical models. A figure has two functions here: a schematic conceptualization, [42] of which Chris

[42] Terms sused are: "simplified schematic form" (Langrish et al., 1972), "schematic representation" (Rothwell and Zegveld, 1985).

Freeman's models are certainly emblematic examples, [43] or a summary of current views. [44] Yet, the figure is often just a toolkit. For example, Albert Rubernstein and John Ettlie's boxes are questions ("What can the government do …") and options ("a generalized list of 'decision points and actions'") (Ruberntein and Ettlie, 1970: 76).

A Tool

Early on, rural sociologists claimed that models are "heuristic" devices (Bohlen, Rogers, Campbell). They were followed by many others. Models are tools. [45] Yet, contrary to

[43] Freeman creates two schematic representations of Joseph Schumpeter's and Jacob Schmookler's "model" (Freeman, 1982: 212-13). As discussed above, Coombs et al. do the same for Nelson and Winter.

[44] A figure (which "presents graphically a summary of the theoretical relationships among variables") is "useful in portraying … findings", "useful as a device to present research findings pictorially … also … to stimulate and guide further investigation" (Coughenour, 1960: 296-97). A "conceptual framework … summarized in … a diagram, in which the arrow signify 'determine'" (Schmookler, 1962). Randnor and Tansik offers two conceptual "models" "summarized diagrammatically" in a figure: variables (boxes) and arrows or "a series of modules of linked propositions" (Radnor and Tansik, 1970). Figure on a "recursive model" = a summary of "past theory and research" on variables influencing the diffusion process (Burt, 1973: 128), followed by a "structural model" = a figure of these variables with correlation numbers (Burt, 1973: 140).

[45] "A useful tool" for studying the action of organized groups" (Green and Mayo, 1954: 327). A "useful as a device to present research findings pictorially" and "to stimulate and guide further investigation" (Coughenour, 1960: 297). "R and D as a continuous spectrum of activities that can for expository purposes be divided into disctrete stages" (Cherington, Peck and Scherer, 1962). "Stage formulation … lead[s] to operational suggestions", namely assigning different stages to different decision-making bodies (Miles, 1964: 650). "Utility" of the "process model": defining sequences of influences (Lionberger, 1965: 32). The process model from sociology as a "framework" to "change promotional efforts in education" (Lionberger, 1965: 43). "Schematic models … have some usefulness provided it is recognized at the outset that few, if any, are likely to be a fair representation in any universal sense" (Allen, 1967a: 22). "In spite of its limitations, the linear formulation highlights of important issues" (Allen, 1967a: 23). "Useful for emphasizing a number of salient features in the overall process" of innovation (Allen, 1967a: 27). "Useful as a source of hypotheses", "giving guidance and coherence to future efforts" (Havelock and Benne, 1967: 69); "A vehicle for illustrating the estimation procedure, but also illustrates how a system of interdependent equations can be justified and tested" (Mason and Halter, 1968: 185). "Enables managers to improve on existing process or to design better ones" (Morton, 1968: 60). Breakdown by stages is "somewhat arbitrary and unrealistic", but it has "sufficient pedagogic value" (Mueller and Tilton, 1969: 571). Phases are not academic but serve to plan or guide change and apply practical strategies (Havelock, 1969: 10-74, 10-75, 10-81, 10-89). Sequences "not always sharply defined"; nevertheless, "identifiable stages remain extremely useful" (Bright, 1969). "The gravest shortcoming of most of the traditional models [of innovation]: their reliance, implicit or explicit, upon a linear-sequential analysis of the innovative process". A "complex and dynamic ecological system … provides the best means for describing" innovation. "Each functional phase is linked in some way to the other". "A graphic portrayal of a plate of spaghetti and meat balls". "A scrambled model". "Innovation is a complex, highly interactive ecological system". "Nevertheless, the concept of process phases is valuable and valid structuring device" (Kelly and Kranzberg, 1975). Linear-sequential models are based on a priori assumptions. "Linearization is a way to simplifying data in order to manipulate it statistically" (Layton, 1977). A "conceptual model" on the innovation process in firms, "serving as a rough guide to our long-term program of investigations" (Rubenstein and Ettlie, 1979: 66).

other disciplines system theorists and mainstream economics, the theorists here do not *work* with models to *learn* about the world or a theory: how does one element vary when others change? What new relations are established? In other disciplines, "the model is worked through to reveal what constraints are entailed, how the interactions work, and what outcomes result from manipulating the relationships in the model ..., how the changes in the elements are bound by the relationships between the elements in the system" (Morgan and Morrison, 1991: 356). In contrast, a model of innovation is not an instrument to explore, manipulate and experiment a theory, to simulate the world and get better theories.

To be sure, several theorists conduct measurements of the variables in a model. But few users do so. To many a model is simply analytical – or graphical. What kind of tool is a model then? From the sample of theorists studied here (see footnote 44), a model serves at least two functions – a third function is mentioned occasionally only (statistical: manipulating data): [46]

1. Theoretical: structuring device; guide to investigation; simplifying research results.
2. Practical: pragmatic or operational value; guide to decisions and checklist; pedagogic; highlighting and emphasizing issues.

A Perspective (That Has Become Paradigmatic)

"A rough guide" to research, namely a list of "decision and action points" of the innovation process (Rubenstein and Ettlie, 1979: 66, 76). "These models are admittedly oversimplified … [Yet, a]s primitive as they may be, such models provide some conceptual guidelines for investigation of important areas" (Mogee, 1980: 259). "The concept of stages in innovation represents a way of organizing the many continuous decisions to be found in innovation processes. It is probably a distortion of reality, but a conceptual useful one … Stages are really only an intellectual tool to simplify a complex process … [I]n practice it may be extremely difficult to identify how decisions feed each other in a linear or logical sequence" (Tornatzky, 1983: 19). Ronald Corwin, to whom models are approaches, summarizes or rather includes all these views. To Corwin, models are: "Useful for both explanation and description", "Provide a basis for extending generalizations", "Summarize a comprehensive number of elements", "Help to guide research", "Serve a preliminary guide to research by identifying the variables that need to be measured and by providing a basis for anticipating and interpreting empirical relationships", "Establish guidelines for future research", "Serve as tools for integrating and interpreting the voluminous literature", "Facilitate the transfer of findings" (Corwin, 1974: 251-52).

[46] A third function is mentioned occasionally only: statistical (manipulating data).

Models are talked about using a fuzzy vocabulary. The reader has had many occasions to see this above concerning the stage model and the linear model. This is far from unique to these models (Table 6). The early alternative to the linear model of innovation, the “need or demand-pull model”, often put in quotes, is called interchangeably the demand-pull “approach” or “notion” or “hypothesis” or “theory” (e.g. Mowery and Rosenberg, 1979; Scherer, 1982). Giovanni Dosi’s model, as an alternative to the linear model (or “technology-push”, as he and some others call it) and the demand-pull model, is an “outlook” or an “interpretive grid focusing on questions often neglected by orthodox economic theory” (Dosi, 1982: 148). In another sense, it is a paradigm, in analogy to Kuhn’ scientific paradigm: “We shall define a ‘technological paradigm’ as ‘model’ and a ‘pattern’ of solution of *selected* technological problems” (Dosi, 1982: 152).

The idea that sums up the diverse vocabulary is perpective or view. “Innovation is often *viewed*” (my italics), claims William Price and Lawrence Bass, “as an orderly process, starting with the discovery of new knowledge, moving through various stages of development, and eventually emerging in final, viable form” (Price and Bass, 1969: 802-803). A model refers to a tradition, a class of more or less analogous conceptualizations – or approaches or frameworks or paradigms, as it was called before the semantic of model, or schools of thought as Ronald Havelock puts it –, shared by several writers, a perspective that has become canonical, to the extent that very often no one knows the origin of the perspective. In this sense, model is a term that serves to give existence to a typical or exemplary theory or conceptual scheme, to synthetize, to caricature. A model is a paradigmatic perspective, in the sense of a summary or caricature of a theory or a set of theories or tradition (Gibbard and Varian, 1978).

Table 6.

