"Pushes and Pulls": The Hi(story) of the Demand Pull Model of Innovation

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Project on the Intellectual History of Innovation
Working Paper No. 13
2013

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Abstract

Much has been written about the linear model of innovation. While it may have been the dominant model used to explain technological innovation for decades, alternatives did exist. One such alternative – generally discussed as being the exact opposite of the linear model – is the demand-pull model. Beginning in the 1960s, people from different horizons started looking at technological innovation from a demand rather than a supply perspective. The theory was that technological innovation is stimulated by market demand rather than by scientific discoveries. However, few traces of the demand-pull model remain in the literature today.

This paper looks at what happened to the demand-pull model from a historical perspective, at three points in time: birth, crystallization and death. It suggests that the idea of 'demand' as a factor explaining technological innovation emerged in the 1960s, was formalized into models in the 1970-80s, then got integrated into multidimensional models. From then on, the demand-pull model disappeared from the literature, existing only as an object of the past, like the linear model of innovation.

In the discussion of ecological or social systems, it is not enough simply to say that everything depends on everything else, and so we must look at the whole system (OECD, *Science, Growth and Society: A New Perspective*, 1971: 57).

It is possible to come up with as many causes as one wishes for any event that ever took place in the course of history". [Yet] "whether I introduce one cause, two, five, or an infinite number of causes says nothing at all about the quality of my historical reflections (Reinhart Koselleck, *On the Need for Theory in the Discipline of History*, 1972: 11, 13).

“Pushes and Pulls”:
The Hi(story) of the Demand Pull Model
of Innovation [1]

Much has been written on the linear model of innovation, a decades-old idea. In fact so much has been written that some researchers have begun to write historiography in recent years. Explanations on the origins of the model are many and diverse. The general view suggests that the model comes from Vannevar Bush’s *Science: The Endless Frontier* (1945), but history does not support this claim. According to David Edgerton (2004), the model is a straw man devised by William Price and Lawrence Bass (1969), then adopted by John Langrish and his colleagues from Manchester (1972). Yet, one can find precursors to these authors, among them James Albert Allen (1967a). Moreover, if one digs deeper into the literature, one finds many other names associated with the same idea and the same model. According to Benoît Godin (2006), the model owes its existence to the cumulative work of many people and to the congruence of multiple factors over several decades.

The linear model is only one of several theories developed over time to explain technological innovation. [2] The model postulates that the process of innovation starts with basic research, continues through applied research and then enters the development phase. The linear model may have been the dominant model for decades, but alternatives did exist. One such alternative – generally discussed as its exact opposite – is the demand-pull model. Beginning in the 1960s, people from different fields began to look at innovation from a demand rather than a supply perspective, arguing that the most critical in innovation is need pull forces (opportunities *pulling* from peoples’ needs and the market) rather than by supply push forces (technological opportunities *pushing* forward from scientific discoveries). Yet today the demand-pull model is rarely found in the literature. Rather, much of the literature uses models of a multidimensional or systemic

[1] We sincerely thank Gerald Barnett and Manfred Modaschl, whose valuable comments have contributed to strengthening the argument of this paper.
[2] The literature reviewed in this paper deals exclusively with technological innovation. We use innovation for short.

kind, which include demand as one factor among many. The demand-pull model rapidly became assimilated into multidimensional models and was lost, disappearing from researchers' agendas.

There exists no history for the demand-pull model, only critical reviews (Mowery and Rosenberg, 1979) and very brief summaries of the literature (Kamien and Schwartz, 1982: 33-36 and chapter 3; Coombs *et al.*, 1987: 94-100). This paper is a genealogical history of the demand-pull model that covers the period c.1960-c.1990, focusing mainly on the literature that deals with *models* as such, either as a notion or explicitly by name. [3] This is more than just a matter of semantics. In using the term "model", researchers generally claim to offer a comprehensive theory, approach or interpretation of reality – although in simplified form (mathematical or pictorial).

The literature on the demand-pull model comes from or involves a specialized community, mainly of European origins, called innovation studies (for a definition of innovation studies, see Fagerberg and Verspagen, 2009; for a critique, see Godin, 2011). When, how and why did the idea of a demand-pull model enter the literature on innovation? What impact, if any, the model has had on representations and understanding of innovation? Why was the alternative to supply-push models neglected?

The first three sections of the paper are historical and are organized according to what we call three moments in the life, or social construction, of the demand-pull model: genesis, crystallization and dissipation. We document that the idea of demand as a factor in innovation emerged in the 1960s, became formalized into a demand-pull model in the 1970-80s, then became integrated into multidimensional models. Following a critique by two researchers, the demand-pull model *per se* disappeared from the literature.

[3] This paper is not a study on how, over time, demand as a *factor* came to explain innovation. Demand, whatever it means, continues to be discussed as a variable in mainstream economics, in the literature on "technological change" and in "innovation studies". The demand-pull model may have disappeared from the literature but historically it may have contributed to the current discussions on demand (e.g. user innovation). Neither does the paper look at demand in public *policy* or at demand-driven policies. For example, public procurement (stimulating innovation through government's demand) is a much discussed topic in contemporary works on innovation policies. This paper is entirely concerned with *models*.

The last section analyses critically the controversy on the demand-pull model. It suggests that the competition between the values underlying two conceptualizations of innovation – the values of science and the values of society – explains the disappearance of the model. To the critics, namely to economists or economically-minded researchers, demand is an economic concept, which is badly theorized by the originators of the model (management and sociology) and the users: understood too broadly (as social needs), demand is of limited use to explain innovation. In conclusion, we ask: What if the demand-pull model had gained precedence in the literature on innovation?

First Moment: Genesis of an Idea

The history of the demand-pull model is intimately linked to that of the linear model of innovation. The linear model (basic research or scientific discoveries as the initiating force for innovation) is the background to every discussion of the demand-pull model, which emerged as an alternative explanation for innovation. The history of the linear model itself will not be repeated here (see Godin, 2006). Suffice it to say that the linear model emerged in an explicit form in the late 1940s in the writings of economic historian W. Rupert Maclaurin (1949) from MIT and of C. C. Furnas (1948) – although the idea had existed previously (e.g. Holland, 1928; Stevens, 1941).

In the 1960s, the first studies of innovation that systematically considered driving forces other than basic research were published. These studies had no theoretical aim; they were conducted by governments and its consultants to get more out of science activities – and out of public funding for research. Two characteristics of the studies deserve mention. First, the studies focused on publicly sponsored research and development (R&D), particularly military R&D. Second, they were conducted to improve project management. For example, Project Hindsight, funded by the US Department of Defense (Sherwin *et al.*, 1966; Sherwin and Isenson, 1969; US Department of Defense, 1969), aimed at, "Develop hypotheses which would assist the Department of Defense to increase its effectiveness in the administration of research and exploratory development" (A. D. Little, 1965: I-1). As the July 1965 memorandum from Harold Brown, Director of

Research and Engineering at the Department of Defense put it, Project Hindsight had two objectives: identifying the "management factors for [productive or useful] research and technology programs", and measuring "cost-effectiveness" or return on the Department's investment in research. The project lasted from 1963 to 1969. It examined twenty weapons systems and other military equipment, and traced the post-World War II contributions of research and development (called Events) backward. [4] To the then-commonplace idea regarding scientific discoveries as being the seed of innovation, Project Hindsight added other factors considered to be "manageable" and "measurable" regarding their contribution to innovation. The project determined that most weapons systems rely on research of the applied type, rather than basic research.

