Invention, Diffusion and Linear Models of Innovation

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Abstract

There exist two sequential or linear models of innovation in the literature. One is the "linear model of innovation" as such. The model comes from management and economics, and their concern with studying the origin of inventions. The other model, of which the linear model of innovation is one part or step, is that of innovation as a process of invention followed by diffusion. This "model", or rather the theory on which it is based, comes from anthropology and was invented as a solution to a controversy on the role of invention and diffusion in explaining culture change.

The sequence 'invention → diffusion' has remained influential in later studies of technological innovation from sociology to management and economics. This paper documents the origin of the sequence and its subsequent use in the study of technological innovation.

One is perpetually hearing sociologists saying that men do not invent customs, but fall into them. Grant that the ninety and nine do follow suit, and in addition grant that each one of us follow his leader all but the thousandth time. It is the one act in a hundred or a thousand that each originates, which constitutes the progress of the world (O. T. Mason, *The Origins of Invention: A Study of Industry Among Primitive Peoples*, 1895).

In most cases a theory which is considered as new has been preceded by a long process of fragmentary attempts. Then comes a time when the ideas that are "in the air" are so to speak crystallized and find their full expression in the thinking of a superior man who impresses on them his personal mark (A.C. Taymans, Tarde and Schumpeter: A Similar Vision, *Quarterly Journal of Economics*, 1950.

Introduction

The first theory of technological innovation is that known as the "linear model of innovation". The model postulates that technological innovation starts with basic research, continues through applied research and then enters the development phase. This model has been much studied, and much criticized, in the last few decades (Godin, 2006; Balconi, 2010). A second theory, a sequential "model", has been just as pervasive in the literature as the linear model of innovation, but has received little critical attention so far. The model has many similarities to the linear model of innovation in the sense that it too looks at technological innovation as a process (in time). It postulates that technological innovation is a sequential and linear process from invention to diffusion. The first such sequences from economists come from the late 1940s-early 1950s. Today, innovation as a process (from the generation of an idea or invention to its diffusion or use and commercialization) is a major characteristic of the literature on innovation.

Yet, the very first sketch of such a model or theory emerged much earlier, as a solution to a controversy in anthropology. Nineteenth-century discussions of changes in culture and of the role of different factors in culture change gave rise to a now-forgotten controversy among anthropologists. While up to and including the Victorian era 'diffusion' as source of civilization or culture was discussed widely among philosophers (commerce or exchanges among writers, enlightenment through learning), some anthropologists of the late nineteenth century began placing the emphasis on 'invention'. This soon gave rise to a controversy between advocates of invention and those of diffusion concerning the role of each factor in culture change.

This controversy, or rather its resolution, had a strong influence on the later understanding of innovation. It gave rise to the study of innovation as a sequential process in time. Invention and diffusion came to be understood as part of the same sequential or linear process: invention is followed by diffusion. From the 1920s onward, such sequences would proliferate in various forms in the writings of anthropologists and sociologists.

This paper documents the origin of this theory back to anthropologists who, decades before the students of technological innovation, invented the theory in order to explain culture change. The first section of this paper presents the diffusion controversy. The second section looks at the alternatives suggested in order to resolve the controversy. Among the alternatives, a sequential process combining both invention and diffusion came to be imagined: culture starts with invention which, in a second step, diffuses through societies. The final section of this paper gives some ideas on the proliferation of the sequence in later studies of innovation, particularly technological innovation.

The paper stops at c.1975. It is at about this date that, in retrospect, one may find the first sketches of the theoretical framework(s) that would define "innovation studies" in the following decades (Godin, 2012a).

The Diffusion Controversy

Early anthropology was concerned with studying practices and beliefs using what came to be known as the comparative method. The study of culture led anthropologists to observe similarities in cultural traits and material culture among societies. As O. T. Mason, American curator and founder of the Anthropological Society of Washington, puts it: "Among peoples far removed from one another geographically and often belonging to different types of mankind there are found words, art products, industries, social structures and customs, folk-tales, beliefs and divinities, and even literatures" alike (Mason, 1895a: 14). Societies or cultures were consequently classified into types, some more 'advanced' than others, and these types were interpreted as evolution or stages of civilization. Societies would have evolved from primitives to barbarians to moderns. These theories are known today as evolutionary social theories (Teggart, 1949; Watson, 1953; Burrow, 1968; Harris, 1968; Nisbet, 1969 and 1980; Meek, 1976; Bowler, 1983).