Terms Used Interchangeably to Model

Scheme, formulation (Allen, 1967a; 1967b)

Scheme (Toulmin, 1969)

Scheme, spectrum (Ziman, 1991)

Schema, outline (Havelock and Benne, 1967)

Schematic representation (Freeman, 1982; Freeman et al., 1982)

Conceptual scheme (Langrish et al., 1972)

View, viewpoint (Morton, 1968; Schon, 1969; Goldhar et al, 1976; Rothwell and Zegveld, 1985)

Flow (Beal, 1957; Baker et al., 1967; Rogers and Shoemaker, 1971; Machlup, 1962a; 1962b; Lionberger, 1965; Rubenstein, 1967; 1969; Gruber and Marquis, 1969)

Chain (Blackett, 1968)

Perspective, point of view, school of thought, conceptualization (Havelock, 1969)

Ideology (Havelock, 1974)

Framework, conceptual framework (Wilkening, 1953; Beal, 1957; Beal and Bohlen, 1957; Rogers, 1962; Schmookler, 1962; Becker and Whisler, 1967; Clark, 1968; Gruber and Marquis, 1969

Construct, theoretical construct (Beal, 1957; Beal, Rogers and Bohlen, 1957)

Scheme, conceptualization, diagram, portrait (Clark, 1968; Rogers and Shoemaker, 1971; Robertson, 1967; 1971)

Paradigm (Rogers, 1962; Campbell, 1966; Rogers and Shoemaker, 1971; von Hippel, 1979; Tornatzky, 1983: viii)

Paradigmatic representation (Zaltman et al., 1973)

Pattern, conceptual pattern (NPA/NSF; Roberts and Romine, 1974)

Representation (Godlhar et al., 1976)

Approach (Rogers, 1962; Corwin, 1974)

Approach, notion, hypothesis, theory (Mowery and Rosenberg, 1979)

Approach, view, idea, interpretation (Wise, 1985)

Conceptual approach (Saren, 1984)

Outlook, interpretive grid, paradigm (Dosi, 1982)

Organizing scheme, perspective, conceptual overview, schematic diagram (Tornatzky, 1983)

To every famous theorist a model is attributed. When Jack Morton or Robert Burns on models of innovation attributes a “bureaucratic model” to Max Weber (Morton, 1971; Burns, 1975), or Diana Crane to Thomas Kuhn (“crisis model”) and to Gerald Holton and Stephen Toulmin (“evolutionary model”), it is in the sense of a paradigmatic perspective (Crane, 1972). Model refers to a commonplace perspective(s) found in a specialty or discipline. When George Wise qualify historians’ alternatives to the “assembly line model” or linear model (like “couple” and “mirror image twins”) as “pieces [that] do not yet constitute a model” but metaphors, he is refering to existing views or perspectives of historians on the autonomy of science and technology. In fact, Wise also uses “approach, view, idea and interpretation” to talk about the historians’ “models” (Wise, 1985: 244; on models in STS as metaphor, see also Mayr, 1976). Terry Clark’s models on the institutionalization of innovation in higher education are “conceptual schemes” commonly used in the literature (“more often implicitly than explicitly”): organic growth model (stages of development), differentiation model (specialization), diffusion model (adoption stage model), to which Clark adds a combined-process model (Clark, 1968). Norman Baker’s models are conceptual approaches (i.e. flow or stage model) and mathematical/statistical methods developed for research and development (R&D) project selection decision and resource allocation (Baker, 1974). Robert Chin’s models are traditional conceptual “approaches” to the study of change (systems and components, organic, development, inter-system) (Chin, 1964: 6). Donald Burt’s models are theoretical or conceptual “modes” or strategies of adoption of innovation by organizations, as the theorists study them (leadership, rational change, response to a need, internal change agent, adopting competitive practice, outside agent, incentives) (Burt, 1973: 29).

Apart from referring to an emblematic author or to a tradition, a model carries the idea of summary or synthesis, as a figure does. Philosopher Toulmin’s is a “model or schema intended to summarize our understanding of innovation” (Toulmin, 1969). Richard Daft analyses two sources of innovation advanced in the literature for explaining innovation in organizations – administrative (leaders) and technical (employees) – and calls his “synthesis or combination” a (dual-core) “model” (or organizational innovation) (Daft, 1978). To Rod Coombs et al., “a particularly powerful attempt to synthetize some of the factors into one model is contained in the work of Nelson and Winter” (Coombs et al., 1987).

Another example is the need or demand-pull model (Godin and Lane, 2013). Reviews of the demand-pull model mix studies concerned with various issues, which are not always conceptually distinguished (Mowery and Rosenberg, 1979; Freeman, 1979; Coombs *et al.*, 1987): social or organizational needs and the kind of research (basic or applied) relevant to these needs; the role of economic or market factors and management in innovation; and the relationship between science and technology, and/or the contribution of scientific information to technological innovation. “Demand” summarizes a wide range of variables *exogenous* to science. The demand-pull model involves and evokes a complex of issues (and polarities) and serves as an umbrella for these issues: scientific discoveries *versus* demand, basic *versus* applied research, science *versus* technology, scientific *versus* non-scientific factors, internal *versus* external criteria in funding choices. What the demand-pull model is is what the reviewers and critics have put into it. This is made possible because a model is an “autonomous agent…partially independent of both theories and the world” (Morgan and Morrison, 1999: 10). Modeling “has its own rationale”, as Mary Morgan claims on economic models. “By representing the economy in a particular form, the economist-scientist at the same time creates [a new] object …” (Morgan, 2012: xvi, 26).

In this sense, a model allows a user to refer to and discuss a commonplace conceptualization or perspective rather than study the world. It also allows one to caricature the views of a scholar or scholars, rather than study their theories. Models are conceptual tools whose life is often only conceptual. A model:

- Organizes knowledge of a field.
- Summarizes interpretations and theories that have become commonplaces (or famous) into easy-to-understand schemas.

- Serves as a caricature. Followers and critics alike construct models to schematize the theory of their favorite author or opposing views for the purpose of argumentation.

Conclusion

The semantic of model has not changed much in the last decades. The prolific theorist Andrew van de Ven is an example. His model of innovation is, echoing Herbert Lionberger, a chronological account of events or narrative: “How institutions are created and change”, states van de Ven and his colleagues, “requires a process theory that explains the temporal order and sequence of events based on a story or historical narrative” (Hargrave and van de Ven, 2006: 806). Over the years, van de Ven developed (diverse) typologies of models (see Table 4), as previous writers had done, and invented his own model as an alternative to previous models (van de Ven et al., 2008). Van de Ven’s vocabulary is equivocal too: he uses model interchangeably with perspective.

From the above survey, models of innovation may be reduced to two main forms, according to usages made of it. First, a model gives form to a reality. A model interprets a reality, attaching a conceptualization to it. Second, a model gives form to a theory or class of theories (those of others), i.e. reduces the latter to a paradigmatic perspective, an “extreme form” that often “correspond to no specific opinion”; “an abstraction … which captures much of the basic structure of current thinking” (Barnes, 1982: 168; Barnes and Edge, 1982).

What is the purpose of talking of models? I suggest that model has a rhetorical function. First, model is a symbol of “scientificity”. Early reviews always start with models from the natural and biooogical sciences as exemplary models (e.g. Deutsch, 1948; 1951). Similarly, Jack Morton’s model is an explicit analogy to system engineering: “a restatement of the scientific method into the system approach”; “nothing but the application of the scientific method to engineering systems” (Morton, 1964: 83, 84). Morton also makes reference to “biological ecology” (the interrelationships between an organisms and the environment) for his system model of innovation. In fact, biology and the "life cycle" of organisms (growth, maturity and decline) is a major source of metaphor to the stage models and others (for explicit references to innovation and the life cycle idea, see Toulmin, 1969; Robertson, 1971; Kuznets, 1972; 1974; Utterback, 1975). [47] Phases are "natural history" (Havelock, 1969: 10.81).