Project Hindsight was highly criticized, as soon as it became known, by the academic researchers. Many critics of the demand-pull model emphasizes Project Hindsight, some to the exclusion of other related studies. But project Hindsight was not the only study conducted for the Department of Defense on the comparative contribution of basic *versus* applied research. There were many others, in the US Air Force and the US Navy for example (Price and Bass, 1969). Federal departments other than Defense also conducted such studies. While Project Hindsight is often contrasted to *Technology in Retrospect and Critical Events in Science* (TRACES) from the National Science Foundation (NSF) (IIT Research Institute, 1968-69), it has rarely been noted that the NSF awarded many contracts for studies on the role of research in innovation in the 1960-70s and later to A. D. Little, the same contractor used by the Department of Defense (A. D. Little, 1963; 1973), and the National Planning Association (Myers and Marquis, 1969). All of the studies concluded, with a result perhaps unwelcome to an organization interested in demonstrating the contribution of basic research to innovation, that economic factors (including demand) play a critical role in innovation.

The messages of all of these studies were twofold. First, need is what drives innovation. "Nearly 95 percent [of innovations in weapons systems] were motivated by a recognized

[4] "An RXD Event is a period of technical activity with a well defined outcome" ["progress report, proposal, journal article, patent disclosure or some other document"] which has influenced the development of weapon systems" (Little, 1965: I-1).

Defense *need*" stated the report on Project Hindsight. "Only 0.3 percent came from undirected science" (Sherwin and Isenson, 1969: 1577). This statement had been made previously at the very beginning of the study five years earlier: "the predominance of Events of an exploratory development rather than a research nature" drives innovation at the department of Defense and this innovation is "triggered by the *needs* and operational requirements of such systems" (A. D. Little, 1965: I-3). This message emerged in similar studies as well. The National Academy of Sciences stated that "the recognition of an important *need* was most frequently the principal factor in stimulating research-engineering interactions" (National Academy of Sciences, 1966: viii; 15-16). This message was also emphasized in early reviews (Price and Bass, 1969; Rothwell and Robertson, 1973; Utterback, 1974): "the majority of successful innovations", summed up Roy Rothwell from the Science Policy Research Unit (SPRU) at Brighton, England, "arise in response to a specific *need*" (Rothwell and Robertson, 1973: 213).

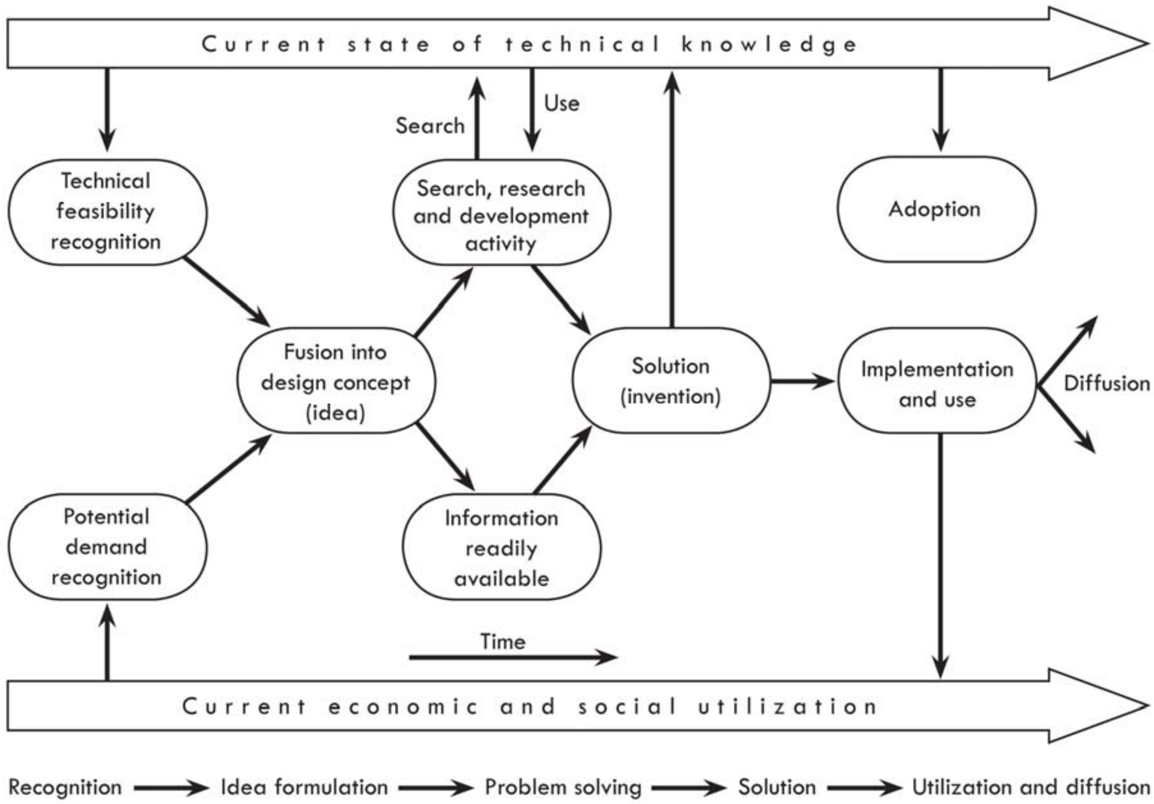
This message emerged at the same time that innovation came to be defined as a process: the introduction of an invention into the economy. Such a conceptualization was explicitly suggested by A. D. Little (1963: 6), and also by the US Department of Commerce, according to which innovation is a process leading from invention to commercialization (US Department of Commerce, 1967). Some authors of the time also explicitly highlighted the role of demand in this process: innovation is the use of an invention "to satisfy a demand or *need*" (Gruber and Marquis, 1969: 256). Herbert Hollomon, then Assistant Secretary of Commerce for Science and Technology, summarized the idea in his speech to a conference on the *Economics of Research and Development* held at Ohio State University (Hollomon, 1965: 253):

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

The second message to emerge from the studies is the need to couple scientific discoveries with needs. Both stimulate innovation, through “fusion” into an idea or design, as Donald Marquis (MIT) and his colleagues put it (Gruber and Marquis, 1969; Myers and Marquis, 1969) (see Figure next page). This message is the central one, even more central than that concerning needs. Innovation may be “an orderly process” composed of (linear) stages – a process “starting with the discovery of new knowledge, moving through various stages of development, and eventually emerging in final, viable form”, as stated by Price and Bass, formerly from the US Department of Defense and A. D. Little – but basic research does not necessarily initiate the process. There is no linear sequence from basic research to invention to innovation. “There is a complex interplay of concepts and people” with dialogue and feedback (Price and Bass, 1969). Price and Bass concluded their paper with a typology of “mechanisms of coupling” based on the analysis of 244 coupling events, from the indirect type (the technologist reading the scientific literature) to the most direct (gatekeepers).