Yet, to most theorists, the science behind a model is mathematics. "Models are good things, mathematical models even better", claims Brodbeck. In fact, curves of growth, maturity and decay are at the origin of sequences, then stage models. As Havelock put it: "The adoption and diffusion processes may be depicted as curves representing activities taking place over a period of time. This analysis of curves of adoption and diffusion will lay the groundwork for the presentation of theoretical models of change" (Havelock, 1969: 10.4). Curves (normal and logistic curves) have been studied by sociologists from Tarde onward and popularized by Stuart Chapin (Tarde, 1890; Chapin, 1928). [48] They serve the description of the innovation adoption process by stages (awareness, information-seeking, trial, adoption or rejection) and the standard deviation of the curve serves to define adopter categories (innovator, early adopter, early majority, late majority, laggards).

Testing empirically a model is frequent (on the stage model, see Beal et al., 1957; Ettlie, 1976; 1980; Pelz, 1983; 1985). It makes it "validated" and "true", so it is believed (Bowlen, 1964: 269, 271). Many also conduct measurement of the variables involved in a model in order to study the phenomena that the model is concerned with. For example, Rupert Maclaurin breaks down, says he, "the process of technological advance into elements that may eventually be more measurable" (Maclaurin, 1953: 97). But in general, measurement is not necessary to analytical models. Measurement is the task of a mathematical model. Yet, mathematical models are always in the background as the implicit examplar (model!) of what a model is – a schematic model of innovation bear

[47] Models of innovation are far from alone in using the metaphor. The metaphor abounds in economics (Penrose, 1952; Rostow, 1952; 1960), management and marketing (product life-cycle: Levitt, 1965; Cox, 1967) and STS (life cycle of disciplines; research productivity life cycle; citation life cycle).

[48] Early sociologists on the study of the diffusion curve empirically are Earl Pemberton (1936a; 1936b; 1937; 1938) and Raymond Bowers (1937; 1938). To Bowers, the *Diffusion Cycle* (and its "stages") as he calls it, is a curve that "inclines upward to a saturatation peak, then levels off or declines" (Bowers, 1938: 25, 29).

clear affinities with the graphs coming out of factor analysis. Rogers' references to models in 1962 are mathematical models. To many others, the "general" or "ideal" model is that of economists, like Edwin Mansfield's (1968) equations (Ross, 1974). Ironically, over time, the mathematics of models has disappeared, except in mathematical models. Analytical models often remain analytical … and pictorial. The picture is all that remains of the ideal of mathematics and formalization. We are back to Brodbeck's query: "What is gained … by calling theories … models?" (Brodbeck, 1959: 383).

Second, model has a rhetorical function in being transdiscursive. Model is a transdiscursive term that has a capacity to travel widely across scholars and domains. [49] Models are nothing else than theories, under a different name. According to the producers and users of models of innovation studied above – in contrast to philosophers to whom models are (simplified) representations of reality –, a model is a conceptualization, or set of conceptualizations (a paradigmatic perspective, a tradition), including narratives, often put in a pictorial form, whose function is to summarize/schematize one's own research agenda (findings) or that of a community of scholars, in order to facilitate its propagation. That it propagates easily … among scholars in a field, across fields and from scholars to practitioners.

Like many magic words (Pollitt and Hupe, 2011) – innovation is another –, model has broadness or high abstraction and wide generality (a variety of definitions), a strongly positive and normative attractiveness (a positive connotation of scientificity), a claim to universality or synthetizing virtue (in the present case, summarizing and reorganizing/reorienting/focusing research) and entails promise of success (scientific productivity and reputation in a field – but rarely predictive success, contrary to the claim made by writerss in the 1960s), [50] all ingredients that make of it a concept capable of

[49] Some calls loose or fuzzy concepts 'boundary concepts' (Lowy, 1992) or 'boundary objects' (Star and Griesemer, 1989; Bowker and Star, 1999). This is bit of a misnomer. These objects or concepts do not establish boundaries between groups, as 'boundary work' does; they are shared among a variety of users. Better call the concepts 'transdiscursive' terms, as Reijo Miettinen does in the case of National Innovation System (Miettinen, 2002).

[50] For example, to political scientist Karl Deutsch, model has four functions: the organizing, the heuristic, the predictive and the measuring. Deutsch puts stress on the predictive: "mere 'explanations' are models of a very low order" (Deutsch, 1963: 9).

mobilization across scholars as well as across domains, both scientific and public. The theorists of innovation address both experts in research and economic policy and policy-makers. Yet, advisers and policy-makers are not interested in scientific theory *per se*. The theorists have to give their findings a different name. A model has such an advertising function. It entails the promise of "effective and efficient actions", to use George Beal and Herbert Lionberger's terms of the 1950s. [51]

[51] "Problem-solving" and "decision-making" are keywords in the literature on models of innovation.

References

Abend, Gabriel (2008), The Meaning of 'Theory', *Sociological Theory*, 26 (2): 173-99.

Alexander, Frank D. (1958), Stydying the Decision-Making Process, in Rural Sociological Society, *The Research Clinic on Decision Making*, Washington (Pullman), State College of Washington : 21-35.

Arthur D. Little Inc (1968), *A Model for Innovation Adoption in Public School Districts*, report to the Office of Education, US Department of Health, Education and Welfare, Washington.

Allen, James Albert (1967a), *Scientific Innovation and Industrial Prosperity*, Amsterdam: Elsevier.

Allen, James Albert (1967b), *Studies in Innovation in the Stell and Chemcial Industries*, Manchester: Manchester University Press.

Baker, Norman R. (1974), R&D Project Selection Models: An Assessment, *IEEE Transactions on Engineering Management*, EM-21 (4): 165-71.

Baker, Norman R., Jack Siegman and Albert H. Rubenstein (1967), The effects of Perceived Needs and Means on the Generation of ideas for Industrial Research and Development Projects, *IEEE Transactions on Engineering Management*, 14 (4): 156-63.

Barnes, Barry (1982), The Science-Technology Relationship: A Model and a Query, *Social Studies of Science*, 12: 166-72.

Barnes, Barry, and David Edge (1982), The Interaction of Science and Technology, in *Science in Context: Readings in the Sociology of Science*, Milton Keynes: Open University Press: 147-54.

Barnett, Homer G. (1953), *Innovation: the Basis of Cultural Change*, New York: McGraw Hill.

Beal, George M. (1957), How Does Social Change Occur?, in *A Basebook for Agricultural Adjustment in Iowa: Prospects for the Year Ahead*, Iowa State College, Agricultural and Home Economics Experiment Station, Issue 21 of Special report, Iowa State College. Agricultural and Home Economics Experiment Station.

Beal, George M. (1958), Information Sources in the Decision-Making Process, in Rural Sociological Society, *The Research Clinic on Decision Making*, Washington (Pullman), State College of Washington : 36-51.

Beal, George M., and Joe M. Bohlen (1955), *How Farm People Accept New Ideas*, Cooperative Extension Science report no. 15, Ames (Iowa): Cooperative Extension Service.

Beal, George M., and Joe M. Bohlen (1957), *The Diffusion Process*, Special report no. 18, Cooprative Extension Service, Iowa State University, Amnes (Iowa).

Beal, George M., Everett M. Rogers and Joe M. Bohlen (1957), Validity of the Cocnept of Stages in the Adoption Process, *Rural Sociology*, 22: 166-68.

Becker, Marshall H. (1970), Sociometirc Location and Innovativeness: Reformulation and Extension of the Diffusion Model, *American Sociological Review*, 35 (2): 267-82.

Becker, Selvin W., and Thomas L. Whisler (1967), The Innovative Organization: A Selective View of Current Theory and Research, *Journal of Business*, 40 (4): 462-69.
Blackett, P.M.S. (1968), Memorandum on the Select Committee on Science and Technology, *Nature*, 219, September 14: 1107-10.
Bohlen, Joe M. (1964), The Adoption and Diffusion of Ideas in Agriculture, in James H. Copp (ed.), *Our Changing Rural Society: Perspectives and Trends*, Ames: Iowa State University Press: 265-87.
Bohlen, Joe M. (1967), Needed Research on Adoption Models, *Sociologia Ruralis*, 7: 113-29.
Bowers, Raymond V. (1937), The Direction of Intra-Societal Diffusion, *American Sociological Review*, 2 (6): 826-36.
Bowers, Raymond V. (1938), Differential Intensity of Intra-Societal Diffusion, *American Sociological Review*, 3 (1): 21-31.
Bowker, Geoffrey and Susan Star (1999), *Sorting Things Out: Classification and its Consequences*, Cambridge (Mass.): MIT Press.
Bright, James R. (1969), Some Management Lessons from Innovation Research, *Long Range Planning*, 2 (1): 36-41.
Brodbeck, May (1959), Models, Meaning, and Theories, in Llwellyn Gross (ed.), *Symposium on Sociological Theory*, Evanston (Ill.): Harper and Row: 373-403.
Brozen, Yale (1951a), Invention, Innovation, Imitation, *American Economic Review*, May: 239-57.
Brozen, Yale (1951b), Studies of Technological Change, *Southern Economic Journal*, 17 (4): 438-40.
Burns, Robert Obed (1975), *Innovation: The Management Connection*, Lexington.
Burt, Donald S. (1973), The Differential Impact of Social Integration on Participation in the Diffusion of Innovations, *Social Science Research*, 2: 125-44.
Campbell, Rex R. (1966), A Suggested Paradigm of the Individual Adoption Process, *Rural Sociology*, 31 (4): 458-66.
Caraça, Joao, Bengt-Ake Lundvall and Sandro Mendonça (2009), The Changing Role of Science in the Innovation Process: From Queen to Cinderella?, *Technological Forecasting and Social Change*, 76: 861-67.
Carter, Charles F., and Bruce R. Williams (1957), Industry and Technical Progress: Factors Governing the Speed of Application of Science, London: Oxford University Press.
Chakrabarti, Alok K. (1973), Some Concepts of Technology Transfer: Adoption of Innovations in Organizational Context, *R&D Management*, 3 (3): 111-120.
Chapin, Francis Stuart (1928), *Cultural Change*, New York: The Century Co.
Cherington, Paul, Merton J. Peck and Frederic M. Scherer (1962), Organization and Research and Development Decision Making Within a Government Department, in National Bureau of Economic Research (1962), *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press: 395-408.
Chin, Robert (1964), Models of and Ides About Changing, in Wesley C. Mierhenry (ed.), *Media and Educational Innovation*, Nebraska: Universityof Nebraska Press: **XX-XX**.

Clark, Terry N. (1968), Institutionalization of Innovations in Higher Education: Four Models, *Administrative Science Quarterly*, 13 (1): 1-25.
Clarke, Sabine (2010), The Meaning of Fundamental Research in Britain, circa 1916-50, *Isis*, 101 (2): 285-311.
Conant, James Bryant (1948), The Scientist in Our Unique Society, *The Atlantic Monthly*, March: 47-51.
Coombs, Rod, Paoto Saviotti and. Vivian Walsh (1987), *Economics and Technological Change*, Totowa (New Jersey): Rowman and Littlefield.
Copp, James H., Maurice L. Sill and Emory J. Brown (1958), The Function of Information Sources in the Farm Practice Adoption Process, *Rural Sociology*, 23: 147-57.
Corwin, Ronald G. (1974), Models of Educational Organizations, *Review of Research in Education*, 2: 247-95.
Coughenour, C. Milton (1960), The Functioning of Farmers Characteristics in Relation to Contact with Media and Practice Adoption, *Rural Sociology*, 25: 283-97.
Cox, William E. (1967), Product Life Cycles as Marketing Models, *Journal of Business*, 40 (4): 375-84.
Crane, Diana (1972), *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*, Chicago: University of Chicago Press.
Daft, Richard L. (1978), A Dual-Core Model of Organizational Innovation, *Academy of Management Journal*, 21 (2): 193-210.
Deutsch, Karl W. (1948), Some Notes on Research and the Role of Models in the Natural and Social Sciences, *Synthèse* 7: 506-33.
Deutsch, Karl W. (1951), Mechanism, Organism, and Society: Some Models in Natural and Social science, *Philosophy of Science* 18 (3): 230-52.
Deutsch, Karl W. (1963), *The Nerves of Government: Models of Political Communication and Control*, New York: Free Press.
Dodd, Stuart Carter (1955), Diffusion is Predicatble: Testing Probability Models for Laws of interaction, *American Sociological Quarterly*, 20 (4): 392-401.
Dosi, Giovanni (1982), Technological Paradigms and Technological Trajectories, *Research Policy*, 11 (3): 147-62.
Edgerton, David (2004), The Linear Model did not Exist, in K. Grandin, N. Worms, and S. Widmalm (eds.), *The Science-Industry Nexus: History, Policy, Implications*, Sagamore Beach: Science History Publications: 31-57.
Edgerton, David (2010), Innovation, Technology, or History: What Is the Historiography of Technology About? *Technology and Culture*, 51 (3): 680-97.
Emery, Frederick Edmund, and Oscar Adolf Oeser (1958), *Information, Decision and Action: A Study of the Psychological Determinants of Change in Farming Techniques*, New York: Cambridge University Press.
Engel, James F. (1968), Diffusion of Innovations, in James F. Engel, *Consumer Behavior*, New York: Holt, Rinehart and Winston: 541-74.
Ettlie, John E. (1976), The Timing and Sources of Information for the Adoption and Implementation of Production Innovations, *IEEE Transactions on Engineering Management*, EM-23 (1): 62-68.
Ettlie, John E. (1980), Adequacy of Stage Models for Decision on Adoption of Innovations, *Psychological Reports*, 46: 991-95.

Freeman, Christopher (1974), *The Economics of Industrial Innovation*, Harmonsworth: Penguin.
Freeman, Christopher (1979), The Determinants of Innovation: Market Demand, Technology, and the Response to Social Problems, *Futures*, June: 206-15.
Freeman, Christopher (1996), The Greening of Technology and Models of Innovation, *Technological Forecasting and Social Change*, 53: 27-39.
Forrest, Janet E. (1991), Models of the Process of Technological Innovation, *Technology Analysis & Strategic Management*, 3 (4): 439-52.
Furnas, Clifford C. (1948), *Research in Industry: Its Organization and Management*, Princeton: D. van Nostrand.
Gellman, Aaron (1967), A Model of the Innovative Process (as Viewed from a Non-Science Based Fragmented Industry), in US National Science Foundation, *Technology Transfer and Innovation*, Proceedings of a Conference Organized by the National Planning Association and the NSF in May 15-17, Washington. NSF 67-5, Washington: NSF: 11-20.
Gibbard, Allan, and Hal R. Varian (1978), Economic Models, *Journal of Philosophy*, 75 (11): 664-77.
Godin, Benoît (2015a), *Innovation as a Process: The Emergence of an Idea, 1922-c.1970*, Project on the Intellectual History of Innovation, INRS: Montreal.
Godin, Benoît (2015b), *Innovation Contested: The Idea of Innovation Over the Century*, London: Routlegde.
Godin, Benoît (2015c), *Technological Innovation: On the Origin of an Inclusive Concept*, Project on the Intellectual History of Innovation, Montreal: INRS.
Godin, Benoît (2014), Invention, Diffusion and Linear Models of Innovation, *Innovation: Journal of Innovation Economics & Management*, 15 (3): 11-37.
Godin, Benoît (2008), In the Shadow of Schumpeter: W. Rupert Maclaurin and the Study of Technological Innovation, *Minerva*, 46 (3): 343-360.
Godin, Benoît (2006), The Linear Model of Innovation: The Historical Construction of an Analytical Framework, *Science, Technology and Human Values*, 31 (6): 639-667.
Godin, Benoît and Joseph Lane (2013), "Pushes and Pulls": The Hi(story) of the Demand Pull Model of Innovation, *Science, Technology and Human Values*, 38 (5): 621-54.
Goldhar, Joel D., Louis K. Bragaw and Jules J. Schwartz (1976), Information Flows, Management Styles, and Technological Innovation, *IEEE Transactions on Engineering Management*, EM-23 (1): 51-62.
Goldsmith, Maurice (1970), Introduction, in M. Goldsmith (ed.), *Technological Innovation and the Economy*, London/New York: Wiley.
Green, James W. and Selz C. Mayo (1954), A Framework for Research in the Actions of Community Groups, *Social Forces*, 31 (4): 320-27.
Gruber, William H., and Donald G Marquis (1969), *Factors in the Transfer of Technology*, Cambridge (Mass.): MIT Press.
Hargrave, Timothy J. and Andrew H. van de Ven (2006), A Collective Action Model of Institutional Innovation, *Academy of Management Review*, 31 (4): 864-88.
Hassinger, Edward (1959), Stages in the Adoption Process, *Rural Sociology*, 24: 52-53.
Havelock, Ronald, and Kenneth D. Benne (1967), An Exploratory Study of Knowledge Utilization, in Goodwin Watson (ed.), *Concepts for Social Change*, NTL Institute