In the mid-1960s, the idea of coupling was everywhere in the literature, to the point where some have qualified coupling as not an original conclusion (Coombs *et al.*, 1987: 102). “Coupling” became “a word of fashion”, as the organizers of a conference on *Coupling Research and Production* put it (Martin and Willens, 1967: 1; see also Rubenstein and Douds, 1969), along with various other terms or synonyms: interface, transfer, liaison, diffusion, interaction, communication and fusion. “What appears to be lacking”, stated George Martin and R. H. Willens, “is a mechanism whereby a pure researcher, or a group of them, can bring their ideas to the development man (…). Alternately, there is also no mechanism whereby production problems are automatically translated and analyzed into their scientific components for possible solutions by development and research men” (Martin and Willens, 1967: 3).

The Myers and Marquis Model
(1969)



Coupling refers to the various people and activities involved in innovation. There is need to couple basic research to development and to couple development to production (Martin and Willens, 1967: 3), to couple the technological, economic and human factors together (Gruber and Marquis, 1969: 4), to couple the technical opportunity with market demand recognition (Myers and Marquis, 1969: 5) and to couple the laboratory with the factory (Gruber and Marquis, 1969: vii). There is a need for interaction between science and technology, and between technology and production (Toulmin, 1969: 35). Rothwell and Robertson produced a review of the literature which placed the message under the umbrella of "communication" issues (Rothwell and Robertson, 1973). Conferences on coupling and transfer were organized. The study of the relationships between science and technology entered into the history and sociology of science (Kranzberg, 1967). [5]

Some Early Conferences on Coupling and Transfer

Technology Transfer and Innovation, National Planning Association and National Science Foundation (15-17 May 1966).
Factors in the Transfer of Technology, MIT (18-20 May 1966).
Coupling Research and Production, American Institute of Mining, Metallurgical and Petroleum Engineers (5-7 October 1966).
Symposium on Interaction of Science and Technology, University of Illinois (17-18 October 1967)

Reactions to the commissioned studies were of two types. First, vigorous opposition from academics because the findings run contrary to the linear model (which states that innovation starts with basic research). The TRACES study funded by the NSF is well-known as a direct reaction to the (preliminary) findings of Project Hindsight – although as mentioned above, the organization commissioned many studies on innovation that produced similar results with regard to the role of demand. One polemical critique came from Karl Kreilkamp, an ex-employee of the NSF. To Kreilkamp, project Hindsight did "not rank high intellectually when compared with other recent efforts in this genre", namely TRACES (Kreilkamp, 1971: 43). To Kreilkamp, "reductionism" and a methodology based on subjective judgments and a too-short time horizon, among other things, was at fault. But the TRACES study served its purpose. It was in fact released prior to the final Project Hindsight report, neutralizing the latter's impact on policy.

[5] For critical surveys on science-technology relationships and models, see: Mayr (1976), Wise (1985), Keller (1985), Barnes (1982), Barnes and Edge (1982).

The second reaction to the reports was growth in the number of factors involved in the study of innovation. Need (most of the time called demand) as a factor was added to the supply of scientific discoveries, but so were many other factors: management, marketing, communication, entrepreneurship, finance. The study of "factors" is an old affair among economists and others (e.g.: the literature on technological change; Maclaurin, 1949; Carter and Williams, 1957). Subsequently, researchers started to produce surveys that measured dozens of factors (Freeman, 1971; Langrish et al., 1972; SPRU, 1972; Rothwell, 1977). Most of the studies used a methodology not very different from that developed by the US Department of Defense: counting 'units' involved in innovation. "Events" – a concept and a term also used by TRACES and others such as Sumner Myers (1967: III-4) – came to be also referred to (or named) as sources of ideas, information units or flows, and other similar terms.

The DoD- and NSF-contracted studies were simply a continuation of a series of studies or criticisms of the linear model. To take just a few examples, both Donald Schon in the United States and James Albert Allen in England had produced books that critically examined the linear model and added need and other factors to the model. [6] To Schon, the process of invention behind innovation is an "oscillation between *need* and technology" (Schon, 1967: 16). To Allen, "the recognition of a [market] *need* at the distribution end and the prospect of exploiting it is probably the most powerful driving force for the total process" of innovation (Allen, 1967a: 23). The messages, on need on one hand and on coupling on the other, thus arose explicitly from different sources in the 1960s: governments, corporate consultants and academics.

Second Moment: Crystallization

The early 1970s saw the emergence of what is today called "innovation studies". Many research groups were set up, particularly in England, such as that at the University of

[6] Shon, a philosopher, worked at A. D. Little from 1957 to 1963, then at the US Department of Commerce until 1966. He wrote the book a year before joining MIT. Allen, a chemist at the University of Newcastle in Australia, wrote his book – and a second one (Allen, 1967b) – during a fellowship at the Center for Business Research at the University of Manchester.

Sussex (SPRU) and that at the University of Manchester (Department of Liberal Studies on Science). They began increasing the number of factors used to explain innovation. Some studies contrasted their multi-factor results to prior single-factor studies (scientific discoveries or need). Innovation is rather a complex process. Yet the eclecticism or multiplicity and diversity of the factors involved in the innovation process suggested to some the need to simply the results, as was indicated by project SAPPHO (SPRU, 1972: 31). One response was to create "models".

A Model

In spite of the idea of coupling need with scientific discoveries, not one but two separate models were developed. In the early 1970s, the polarized debate on the role of scientific discoveries *versus* needs in innovation was formalized into what came to be called models. A model generally means a simplification of *reality*. However, model is also a term used as a simplification of *theory*. Researchers use the term model applied to the theories of others, even if these others have no model as such. In this sense, the term serves to caricature an idea or theory under study or criticism.

For some years, the conceptualization of innovation as a linear sequence (under various names) had been labeled as a model. Now, need received its own model. In fact, two separate models, the name of which came from *Wealth from Knowledge* by researchers from the University of Manchester, were imagined as a caricature of two opposite hypotheses: the linear or "discovery-push" model, and the "*need*-pull" model (Langrish *et al.*, 1972: 72-73). Each model postulates one single explanatory factor ("scientific or technological discovery" *versus* "customer or management *need*"), then depicts a story describing the sequence of events which leads to innovation. [7]

It is no coincidence that this model, or rather the concepts and terms "push" and "pull", came from the University of Manchester. In the late 1950s, two researchers at the same

[7] Contrary to Edgerton (2004), Langrish *et al.* are not the fathers of the linear model, but of the demand-pull model.

university (C. F. Carter and B. R. Williams), whose contribution to the study of innovation has yet to be properly recognized, produced a series of books on the factors responsible for firms' "progressiveness", namely the application of scientific discoveries in industry, or "innovation". The work was conducted between 1952 and 1956 for a committee of the British Association for the Advancement of Science. Chapter 10 of their book *Industry and Technical Progress* (1957) is entitled "Pushes and Pulls". The researchers contrast the "out of date" view to the effect that scientists and in-house R&D necessarily drive innovation (science or technology-push) to the view in which conditions such as "money, receptive management, favourable markets" are equally to innovation essential (demand-pull). According to Carter and Williams, many firms simply borrow (adopt or imitate) ideas for innovation from outside the firm – an idea that A. D. Little (1963), Schon (1967) and Myers and Marquis (1969) took seriously … as well as Luke Georghiou and his colleagues from Manchester in their follow up of *Wealth From Knowledge* (Georghiou et al. , 1986). According to Carter and Williams, such a firm is nevertheless innovative. In their view a firm may be "highly progressive without showing much trace of originality". It "may simply copy what is done elsewhere: it may be *pushed* into the stream of advancement by its suppliers, or *pulled* there by its customers" (italics are ours) (Carter and Williams, 1957: 108). [8]

In the decade following *Wealth from Knowledge* the labels "push" and "pull" appeared in almost every study discussing the issue of scientific discoveries *versus* demand (e.g.: Nelson and Winter, 1977; Freeman, 1979; 1996; Kamien and Schwartz, 1982; Walsh, 1984; Rothwell and Zegveld, 1985; Rothwell, 1994; Kleinknecht and Verspagen, 1990; Howells, 1997; Piva and Pivarelli, 2007; Nemet, 2009). [9] Each of the two models also came to be defined or explained with the aid of a diagram (see figure next page). Like

[8] To these authors, push is used to represent either research (in-house research) or ideas from (outside) suppliers. As an indicator that the terms push and pull were in the vocabulary of the time, note that Myers used the term "push" some years later. He talked of the necessity for organizations to "push" innovative ideas "against hostilities and inertia" (Myers, 1965).

[9] As an indicator of the diffusion of the terms, compare Morton Kamien and Nancy Schwartz's book to their review of the literature. The book (1982) makes use of the terms push and pull and "technology-push" and "demand-pull" to frame the discussion, while the review of 1975 literature discusses the same issue without the terms: "Does the presence of basic knowledge, also called "technological opportunity", stimulate inventive activity or is the stimulus the profit potential of innovations that satisfy an existing want?" (Kamien and Schwartz, 1975: 6).

statistics, diagrams have the virtue of simplifying a complex reality – or a complex theory. The literature on management, and that on the linear model of innovation and its variants, was already full of such diagrams (e.g.: Furnas, 1948; Schon, 1967; Utterback, 1971). Then researchers drew a diagram composed of two figures composed of boxes and arrows, and contrasted the two "models". The first such pairs of figures came from researchers at SPRU in the 1980s (Freeman, 1982; Freeman *et al.* 1982; Rothwell and Zegveld, 1985; Coombs *et al.*, 1987; Freeman, 1996).

Rothwell's Diagram

(1985)

"*Technology-push*" model:

Basic Science → Applied Science and Engineering → Manufacturing → Marketing

"*Need-pull*" model:

Market *Need* → Development → Manufacturing → Sales

Despite the schematic polarization, most authors would agree that innovation results from both technology-push and demand-pull. [10] Rothwell's early review of the field included, in contrast to the figure below, a schema that combines "technological capability" and "recognition of a new societal or market *need*" (Rothwell and Robertson, 1973). [11] Freeman talked of the "one-sided approaches" ("science-push theories" and "demand-pull theories") with reference to *Wealth from Knowledge*, as "complementary rather than

[10] The "discovery-push" model of Langrish et al. came to be called science-push or technology-push indiscriminately, and over time the latter became the most used appellation. We will thereafter use 'technology-push'

[11] Rothwell's schema is an exact copy of that of Myers and Marquis, except for the terms used. For example, "potential demand recognition" becomes "recognition of a new societal or market *need*".

mutually exclusive", as John Langrish and his colleagues themselves put it (Langrish *et al.*, 1972: 75). To Freeman, "any satisfactory theory must simultaneously take into account both elements" (Freeman, 1982: p. 109-10).

The idea and semantics of "coupling" from the 1960s is present in every subsequent study, and new terms make their appearance: interaction, combination, symbiosis, synthesis and complexity. Langrish and his colleagues suggested a "complex process involving the interaction of many factors" (Langrish *et al.*, 1972). Project SAPPHO called it a "complex sequence of events" (SPRU, 1972). Chris Freeman called it a "combination": "almost any of the innovation which has been discussed" could be cited in support of this "creative and imaginative matching" or "combination" of ideas (Freeman, 1974: 167-69). [12] Yet the discourse on coupling did nothing to prevent the construction of two separate models and schemas which crystallized the opposition.

A Vocabulary

Project Hindsight and similar studies talked of needs, using a vocabulary that originated with management, and used by policy-makers (Hollomon, 1965) and management (Baker, Siegman and Rubenstein, 1967; Rubenstein and Douds, 1969). The Battelle study for the NSF also used the term need (Battelle, 1973). The studies that followed used the same vocabulary: Langrish *et al.* (1972), Rothwell and Robertson (1973) and project SAPPHO (SPRU, 1972). But this vocabulary did not last long. The term need was soon shifted to the term demand. In just a few years, the need-pull model became, and is still known today as, the "demand-pull model", usually shown in quotation marks. David Mowery and Nathan Rosenberg, in a survey of the studies produced at that time, are

[12] Combination is an old idea among writers on innovation. It goes back to sociologists like Gabriel Tarde and S. Colum Gilfillan. Freeman's combination makes analogies with Abbott P. Usher's 'Gestalt' theory of an "imaginative process of 'matching' ideas". "All theories of discovery and creativity stress the concept of imaginative association or combination of ideas", stated Freeman: "coupling first takes place in the minds of imaginative people" (Freeman, 1982: 111-12). Freeman expands the theory of the mind to "the whole of the experimental development work and the introduction of the new product" – "linking and coordinating different sections, departments and individuals", "communication within the firm and between the firm and its prospective customer" (Freeman, 1982: 112) – and the entrepreneur: "the crucial contribution of the entrepreneur is to *link* the novel ideas and the market" (Freeman, 1982: 110).

responsible for the new label (Mowery and Rosenberg, 1979). As discussed below, to the authors demand refers to a specific economic concept, as opposed to (human and social) needs.