for Applied Behavioral Science, National Education Association, Washington: 47-70.
Havelock, Ronald G. (1969), *Planning for Innovation Through Dissemination and Utilization of Knowledge*, Center for Research on Utilization of Scientific Knowledge (CRUSK), Institute for Survey Research, Ann Arbor, University of Michigan.
Havelock, Ronald G. (1970), *A Guide to Innovation in Education*, Center for Research on Utilization of Scientific Knowledge, Institute for Social Research, Univesoty of Michigan, Ann Arbor: Michigan.
Havelock, Ronald G. (1974), *Models of the Innovation Process in US School Districts*, Annual Meeting of the American Educational Research Association, Chicago, Illinois, Apris 18.
Havens, A. Eugene (1965), Increasing the Effectiveness of Predicting Innovativeness, *Rural Sociology*, 30 (2): 151-65.
Havens, A. Eugene, and Everett M. Rogers (1961), Adoption of Hybrid Corn: Profitability and the Interaction Effect, *Rural Sociology*, 26: 409-14.
Heirich, Max (1964), The Use of Time in the Study of Social Change, *American Sociological Review*, 29 (3): 386-97.
Heyck, Hunter (2014), The Organizational Revolution and the Human Sciences, *Isis*, 105 (1): 1-31.
Holland, Maurice (1928), Research, Science and Invention, in F.W. Wile (ed.), *A Century fo Industrial Progress*, American institute of the City of new York, New York: Doubleday, Doran & Co.: 312-24.
Hollomon, John Herbert (1965), Science and Innovation, in R. A. Tybout (ed.), *Economics of Research and Development*, Ohio State University Press: 251-57.
Hoselitz, Bert F. (1960), Theories of Stages of Economic Growth, in B.F. Hoselitz (ed.), *Theories of Economic Growth*, New York: Free Press.
Hughes, Thomas (1983), *Networks of Power: Electrification in Western Society, 1880-1930*, Baltimore: Johns Hopkins University Press.
Katz, Elihu, Levin, Martin L., and Hamilton, Herbert, Traditions of Research on the Diffusion of Innovation, *American Sociological Review*, vol. 28, no. 2: 237-52.
Kelly, Patrick, and Melvin Kranzberg (eds.) (1975), *Technological Innovation: A Critical Review of Current Knowledge*, San Francisco: San Francisco Press [1978].
Kimberly, John R. (1981), Managerial Innovation, in Paul C. Nystrom (ed.), *Handbook of Organizational Design*, London: Oxford University Press: 84-104.
Kline, Stephen J. (1985), Innovation is Not a Linear Process, *Research Management*, July-August: 36-45.
Kline, Stephen J., and Nathan Rosenberg (1986), An Overview of Innovation, in R. Laudan and N. Rosenberg (eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, Washington: National Academies Press: 275-305.
Knight, Kenneth E. (1967), A Descriptive Model of the Intra-Firm Innvoation Process, *Journal of Business*, 40: 478-96.
Kuznets, Simon (1972), "Innovations and Adjustments in Economic Growth", *The Swedish Journal of Economics*, 74 (4): 431-51.

Kuznets, Simon (1975), Technological Innovations and Economic Growth, in Patrick Kelly and Melvin Kranzberg (eds.), *Technological Innovation: A Critical Review of Current Knowledge*, San Francisco: San Francisco Press [1978]: 476-541.
Langrish, John, Michael Gibbons, William G. Evans and Frederik R. Jevons (1972), *Wealth from Knowledge: Studies of Innovation in Industry*, London: Macmillan.
Larsen, Judith K., and Rekha Agarwala-Rogers (1977), The Appropriateness of Adaptation in the Transfer of Innovations: Re-Invention of Innovative Idea: Modified? Adopted? None of the Above, *Evaluation*: 136-40.
Layton, E. (1977), Conditions of Technological Development, in D. De Solla Price and I.D. Spiegel-Rosing (eds.), *Science, Technology and Society*, Beverly Hills (Calif.): Sage: 197-222.
Levitt, Theodore (1965), Exploit the Product Life Cycle, *Harvard Business Review*, 43 (6): 81-94.
Lionberger, Herbert F. (1960), *Adoption of New Ideas and Practices*, Ames (Iowa): Iowa State University Press.
Lionberger, Herbert F. (1965), Diffusion of Innovations in Agricultural Research and in Schools, in Robert Rosborough Leeper (ed.), *Strategy for Curriculum Change*, Washington (D.C.): Association for Supervision and Curriculum Development.
Lowy, Ilana (1992), The Strength of Loose Concepts – Boundary Concepts, Federative Experimental Strategies and Disciplinary Growth: The Case of Immunology, *History of Science*, 30: 371-96.
Lubart, Todd I. (2000-2001), Models of the Creative Process: Past, Present and Future, *Creativity Research Journal*, 13 (3-4): 295-308.
Machlup, Fritz (1962a), *The Production and Distribution of Knolwedge in the United States*, Princeton: Princeton University Press.
Machlup, Fritz (1962b), The Supply of Inventors and Inventions, in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press: 143-69.
Maclaurin, William Rupert (1949), *Invention and Innovation in the Radio Industry*, New York: Macmillan.
Maclaurin, William Rupert (1950), The Process of Technological Innovation: the Launching of a New Scientific Industry, *American Economic Review*, 40, 1950: 90-112.
Maclaurin, William Rupert (1953), The Sequence from Invention to Innovation and its Relation to Economic Growth, *Quarterly Journal of Economics*, 67 (1): 97-111.
Mansfield, Edwin (1968a), *Industrial Research and Technological Innovation*, New York: Norton.
Mansfield, Edwin (1968b), *The Economics of Technological Change*, New York: Norton.
Marinova, Dora, and John Phillimore (2003), Models of Innovation, in Larisa V. Shavinina (ed.), *The International Handbook on Innovation*, 44-53: Elsevier.
Mason, Robert, and Albert N. Halter (1968), The Application of a System of Simultaneous Equations to an Innovation Diffusion Model, *Social Forces*, 47 (2): 182-95.
Mayr, Otto (1976), The Science-Technology Relationship, *Technology and Culture*, reprinted in Barnes, B., and D. Edge (1982), The Interaction of Science and

Technology, in *Science in Context: Readings in the Sociology of Science*, Milton Keynes: Open University: 155-163.

Meek, Ronald L. (1976), *Social Science and the Ignoble Savage*, London and New york: Cambridge University Press.

Mees, C.E. Kenneth (1917), The Production of Scientific Knowledge, *Science*, November 30: 519-28.

Mees, C.E. Kenneth (1920), *The Organization of Industrial Scientific Research*, New York: McGraw-Hill.

Mees, C.E. Kenneth, and John A. Leermakers (1950), *The Organization of Industrial Scientific Research*, New York: McGraw-Hill.

Miettinen, Reijo (2002), *National Innovation System: Scientific Concept or Political Rhetoric*, Helsinki: Edita.

Miles, Matthew B. (ed.) (1964), *Innovation in Education*, New York: Columbia University.

Mintzberg, Henry, Duru Raisinghani and André Théorêt (1976), The Structure of 'Unstructured' Decision Processes, *Administrative Science Quarterly*, 21: 246-75.

Mogee, Mary Ellen (1980), The Relationship of Federal Support of Basic Research in Universities to Industrial Innovation and Productivity, in Joint Economic Committee, *Research and Innovation: Developing A Dynamic Nation*, US Congress, Special Study on Economic Change, Volume 3, Washington: USGPO: 257-79.