In fact, an authoritative literature existed to support a vocabulary of demand. In the economic literature, the two theses on push and pull have analogues in terms of supply and demand, two central concepts of economic theory. “The problem may be stated in the parlance of traditional economics”, Jacob Schmookler had suggested (Schmookler, 1962: 197). Together with a vocabulary on input and output, the terms “supply” and “demand” entered into studies of science early on, first as factors that determine the level of scientific and technical manpower (e. g.: UK Privy Council, 1946; Blank and Stigler, 1957), and then as factors that determine technological change (US National Bureau of Economic Research, 1962; Nelson *et al.*, 1967: 28-43; Mansfield, 1968: 17-18; Rosenberg, 1969). [13] Thereafter, the two concepts entered the literature discussed here, and the term demand replaced need. This occurred in two stages. First, need came to be discussed in terms of market needs. As Chris Freeman put it: “*need*” is, “more precisely in economic terms, a potential market for a new product or process” (Freeman, 1974: 165). To others, “social and market *needs*” (Rothwell and Robertson, 1973) became simply “market *needs*” (Rothwell and Zegveld, 1985). These changes gave a definite market orientation to the term need. In a second step, the term need was readily supplanted by the term demand by researchers, who almost exclusively henceforth referred to the demand-pull model.

A Story

The economist Jacob Schmookler has been an ardent promoter of the role of economic factors, as opposed to scientific discoveries, in innovation. From his very first papers in

[13] To Fritz Machlup, supply means opportunities arising from research discoveries or technological opportunities: “variations in the flow of new inventions becoming available for eventual industrial application” (Machlup, 1962: 143). To Jacob Schmookler, “the supply of inventions is in a sense determined by the number of creative individuals skilled in the technical arts, and by the state of knowledge which affects the conversion of inventive effort into inventive output. The demand for inventions, in turn, is presumably determined by economic conditions” (Schmookler, 1962: 197).

the 1950s to his book *Invention and Economic Growth* in 1966 Schmookler has stressed the influence of economic conditions in decisions about science and their effects on the demand for inventions (Schmookler was not concerned with innovation, but invention). To Schmookler, both ingredients, “knowledge” and “wants”, are essential: “Without wants [demand or need] no problems would exist. Without knowledge they could not be solved” (Schmookler, 1966: 11-12). Schmookler also drew what is perhaps the first schematic model, or “framework” as he calls it, of the determinants of invention (Schmookler, 1962: 196). He also framed the debate between technology-push and demand-pull using earlier terms: inventions are “knowledge-induced or demand-induced” (Schmookler, 1966: 12). The word “induced” was used widely in the early 1960s in the economic literature on “induced innovation”.

However, Schmookler was an isolated author whose views, incidentally, were not considered in the debates of the 1960s discussed above. He was alone and preaching in the desert. [14] The case of “social need” and “demand” has been “overemphasized”, claimed Richard Nelson in his early review on the economics of invention. “Demand and cost analysis is less successful in explaining invention itself, as opposed to inventive effort, because of the major role played by uncertainty” (Nelson, 1959: 110). [15]

Schmookler’s ideas (re-) entered theories in the 1980s, as part of retrospective rehabilitations in the hands of storytellers of the demand-pull model, among others. Two authors came to be identified as the fathers of the two alternative models: Joseph Schumpeter (technology-push) and Schmookler (demand-pull). The studies of the 1960s were ignored or downgraded to prehistory. They correspond to the “natural history phase” of research on innovation, as Rod Coombs and his colleagues put it (Coombs *et al.*, 1987: 97), with an “appearance of statistical support” (Freeman, 1979: 207). By contrast, Schmookler’s vocabulary on demand is considered to arise from an authoritative

[14] Of course some mentions of Schmookler may be found, in Myers and Hollomon for example, but only in passing, as support for or as a supplementary example of one’s own view. The studies from social researchers in the early 1970s, some of whom made much use of Schmookler’s ideas later on, made no use of him either (SPRU, 1972; see also Langrish et al., 1972).

[15] Nelson refers to sociologists like S. C. Gilfillan rather than Schmookler, who is mentioned only with regard to a separate issue (firm size).

discipline – economics. Furthermore, the economist offers an original methodology espoused by these authors: patent counts.

The early studies like Project Hindsight have nothing to do with (market) demand and the demand-pull model, contrary to what reviewers like Mowery and Rosenberg suggest. This model developed independently. For example, Rosenberg's early paper on supply and demand made no mention of these studies at all, but cited the economic literature (Rosenberg, 1969). Equally, the studies on demand cited in project SAPPHO are not Project Hindsight and similar ones, and Langrish *et al.* used policy-makers (P. M. S. Blackett and H. Hollomon) as examples or representatives of the demand-pull model rather than Project Hindsight.

In the footsteps of Rosenberg (1974), researchers from SPRU (Chris Freeman, Roy Rothwell, Vivian Walsh) and others (F. M. Scherer) contributed to making Schmookler not just an "exponent" of the demand-pull model, but its supreme representative. To Freeman, Schmookler was "the most scholarly and probably the most influential, at least within the economics profession" (Freeman, 1979: 208); he "has given some credence" to the demand hypothesis (Freeman *et al.*, 1982: 82) and has provided "a more theoretical level" and "a more sophisticated historical justification" (Freeman, 1994: 479). According to Walsh, "Schmookler was probably the major contributor to the "victory" of demand-pull theories" (Walsh, 1984: 212). Certainly these researchers admit that making Schmookler a supreme representative of demand-pull is a simplification, but at the same time, their stories (as opposed to history) crystallized the attribution of the demand-pull model to Schmookler. The two competing models were thereafter accompanied by a title attributing them to Schumpeter and Schmookler, respectively (Freeman *et al.*, 1982: 37-40; Rothwell and Zegveld, 1985: 62-63).

Third Moment: Dissipation of the Model

The demand-pull model did not last long. It was subsumed under multidimensional models following what was characterized as a "devastating critique" (devastating in its effects, at least) of the studies we discussed in the first section above which the two authors grouped without discrimination under the label “demand-pull” (Mowery and Rosenberg, 1979). In fact, researchers do not read the earlier studies anymore, but instead cite Mowery and Rosenberg’s paper as the definitive position. What is it in this paper that convinced researchers to abandon the demand-pull model? Rosenberg had previously paved the way for this critique. In 1974, he wrote a paper criticizing Schmookler’s thesis that demand explains variations in inventive activity. “Although economic forces and motives have inevitably played a major role in shaping the direction of scientific progress”, stated Rosenberg, “they have not acted in a vacuum, but within the changing limits and constraints of a body of scientific knowledge” (Rosenberg, 1974: 100). Then, together with Mowery, Rosenberg launched a second and similar attack on the empirical studies of the 1960s by concluding: “the “demand-pull” approach simply ignores, or denies, the operation of a complex and diverse set of supply side mechanisms which are continually altering the structure of production costs” (Mowery and Rosenberg, 1979: 142).

To Mowery and Rosenberg, the demand-pull model (or “hypothesis”, as they call it) is wrong for methodological reasons (while the NSF study offers a “more reasonable view” of innovation, p. 122). What are the model’s limitations according to Mowery and Rosenberg? They add up to a failure to distinguish between need and demand. The authors contend that the demand-pull hypothesis missed the point when talking of needs, a “shapeless and elusive notion”: (human) needs are unlimited, and therefore not capable of driving decisions about research, while market demand is identifiable using precise (economic) criteria:

> “Demand” can be either current demand, or potential demand [need], which largely deprives the concept of market demand of any operational meaning. Potential demand may exist for almost anything under the sun, and the mere fact that an innovation finds a market can scarcely be used as evidence of the undisputed primacy of “potential demand-pull” in explaining innovation (p. 107).
>
> In order to retain its analytic content, market demand must be clearly distinguished from the potentially limitless set of human *needs*. Demand, as expressed in and mediated through the marketplace, is a precise concept (p. 140).

The responses to (or impacts of) Mowery and Rosenberg's critique were twofold. First, the study of the demand-pull model dwindled to a few studies in the following decades (e.g.: Scherer, 1982; Kleinknecht and Verspagen, 1990; Piva and Pivarelli, 2007; Nemet, 2009). Thereafter, the demand-pull model was studied mainly as opposed to the technology-push model, as in Vivian Walsh's framework (Walsh, 1984) [16] and Georghiou et al. (1986). Further developing Freeman's idea (1974; 1979; 1982), which she mapped onto James Utterback's metaphor of the life-cycle – a metaphor that has given rise to many models throughout history – Walsh showed how the respective contributions of scientific discoveries and demand correspond to different stages of development or levels of maturity within a particular industry. Such a dynamic framework, with a differentiated role for each of the two factors, has attracted some followers recently (van den Ende and Dolfsma, 2005; Schmoch, 2007; Kim and Lee, 2009; Nemet, 2009).

A second response was a return to a focus on scientific discoveries, as the ultimate causal factor in generating innovation. Giovanni Dosi is an ideal representative of this response. He presented his idea of technological paradigm as a resolution to "the long debate on the relative importance of 'demand-pull' versus technology push" (Dosi, 1988: 228). In his view, not unlike Rosenberg's "inducement mechanisms" or "focusing devices" (Rosenberg, 1969), there are "technological paradigms" which constrain demand (Dosi, 1982; 1988). Dosi holds that demand certainly plays a role in innovation, but it is technological opportunities or technological paradigms that channel the direction of innovation. Dosi's idea has had many followers, although over time, technological paradigms as a concept stopped being discussed with reference to the debate on scientific discoveries *versus* demand. It got an autonomous status.

[16] We refer to Walsh's article from 1984 rather than the report produced for the SSRC (V. Walsh *et al.*, *Trends In Invention and Innovation in the Chemical Industry*, Sussex, 1979). The latter has not circulated much (it is currently available in only one library worldwide). The results of the report are also discussed in Freeman (1979) and Freeman *et al.*, (1982). Before these authors, the idea was discussed in Langrish (1974: 615-16).

From that point on, the demand-pull model lost its status as an autonomous model. A third and more lasting response appeared in narratives. Researchers constructed stories that relegated the model to a brief moment in history. The model was discussed as a relic of the past together with the "technology push" model. According to a story offered by Rothwell and regularly cited since then, there have been five successive generations of models of innovation: the technology push model, the need-pull model, the coupling model, the integrated model, and the system and network model (Rothwell, 1992). Rothwell's last three generations of models are multidimensional models.

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.

Rothwell's story seems essentially accurate. Researchers have revised and converted previous models, particularly the linear or technology push model, into multidimensional models. In the literature, the representative example of a multidimensional model is that from Stephen J. Kline (1985). Every author on these issues has cited the paper since its publication, or rather that of Kline and Rosenberg (1986). For the third time in over a decade, Rosenberg had published a paper criticizing linear or single-factor models. Kline's model is a "chain-linked model", with interactions and feedback loops among all the factors involved in the process of innovation. According to Kline, the literature from engineering designers "discussed models of innovation that look very much like the chained-linked model for a long time [*circa* 1965]. However, these models usually exclude economic considerations, are often more complex in details, and typically are couched in jargon that only engineers understand" (Kline, 1985: 43).

Given the call to create more complex models, the interesting question to ask is, what happened to the demand-pull model? Why did it vanish so quickly? Or has it? The demand-pull model simply seems to be ignored by some scholars' narrative, or rather storytelling. It is symptomatic of the short life of the demand-pull model that Kline and Rosenberg offer their systematic model as the alternative to the linear model, without even mentioning the existence of the demand-pull model in between, although it had been Rosenberg's target up until then. [17] Certainly Kline's model includes demand as the starting point ("market findings"), as many multidimensional models do, but without discussing the demand-pull model as such. [18] Similarly, the story from Bengt-Ake Lundvall and his colleagues follows Kline and Rosenberg's ("moving from a linear to a chain-linked model of interpretation"), to which they add their own model. The authors explicitly omit discussion of the demand-pull model that developed in between (and of later generations identified by Rothwell). In a footnote, they explain that their decision was for simplification reasons (Caraça *et al.,* 2009: 182).

[17] To a certain extent, models like those of Myers and Marquis and Rothwell were also multidimensional, or at least combined scientific discoveries with demand (Myers and Marquis, 1969; Rothwell and Robertson, 1973).
[18] To be sure, Kline and Rosenberg include "potential market" as one of five elements in their model, and mention the "artificial" opposition between "market pull" and "technology push", but without any reference to the demand-pull model *per se* and its literature. It is interesting to note too that Rosenberg talks of need in this co-authored paper, despite his criticism of the notion in 1979.

In sum, the storytelling goes from linear models to models of a multidimensional type. Demand has shifted back to what it was in the 1960s: a single factor (among many) – under many guises: interactions between suppliers and users, user innovation, etc. The field began constructing new kinds of "mental models", as John Ziman called them (Ziman, 1991): multidimensional rather than single-factor oriented. The terms used to describe such models are many: iterative, interactive, recursive, systemic. Every author has his own label (and story):

Concomitance model (Schmidt-Tiedemann (1982).
Chain-linked model (Kline, 1985).
Multidirectional model (Pinch and Bijker, 1987).
Neural net model (Ziman, 1991).
Coupling model (Rothwell, 1992).
Interactive model (Newby, 1992).
Linear-plus model (Tait and Williams, 1999).
Multi-Channel Interactive Learning Model (Caraça *et al.*, 2009).

"What is a model?" is a question that remains most of the time unanswered. Contrary to other disciplines like physics and economics, researchers from innovation studies 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, 1999: 356). In contrast, a model here is not an instrument to explore, manipulate and experiment a theory, to simulate the world and get better theories. A model is a mere scheme or figure, or a conceptual framework put into a schematic figure.

Two Conceptualizations of Innovation

One reason for the shift from need to demand in the vocabulary and related analyses is because scholars chose to study innovation in the context of the firm and related market factors. As the title of most studies on innovation attest (from Myers and Marquis onward), researchers focus on firms as originators of innovation and their environment, rather than public organizations as sponsors or societal needs. The environment considered is the market – rather than both market and non-market factors, to use Richard Nelson’s clarification (National Bureau of Economic Research, 1962; Nelson and Winter, 1977; 1982). When the non-market environment (such as government) is considered, it is studied as a market (the demand from government or government as a purchaser of new products) – or as a barrier to industrial innovation. This brings us to discuss what demand actually represents.