Morgan, Mary S. (2012), *The World in the Model: How Economists Work and Think*, Cambridge: Cambridge University Press.

Morgan, Mary S., and Till Grune-Yanoff (2013), Special Issue on Modeling in the Social Sciences, *Prespectives on Science*, 21 (2).

Morgan, Marys S., and Margaret Morrison (1991), *Models as Mediators: Perspectives on Natural and Social Science*, Cambridge: Cambridge University Press.

Morison, Elting E. (1950), A Case Study of Innovation, reprinted in W.G. Bernis (ed.), *The Planning of Change: Readings in the Applied Behavioral Sciences*, New York: Holt, Rinehart and Winston, 1962: 592-605.

Morton, Jack A. (1964), From Research to Technology, *International Science and Technology*, May: 82-92.

Morton, Jack A. (1966), A Model of the Innovative Process (as Viewed from a Science-Based Integrated Industry), in US National Science Foundation, *Technology Transfer and Innovation*, Proceedings of a Conference Organized by the National Planning Association and the National Science Foundation, May 15-17, Washington. NSF 67-5, Washington: NSF: 21-31.

Morton, Jack A. (1968), The Innovation of Innovation, *IEEE Transactions on Engineering Management*, EM-15 (2): 57-65.

Morton, Jack A. (1971), *Organizing for Innovation: A Systems Approach to Technical Management*, New York: McGraw Hill.

Mowery, David, and Nathan Rosenberg (1979), The Influence of Market Demand Upon Innovation: A Critical Review of Some Recent Empirical Studies, *Research Policy*, 8: 102-53.

Muller, D.C., and J.E. Tilton (1969), Research and Development: Costs as a Barrier to Entry, *Canadian journal of Economics*, 2 (4): 570-79.

Mulkay, Michael J. (1975), Three Models of Scientific Development, *Sociological Review*, 23: 509-26.
Muller, Rolland (2004), Model : The History of the Concept and of Its Use in Science, in Massimo Negrotti (ed.), *Models in Contemporary Science*, Yearbook of the Artificial, volume 2, Bern: Peter Lang: 239-62.
Myers, Sumner (1967), *Technology Transfer and Industrial Innovation*, Washington: National Planning Association.
Myers, Sumner and Donald G. Marquis (1969), *Successful Industrial Innovations: A Study of Factors Underlying Innovation in Selected Firms*, NSF 69-17, Washington: National Science Foundation.
National Science Foundation (1967), *Technology Transfer and Innovation*, Proceedings of a Conference Organized by the National Planning Association and the National Science Foundation in May 15-17 1966, Washington. NSF 67-5, Washington: National Science Foundation.
Nelson, Richard R. and Sidney G. Winter (1974), Neoclassical vs. Evolutionary Theories of Economic Growth: Critique and Prospectus, *Economic Journal*, 84 (336): 886-905.
Nelson, Richard R. and Sidney G. Winter (1982), *An Evolutionary Theory of Economic Change*. Cambridge (Mass.): The Belknap Press.
Nelson, Richard R., Merton J. Peck and Edward D. Kalachek (1967), Technology, Economic Growth and Public Policy, Washington: Brookings Institution.
Newby, Howard (1992), One Society, one Wissenschaft: a 21st Century Vision, *Science and Public Policy*, 19 (1): 7-14.
Nisbet, Robert (1969), *Social Change and History*, New York: Oxford University Press.
O'Brien, M.P. (1962), Technological Planning and Misplanning, in J.R. Bright (ed.), *Technological Planning at the Corporate Level*, Boston: Harvard University Press: 73-92.
OECD (1969), *The Management of Innovation in Education*, Center for Educatioonal Research and Innovation (CERI), Paris: OECD.
Ozanne, Urban B., and Gilbert A. Churchill (1971), Five Dimensions of the Industrial Adoption Process, *Journal of Marketing Research*, 8: 322-28.
Pelz, Donald C. (1983), Quantitative Case Histories of Urban Innovations: Are There Innovating Stages?, *IEEE Transactions on Engineering Management*, 30 (2): 60-67.
Pelz, Donald C. (1985), Innovation Complexity and the Sequence of Innovating Stages, *Science Communication*, 6: 261-91.
Pemberton, Earl H. (1936a) Culture Diffusion Gradients, *American Journal of Sociology*, 42: 226-33.
Pemberton, Earl H. (1936b), The Curve of Culture Diffusion Rate, *American Sociological Review*, 1 (4): 547-56.
Pemberton, Earl H. (1937), The Effect of a Social Crisis on the Curve of Diffusion, *American Sociological Review*, 2: 55-61.
Pemberton, Earl H. (1938), The Spatial Order of Cultural Diffusion, *Sociology and Social Research*, 22: 246-51.
Penrose, Edith Tilton (1952), Bioloogical Analogies in the Theory of the Firm, *American Economic Review*, 42 (5): 804-19.

Pinch, Trevor J., and Wiebe E. Bijker (1987), The Social Construction of Facts and Artifacts, in W.E. Bijker, T.P. Hughes and T. Pinch (eds.), *The Social Construction of Technological Systems*, Cambridge: MIT Press: 23-50.

Poole, Marshall Scott, and Andrew H. van de Ven (eds.) (2004), *Handbook of Organizational Change and Innovation*, Oxford: Oxford University Press.

Price, William J., and Lawrence W. Bass (1969), Scientific Research and the Innovative Process, *Nature* 164, 16 May: 802-806.

Radnor, Michael, and Albert H. Rubenstein (1970), Implementation in Operations Research and R&D in Government and Business Organization, *Operations Research*, 18 (6): 967-91.

Robertson, Thomas S. (1967), Consumer Innovators: The Key to New Product Success, *California Management Review*, Winter: 23-30.

Robertson, Thomas S. (1968a), Prediction of Consumer Innovators: Application of Multiple Discriminant Analysis, *Journal of Marketing Research*, 5 (1): 64-69.

Robertson, Thomas S. (1968b), Purchase Sequence Responses: Innovators vs. Non-Innovators, *Journal of Advertising Research*, 8 (1): 47-52.

Robertson, Thomas S. (1971), *Innovative Behavior and Communication*, New York: Holt, Rinehart & Winston.

Roberts, Robert E., and Charles A. Romine (1974), *Investment in Innovation*, Midwest Research Institute, Kansas City, Report prepared for the NSF.

Rogers, Everett M. (1958a), Categorizing the Adopters of Agricultural Practices, *Rural* Pelz, Donald C. (1983), Quantitative Case Histories of Urban Innovations: Are There Innovation Stages?, *IEEE Transactions on Engineering Management*, EM-30 (2): 60-67.

Rogers, Everett M. (1958b), The Importance of Personal influence in the Adoption of Technological Change, *Social Forces*, 36 (4): 329-35.

Rogers, Everett M. (1960a), Communication of Agricultural Technology: How People Accept New Ideas, in Everett M. Rogers, *Social Change in Rural Society: A Textbook in Rural Sociology*, New York: Appleton-Century Crofts: 396-422.

Rogers, Everett M. (1960b), *Social Change in Rural Society: A Textbook in Rural Sociology*, New York: Appleton-Century Crofts.

Rogers, Everett M. (1961), The Adoption Period, *Rural Sociology*, 26 (1): 77-82.

Rogers, Everett, M. (1962), *The Diffusion of Innovation*, New York: Free Press.

Rogers, Everett M. (1969), *Modernization Among Peasants: The Impact of Communication*, New York: Holt, Rinehart and Winston, Inc.

Rogers, Everett M., John D. Eveland and Constance Klepper (1977), *The Innovation Process in Public Organizations*, report to the US National Science Foundation, Department of Journalism, University of Michigan, Ann Arbor: Michigan.

Rogers, Everett M., and Rekha Agarwala-Rogers (1976), *Communication in Organizations*, New York: Free Press.

Rogers, Everett M., and A. Eugene Havens (1962), Profitability versus Interaction: Another False Dichotomy, *Rural Sociology*, 27: 327-32.

Rogers, Everett M., and F. Lloyd Shoemaker (1971), *Communication of Innovations*, New York: Free Press.