As mentioned above, “demand” in social sciences is a concept that comes from economic theory. Together with “supply”, it constitutes one of two central concepts of economics. “Demand-pull” also comes from economics, in this case inflation theory from the 1950s (inflation due to demand exceeding supply). Both Mowery and Rosenberg (1979) and Freeman (1979) noted rightly that the studies of the 1960s on demand (or rather needs) came from one particular group: governments and their consultants. However, they did not point to the consequence we draw here. The authors of the time gave need a different meaning than market demand *because* their focus was different than that of economists. They wanted to study the role of public organizations – not firms – in the innovation process.

To a certain extent, Mowery and Rosenberg are right with their statement that researchers used the terms need and demand interchangeably. For example, Myers and Marquis reviewed the rather diverse studies (on needs) produced until then and put them under the umbrella of demand (Myers and Marquis, 1969: 31-35). That practice continued among subsequent literature reviewers. Yet, to the early writers, namely the consultants to the US Department of Defense, the needs of the Department (national security requirements for new weapons) do not constitute demand in the strict economic sense, and demand is not used as a term in the reports. To these writers, those needs concern public decisions made in the "national interest" and have nothing to do with the "free market". In their view, such national needs are not expressed through the market. According to pure economic theory, Mowery and Rosenberg were probably right: need is not demand. However, a more charitable explanation is possible. At the time, the consultants to governments were looking at public organizations that were not market-oriented, not at private firms. Public needs "are inadequately articulated in terms of market demand", suggested A. D. Little in 1973. More attention needs to be given to "pull mode" ("human and societal *needs* translated into market demands") (A. D. Little, 1973: 2).

The concept of needs refers to specific social issues, which fact may have been loosely articulated by the users of the term at the time [19] and poorly understood by the later reviewers and critics. Certainly, there have been discourses, or rather debates, since the 1930s on the idea that the funding of scientific research should be more oriented toward addressing societal needs. Examples are J. Huxley, *Science and Social Needs* (1935) and J. D. Bernal, *The Social Function of Science* (1939). In the 1960s, the issue was discussed in terms of national goals and "scientific choices" (Weinberg, 1962). Operation research and system analysis as practiced at RAND were entirely concerned with developing a framework to operationalize R&D decisions regarding military objectives or needs. To RAND, the issue of needs is that of public choices *versus* costs: "the right question is, How much is needed for defense more than it is needed for other purposes?" (Hitch and McKean, 1960: 48). And in the 1970s, needs came to be discussed in terms of "priorities" of public expenditures, as the Brook report (OECD, 1971) and Freeman did. [20]

The OECD report is a perfect witness of the vocabulary of the time and an indication of how needs were really discussed in terms of "social demand" and "collective needs" in science policy matters. The report uses a cluster of words to make the meaning of need clear: social demand, social needs, collective needs, social objectives, national goals,

[19] Just to take one example, Schmookler spoke interchangeably of demand, want and desire.
[20] In this context, "users' needs" and "consumer sovereignty" were Freeman's catchwords (Freeman, 1974: chapter 9).

priorities, choices, ends, aims, wants, aspirations. The report suggests that “Governments of member States should channel their technological policies into areas capable of producing alternative, socially oriented technologies, i.e. technologies capable of directly contributing to the solution of present infrastructural problems, of satisfying so far neglected collective *needs* and finally of replacing existing environmentally deleterious technologies” (OECD, 1971: 97-97). In spite of these thoughts, the empirical research on these issues was “still very inadequate”, as Freeman put it (Freeman, 1974: 297).

Another explanation for the confusion between need and demand is that two conceptualizations of innovation are competing here: a large or social conceptualization (need includes both societal needs and market demand) and a restricted or economic one (need as market demand). Mowery and Rosenberg may have missed the message. To economists, the term demand may be preferable to need, simply because it corresponds to market demand. Market demand is a relationship between quantity and price and is analyzed in term of a production function, as Mowery and Rosenberg pointed out. However, to a sociologist, or in a social conceptualization, need has a broader meaning. To Langrish and his colleagues, need represents change in the market *and* in social condition (Langrish *et al.*, 1972: 8). It includes the needs of institutions and their managers. To public managers, need is broader too. For example, to Hollomon, demand explicitly includes demand from the market *and* the government (Hollomon, 1967: 34).

To the early users of the concept then, need adds up to the counterpart in the public sphere of market demand (or includes both) - and represents an infinite number. [21] Need refers to a social problem or public goal addressed in a program, particularly the program of a mission-oriented organization. Needs represent operational problems or goals of public organizations. To be sure, a distinction between demand and need existed before Mowery and Rosenberg. But there were few discussions on the semantics of needs at the time. People took the presence of needs more or less for granted: huge sums of public

[21] Myers and Marquis (1969) and Gruber and Marquis (1969) admit that needs are infinite, and limit demand to market need, that is, need translated into market demand. The latter involves the recognition of an economic value. However, to these authors, demand includes both the commercial market and the public market. Military needs are a proxy for the ‘market needs’ in the case of a public organization (Gruber and Marquis, 1969: 272).

money are invested in research programs in the name of innovation or, as Schmookler put it, for "utilitarian considerations", and these sums are driven by expected outcomes or social needs (Schmookler, 1968). The discussions rather concentrated on what kind of research best addresses these social needs: basic research or applied research? The discussions concerned the imperative to link science and technology to generate innovation.

That needs are infinite may be a philosophical issue, yet needs have concrete manifestations. In the case of customers, needs manifest themselves through the acquisition and consumption of goods and services, otherwise called market demand. John Howells of Brumel University, one of the very writers to have addressed the conceptual issue since Mowery and Rosenberg, had already made this point. Rather than reject the concept, Howells suggested making it more precise, that is, need is use (Howells, 1997: 1210). However, Howells did not address the other kinds of needs. In the case of public organizations for instance, the mechanism for the realization of needs involves not the market but political justification, budget appropriations and implementation of publicly-sponsored programs. As the OECD put it in 1971, "Social demands [are] expressed by consumers through the market and *by society collectively through the political process*" (our italics) (OECD, 1971: 15).

Over time, demand was restricted to exclude human and social needs, public and national needs, as discussed above. At the same time, demand was broadened in two senses. First, demand has become a shortcut for discussing more than demand *per se*, namely the economic factors involved in innovation, as well as a symbol for the thesis on the economic determinants of innovation – like technology-push has become an umbrella term for the 'autonomous or quasi-autonomous' role of science, basic research and technology in innovation. For example, what was called "market factors" in the early days (Carter and Williams, 1957; National Bureau of Economic Research, 1962) included profit opportunity, costs (productivity), supplies (material and labor), competition, market structure, market size, marketing and demand. This was the understanding of Rosenberg too in an early paper on the "economic forces" involved in innovation: prices, costs, profits (Rosenberg, 1969). Later authors maintained the same diversity under the single term demand. Most of the time demand did not refer to market demand (consumption and purchases are rarely measured), but to a whole series of economic variables, of which market demand is one. For example, Myers' vocabulary on "market factors" (Myers, 1967: V-15) [22] shifted in a matter of two years to one on "demand", with the same components included: market factors and manufacturing or production factors (Myers and Marquis, 1969: 31).