Ross, Paul F. (1974), Innovation Adoption by Organizations, *Personnel Psychology*, 27: 21-47.

Rossman, Joseph (1931), *The Psychology of the Inventor: A Study of the Patentee*, Washington: The Inventors Publishing Co.

Rostow, Walt Whitman (1952), *The Process of Economic Growth*, New York: W.W. Norton and Co.

Rostow, Walt Whitman (1960), *The Stages of Economic Growth: A Non-Communist Manifesto*, Cambridge: Cambridge University Press [1999].

Rothwell, Roy (1992), Successful Industrial innovation: Critical Factors for the 1990s, *R&D Management*, 22 (3): 221-39.

Rothwell, Roy, and A.B. Robertson (1973), The Role of Communications in Technological Innovation, *Research Policy*, 2 (3): 204-25.

Rothwell, Roy, and Walter Zegveld (1985), *Reindustrialization and Technology*, New York: M.E. Sharpe.

Rubenstein, Albert H. (1962), Organization and R and D Decision Making, in National Bureau of Economic Research (1962), *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press: 385-93.

Rubenstein, Albert H. (1969), A Program of Research on Coupling Relations in Research and Development, *IEEE Transactions on Engineering Management*, 16 (4): 137-43.

Rubenstein, Albert H., and John E. Etlie (1979), Innovation Among Suppliers to Automobile Manufacturers: An Exploratory Study of Barriers and Falicitators, *R&D Management*, 9 (2): 65-76.

Ryan, Bryce (1948), A Study of Technological Diffusion, *Rural Sociology*, 13: 273-85.

Ryan, Bryce (1965), The Resuscitation of Social Change, *Social Forces*, 44 (1): 1-7.

Ryan, Bryce, and Neal C. Gross (1943), The Diffusion of Hybrid Seed Corn in Two Iowa Communities, *Rural Sociology*, 8: 15-24.

Ryan, Bryce, and Neal Gross (1950), *Acceptance and Diffusion of Hybrid Corn Seed in Two Iowa Communities*, Research Bulletin no. 372, Agricultural Experiment Station, Iowa State College of Agriculture and Mechanical Arts, Ames (Iowa).

Saren, M.A. (1984), A Classification and Review of Models of the Intra-Firm Innovation process, *R&D Management*, 14 (1): 11-24.

Scherer, Frederic M. (1959), The Investment Decision Phases in Modern Invention and Innovation, reprinted in J.J. Galvin et al., *Patents and the Corporation*, Boston [**19??**]: 1-7.

Scherer, Frederic M. (1982), Demand-Pull and Technological Invention: Schmookler Revisited, *Journal of Industrial Economics*, 30 (3): 225-37.

Schmidt-Tiedemann, K. J. (1982), A New Model of the Innovation Process, *Research Management*, 25 (2): 18-21.

Schmookler, Jacob (1962), Changes in Industry and in the State of Knowledge as Determinants of Industrial Invention, in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press: 195-232.

Schon, Donald A. (1967), *Technology and Change: The Impact of Invention and Innovation on American Social and Economic Development*, New York: Delta Books.

Schon, Donald A. (1971), *Beyond the Stable State: Private and Public Learning in a Changing Society*, London: Temple Smith.

Senker, Jacqueline (1995), Tacit Knowledge and Models of innovation, *Industrial and Corporate Change*, 4 (2): 425-47.

Siegel, Irving (1962), Scientific Discovery and the Rate of Invention, in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press: 441-57.

Slevin, Dennis P. (1971), The Innovation Boundary: A Specific Model and Some Empirical Results, *Administrative Science Quarterly*, 16: 515-31.

Slevin, Dennis P. (1973), The Innovation Boundary: A Replication with Increased Costs, *Administrative Science Quarterly*, 18: 71-75.

Star, Susan Leigh and James R. Griesemer (1989), Institutional Ecology, 'Translations', and Boundary Objects: Amateurs and Professionals at Berkeley's Museum of Vertebrate Zoology, 1907-39, *Social Studies of Science*, 19 (3): 387-420.

Staudenmaier, John M. (1985), *Technology's Storytellers: Reweaving the Human Fabric*, Cambridge (Mass.): MIT Press.

Stevens, Raymond (1941), Introduction, in US National Research Council, *Research: A National Resource (II): Industrial Research*, Washington: National Resources Planning Board: 5-16.

Stoneman, Paul, and Paul Diederen (1994), Diffusion and Public Policy, *Economic Journal*, 104 (July): 918-30.

Tarde, Gabriel (1890), *Les lois de l'imitation*, Paris : Seuil [2001].

Tait, Joyce, and Robin Williams (1999), Policy Approaches to Research and Development: Foresight, Framework and Competitiveness, *Science and Public Policy*, 26 (2): 101-12.

Tidd, Joe (2006), *Innovation Models*, Tanaka Business School, London: Imperial College.

Tornatzky, Louis G., J.D. Eveland, M.G. Hoylan, W.A. Hetzner, E.C. Johnson, D. Reitman and J. Schneider (1983), *The Process of Technological Innovation: Reviewing the Literature*, Washington; National Science Foundation.

Toulmin, Stephen (1969), Innovation and the Problem of Utilization, in W.H. Gruber and D. G. Marquis (eds.), *Factors in the Transfer of Technology*, Cambridge (Mass.): MIT Press**:** 24-38.

Utterback, James M. (1971a), The Process of Innovation: A Review of Some Recent Findings, in George W. Wilson (ed.), *Technological Development and Economic Growth*, Bloomington: Indiana University Press: 139-60.

Utterback, James M. (1971b), The Process of Technological Innovation Within the Firm, *The Academy of Management Journal*, 14 (1): 75-88.

van de Ven, Andrew H., H.L. Angle and M.S. Poole (1989), *Research on the Management of Innovation: the Minnesota Studies*, New York: Ballinger, Harper and Row.

van de Ven, Andrew H., Douglas E. Polley, Raghu Garud and Sankaran Venkataraman (2008), *The Innovation Journey*, Oxford: Oxford University Press.

Walsh, V. (1984), Invention and Innovation in the Chemical Industry: Demand-Pull and Discovery-Push?, *Research Policy*, 13 (4): 211-34.

Wilkening, Eugene (1953), *Adoption of Improved Farm Practices As Related to Family Factors*, AES Research Bulletin no. 183, University of Wisconsin, Madison.

Williams, Bruce R. (1967), *Technology, Investment and Growth*, London: Chapman and Hall Ltd.

Wise, George (1985), Science and Technology, *OSIRIS*, 1: 229-46.

Witte, Eberhard, Norbert Joost and Alfred L. Thimm (1972), Field Research on Complex Decision Making Processes – The Phase Theorem, *International Studies of Management & Organizations*, 2 (2): 156-82.

Zaltman, Gerald, Robert Duncan and Jonny Holbek (1973), *Innovations and Organizations*, New York: John Wiley.

Ziman, John (1991), A Neural Net Model of Innovation, *Science and Public Policy*, 18 (1): 65-75.

Annex.
Sequences of the Innovation Process

Anthropologists, Sociologists and Other Social Researchers

Seely (1885)	Discovery, invention
Tarde (1890)	Invention, opposition, imitation
Ogburn (1920)	Invention (and diffusion), maladjustment (lag)/adjustment
Bernard (1923)	Formula, blue print, machine [52]
Wissler (1923)	Invention, diffusion
Dixon (1928)	Discovery, invention, diffusion
Chapin (1928)	Invention, accumulation, selection, diffusion
Harrison (1930)	Discovery, invention
Ogburn and Gilfillan (1933)	Idea, trial device (model or plan), demonstration, regular use, adoption
Gilfillan (1935)	Idea; sketch; drawing; model; full-size experimental invention; commercial practice
Linton (1936)	Discovery, invention, diffusion [53]
Gilfillan (1937)	Thought, model (patent), first practical use, commercial success, important use
US National Resources Committee (1937)	Beginnings, development, diffusion, social influences
Mort (1938)	Invention, introduction, diffusion
Ogburn and Nimkoff (1940)	Idea, development, model, invention, improvement, marketing
Farnsworth (1940)	Need accentuated, leadership recognizes need, solution proposed, trial attempts, financial aid, studies of conditions, official approval, sponsors, agency designated, state and federal stimulation
Ogburn (1941)	Idea, plan, tangible form, improvement, production, promotion, marketing, sales
Ryan and Gross (1943)	Knowledge, adoption
Noss (1944)	Rise, growth, disintegration
Ogburn (1950)	Invention, accumulation, diffusion, adjustment
Wilkening (1953)	Initial knowledge, acceptance (of the idea), trial, adoption
Barnett (1953)	Creation (initiation), acceptance/rejection (individuals), diffusion (collective)
Beal and Bohlen (1955)	Awareness, interest, evaluation, trial, adoption
Emery and Oeser (1958)	Present situational supports for motivation, receptivity to new ideas, communication behavior, adoption
Rogers (1962)	**Innovation**, diffusion, adoption Adoption = Awareness, interest, evaluation, trial, adoption
Hagen (1962)	Mental conception, material form
Jewkes, Sawers and Stillerman (1969)	Science, invention, development
Rogers (1969)	Invention, diffusion, consequences
Rogers and Shoemaker (1971)	Knowledge, persuasion, decision, confirmation Antecedents, process, consequences
Mulkay (1972)	Generation, acceptance (or rejection), diffusion
Brewer (1973)	Initial introduction, reaction or rejection, partial incorporation, diffusion
Rogers and Rogers (1976)	Adoption, **innovation** (testing, installation, institutionalization)
Rogers, Eveland	

[52] For social invention, the stages are: theory, rules, organizations and institutions.
[53] Diffusion is composed of three steps: presentation, acceptance and integration.

and Klepper (1979)	Agenda-setting, matching, redefining, structuring, interconnecting
Rogers (1983)	Needs/problems, research, development, commercialization, diffusion and adoption, consequences

Management, Economists
and Others "Economically-Oriented" Studies [54]

Mees (1920)	Pure science, development, manufacturing
Epstein (1926)	Idea, sketch, drawing, test, use
Holland (1928)	Pure science research, applied research, invention, industrial research [development], industrial application, standardization, mass production
Usher (1929)	Elaboration of the concept, primary synthesis, critical revision [55]
Jewett (1932)	Plan (design), control (tests), preliminary small-scale operation, tool-made model, large scale production
Stevens (1941)	Fundamental research, applied research, test-tube or bench research, pilot plant, production (improvement, trouble-shooting, technical control of process and quality)
Bichowsky (1942)	Research, engineering (or development), factory (or production)
Maclaurin (1947)	Fundamental research, applied research, engineering development, production engineering
Furnas (1948)	Exploratory and fundamental research, applied research, development, production
Deutsch (1949)	idea, model, integrated arrangement
Cole (1949)	Initiation, introduction, **innovation**
Bright (1949)	Birth of a new idea, commercial fruition
Maclaurin (1947)	fundamental research, applied research, engineering development, production engineering
Maclaurin (1949)	Fundamental research, applied research, engineering development, production engineering, service engineering
Maclaurin (1950)	Science, engineering, **innovation**
Morison (1950)	development of an idea, introduction, reception
Mees and Leermakers (1950)	Research, development (establishment of small-scale use, pilot plant and models), adoption in manufacturing
Baldwin (1951)	invention, development, manufacture
Brozen (1951a)	Invention, **innovation**, imitation
Brozen (1951b)	Research, engineering development, production, service
Baldwin (1951)	Invention, development, manufacture
Rostow (1952)	Fundamental science, application of science, acceptance (of **innovations**)
Maclaurin (1953)	Pure science, invention, **innovation**, finance, acceptance or diffusion
Redlich (1953)	acceptance, transmission (over time within a group), migration (to other groups in space)
Usher (1954, 1955)	Perception of an unsatisfied need, setting of the stage, primary act of insight, critical revision and development
Carter and Williams (1957)	Basic research, applied research, pilot plant, development, production
Mueller (1947)	Research, development, pilot plant, production, marketing
Brown (1957)	Idea, new machine, design, production
Enos (1958)	Invention, development, application

[54] Mees, Holland, Jewett and Stevens are "industrialists" (managers or consultants). They appear in the list because of their "innovativeness" and/or influence on business schools and economists.
[55] This is only one of Usher's descriptions of the process. Others are: 1) technologies, consequences, adaptation; 2) discoveries and inventions, synthesis (concept, device), construction (design); 3) problem, setting of the stage, achievement (configuration).

Ruttan (1959)	Invention, **innovation**, technological change
Ames (1961)	Research, invention, development, **innovation**
Enos (1962)	Invention, securing financial backing, establishing an organization, finding a plant, hiring workers, opening markets, production and distribution
Machlup (1962)	Basic research, inventive work, development, plant construction
Bright (1964)	Scientific invention, economic reality
Scherer (1965)	Invention, entrepreneurship, investment, development
Schmookler (1966)	Research, development, invention
Adams and Dirlam (1966)	Invention, **innovation**
Hollomon (1965)	Perceived need, invention, **innovation**, diffusion or adaptation
Hollomon (1966)	Invention**, innovation**, diffusion
Hollomon (1967)	Invention, **innovation**, diffusion
US DoC (1967)	R&D, product engineering and design, manufacturing engineering and tooling, manufacturing start-up, market start-up
Allen (1967)	Research, development, investment, construction, production, distribution
Shepard (1967)	Idea generation, adoption, implementation
Becker (1967)	Invention, **innovation**, adoption
Havelock and Benne (1967)	Preparation (assembly, recoding, screening, packaging and labeling), transmission
Parsons (1968)	Basic ideas, development of ideas, manufacturing process (culmination of ideas, production, market)
Robertson (1968)	Awareness, knowledge, liking, preference, conviction, purchase
Mansfield (1968; 1971)	Invention, **innovation**, imitation, diffusion
Myers and Marquis (1969)	Problem solving, solution, utilization, diffusion
Mueller and Tilton (1969)	**Innovation** (itself composed of invention, development, introduction to the market), imitation, technological competition, standardization
Havelock (1969)	basic research, applied research and development, practitioners, consumers and society
Gruber and Marquis (1969)	Invention and discovery, **innovation**, adoption and diffusion
Goldsmith (1970)	Pure science, applied science, development, design, production, marketing, sales and profits
Turner and Williamson (1971)	Invention, development, final supply
Utterback (1971)	Idea generation, problem-solving, implementation, diffusion
Rothwell and Mansfield et al. (1971)	Applied research, preparation and specification, prototype or pilot plant, drawing, tooling and facilities, manufacturing start-up
Martilla (1971)	Introduction, consideration, post-purchase evaluation
Robertson (1971)	Idea generation, project definition, problem solving, design and development, production, marketing
Zaltman et al. (1973)	Initiation, implementation
Sayles (1974)	Planning, goal setting, development
Utterback (1974)	Generation of an idea, problem-solving or development, implementation and diffusion
Rowe and Boise (1974)	Knowledge accumulation, formulation, decision, implementation and diffusion
Kamien and Schwartz (1975)	Basic research, prototypes, development and commercialization (marketing)
Duncan (1976)	Initiation (substages: knowledge awareness, attitude formation, decision), implementation (substages: initial implementation, continued-sustained implementation) Resistance process: perception, motivation, attitude, legitimation, trial, evaluation, adoption or rejection

Kuznets (1977)	Preconception, **innovation**, diffusion
Von Hippel (1979)	Three different phrasings: Product request from customers, custom industrial product, adoption by others. Apprehension of problem (need), determination of a solution type, development of product Functional specification, development of product design specification, complete product design. Generally know user need, advance in technology, development of responsive product
Daft (1978)	Idea, adoption, implementation
Ettlie and Rubenstein (1980)	Initiation (R&D), transfer, adoption, implementation
Pelz (1985)	Concern, search, appraisal, design, commitment, implementation, incorporation, diffusion

Others (Politics, Philosophy)

NSF (1952)	Basic research, applied research, development
Thompson (1965)	Generation, acceptance, implementation
Carlson (1965)	Invention, development and promotion adoption, diffusion, demise
Toulmin (1969)	Mutation, selection, diffusion
Johannes (1972)	Initiation, legitimation

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