Schmookler's semantics is far from univocal too. He talked regularly of economic conditions, rather than demand *per se* (Schmookler, 1962: 197-98; 1968: 47). But what did Schmookler mean when he said "demand for inventions is determined by economic conditions"? Demand here is certainly not equivalent to the market. What the sentence says, rightly in our view, is that demand (for inventions) is pulled by economic or market conditions. If this vocabulary is adopted, the opposite thesis (or model) would be that demand is pushed by the supply of scientific discoveries (inventions) or technological opportunities. If a demand (rather than innovation) can be either technology-pushed or market-pulled, then demand is not an independent variable, but the dependent one. All this added to the confusion.

Second, demand was broadened to became a symbol (and shortcut) for a wide range of variables exogenous to science. The demand-pull model referred to many issues, which are not always conceptually distinguished. In fact, the demand-pull model involves and evokes a complex of issues and serves as an umbrella for these issues: the role of economic or market factors and management in innovation (Carter and Williams; Myers and Marquis; project SAPPHO); social or organizational needs and the kind of research relevant to these needs (Department of Defense; National Science Foundation); the relationship between science and technology and/or the contribution of scientific information to technological innovation (Gibbons and Johnson, 1970; Langrish, 1974).

[22] To Myers, markets factors are: changes in production to meet changes in demand, changed market requirements, anticipated potential demand, direct response to competitive products.

These issues are generally framed into polarized theses. [23] Not surprisingly, the critics of the demand-pull model have encountered conceptual confusion regarding what demand is, and in fact contributed to this confusion. They have mixed different studies and various issues under the term demand. The demand-pull model now represents what the revisionist critics have made it, not what the original contributors intended. The persistence of the market-first perspective speaks more about the values of the scholars promoting it than to its contribution to understanding innovation.

Three Meanings of Demand

1. Economic or market demand:
   - Narrow meaning: Demand for a product, as a function of price.
   - Broad meaning: economic conditions; factors such as the structure of industry, competition, firm size, and profitability.
2. Social meaning: human and societal needs, as articulated in the goals of government organizations.
3. Loose meaning: demand as part of a semantic or then-emerging discourse that placed the emphasis on the contribution to innovation of factors external to or other than scientists' pure motivations (i.e.: economic, social, cultural and historical factors).

Conclusion

Models are short-lived. They survive only as long as they have proponents. The linear model emerged in formalized form in the late 1940s. Challenges arose over the ensuing decades ("out of date", claimed Carter and Williams in 1957). As an alternative, the demand-pull model appeared in 1972. It started as one of two polarized schemas, then

[23] Scientific discoveries *versus* demand, of course, but also basic *versus* applied research, science *versus* technology, scientific *versus* non-scientific factors, internal *versus* external criteria in funding choices.

became coupled with its opposite, the linear model. By the mid 1980s, researchers had stopped discussing the demand-pull model except as an object of the past. Multidimensional models made their arrival and succeeded one another depending on the writers.

We have suggested that two competing conceptualizations or readings of innovation explain the controversy over the demand-pull model. Demand refers to economic theory – and economists or economically-minded researchers have criticized the use of the concept by non-economists – while (human and social) needs refer to psychology and sociology – and were discussed, from the very first studies analyzed here, in terms of public or national needs (government's demand as signaling societal needs). What got lost in the controversy is the study of demand broadly defined. There is actually a blind spot in models of innovation, whatever their source, that human and social needs are excluded. [24] Still, social and human needs extend beyond a person's or a society's ability to express (or signal) those needs in the form of a strict economic definition of market demand.

All of the studies from the 1960s pointed to the fact that ideas for innovation originate from either public or private demand (or need). However, subsequent authors ignored the lesson and, after admitting the need to consider both push and pull, rarely ever considered studying needs, broadly defined. In fact, most of the new (multidimensional) models remain technology-push overall, and have not, despite the aims of their authors, really abandoned the old assumptions. They have simply added complexity to the linear model, which remains as the background (e.g. Balcony et al, 2010). Multidimensional models often remain linear, although they are rarely admitted to be so. One exception is John Ziman: "What we want to do is to retain the principal characteristic of the linear model – the notion of a spectrum of R&D activity from basic science to the market place" (Ziman, 1991: 68).

[24] For example, sociologist E.M. Rogers' *Diffusion of Innovation* includes the "recognition of a *need*" as the first step in his model of innovation (Rogers, 1983: 136). Nevertheless, Rogers, like the economists, do not study the issue of needs/problems at all. He takes needs for granted, ignores the process of generating innovation and instead concentrates on post-deployment variables such as communication and adoption.

One lesson to be learned from the above history it is that models shape how innovation is understood and, as a consequence, what policies are formulated and implemented. Starting in the 1970s, need was whittled down to demand. Demand fits into economic theory and models while need does not. Need is a second-class object or an object of limited study among researchers to whom the main object of interest is, by definition, science and technology (as supply). [25] A corollary lesson is that despite the presence of alternative models, the perspective (and values) of supply prevailed. Over the period studied here, demand is treated as a counter-concept. [26] It has no existence or only limited existence except as an opposite to supply. [27] Today, the demand-pull model is rarely discussed except together with its opposite, the "technology-push" model, and as an object of the past. [28]

In the past thirty years or so demand was diverted to mean economic demand and was peeled off from need. Yet, supply (scientific discoveries) would play a different role in theories and policies than it currently plays if models placed the emphasis on needs and the beneficiaries of innovation. Rather than the dichotomy of either universities or firms being the drivers of innovation systems around which other participants play the role of "context", the emphasis would be on 1. consumers, citizens and their community associations, 2. public managers and programs, 3. governments, public organizations and policies. This is what J. D. Bernal suggested in 1939, although from a normative rather than an analytical point of view, "If we take human life and its development as the center of our study, the activities of science assume a different aspect" (Bernal, 1939: 345).

[25] The literature on user innovation is concerned with market demand rather than need.
[26] On counter-concepts, see Koselleck (1975).
[27] Barnes and Edge talk of models as "correctives" to earlier models (Barnes and Edge, 1982: 152).
[28] One has to turn to a different literature – evaluation studies – for discussions of the demand-pull model (called the logic model). The critical point is that when planning innovation programs intended to achieve socio-economic benefits, the sequence is planned backward and then implemented forward. Under the logic model approach, the planning process first identifies the production requirements for the envisioned product or service (need), then details the design and performance requirements for the product, and finally identifies the required underlying scientific knowledge. If the scientific discovery already exists, no further research activity is required, but development and production. However, if and only if the discovery does not exist, then the collaborating scientists would have to design the appropriate study. The final backward planning task involves securing the resources necessary to accomplish the plan.

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