The explanation of civilization through stages has a long history going back to ancient philosophers and many other writers and theories that explain civilization in terms of

evolution and distinct stages, like A. Comte on knowledge, H. Spencer on society, K. Marx on economics, L. H. Morgan on kinship, E. B. Tylor on religion, and various historians (see Appendix 1). Several assumptions are involved in such theorizations. The first is that human nature is everywhere the same, that there is one path which all nations follow. The second is that differences among societies represent different stages in the same process or different rates of progress. And last but not least is the idea that development by stages is an analogy to the embryo's life-cycle, or to organic change or growth.

But how do the stages evolve? How does civilization occur? What is the *process* behind progress? As American anthropologist Franz Boas put it in 1896, "We agree that certain laws exist which govern the growth of human culture, and it is our endeavor to discover these laws. [But] the object of our investigation is to find the *processes* [Boas' italics] by which certain stages of culture have developed" (Boas, 1896: 276). There are two opposing theses among early anthropologists. Either civilization arises in one culture and is thereafter propagated to other geographical areas (diffusion), or it is the result of parallel and independent developments in every society (invention). [1]

The answer to the anthropologist's question of how civilization (by stages) occurs was discussed in terms of invention *versus* diffusion. Given the voluminous literature produced on this question, I will concentrate on theoretical papers rather than case-studies, which also mention the issue but often with little in-depth discussion. We may begin with Boas and the way he framed the problem. On one side is the psychological explanation. It combines with an evolutionary perspective and "a subjective valuation of the various phases of development, the present serving as a standard of comparison" (Boas, 1904: 26). To Boas, "the literature of anthropology abounds in attempts to define a number of stages of culture leading from simple forms to the present civilization, from savagery through barbarism to civilization, or from an assumed pre-savagery through the

[1] At the time, similar theses were being discussed in biology, and more particularly in biogeography and paleontology (Bowler, 1983; 1989), and these have influenced anthropologists. For example, the concept of "survivals" from anthropologist E. B. Tylor is a direct analogy to fossils, and that of "convergence" (of cultures) comes from post-Darwin biology.

same stages to enlightenment" (Boas, 1904: 28). Similarity of customs in remote part of the world is witness to a "uniform manner in which civilization developed the world over" (Boas, 1904: 27).

This kind of explanation refers to psychic unity: the human mind is the same everywhere. [2] The 'uniform working of the human mind' (Boas, 1896: 270) explains "independent invention" or the fact that some inventions appear the same everywhere. Among anthropologists, it was A. Bastian (*Man in History*, 1868), E. B. Tylor (*Researches into the Early history of Mankind*, 1870) and L. H. Morgan (*Ancient Society*, 1877) who were the early promoters of this view. [3]

Opposing the psychological view, a historical view developed, of which Boas is a representative. Culture is explained by diffusion (or communication). There are many arguments developed to support this view. To some diffusionists, inventions have a common geographical origin: they emerge from one center and diffuse among societies. This is why there are so many similarities. Some have explained this thesis with the further hypothesis that man is essentially un-inventive (F. Graebner; Smith, 1916: 191). Inventions occur rarely, and when they do, they are more often than not imitations.

Along with the geographical argument, other arguments developed supporting the case of diffusion and these, to a certain extent, considered both invention and diffusion. Like Mason, Boas constructed his argument against psychic unity on historical grounds. First, he stressed varieties of forms among societies or cultures: no one invention is identical, rather taking many forms. Similarity is not sameness (psychic unity). How do we explain

[2] The idea on the psychic unity of mankind goes back to Hobbes, Locke and many others in the Eighteenth Century (Joseph Lafitau, Adam Ferguson, William Robertson).

[3] With regard to Bastian and Tylor, there is a debate concerning to what extent they really held this view (Stocking, 1968; Koepping, 1983). In fact, many have argued that such a view is falsely attributed to authors who generally espoused both invention and diffusion as factors in culture change (White, 1945: 341-43; Harris, 1968). As A. A. Goldenweiser put it on several occasions, diffusion is "by no means foreign even to these thinkers, although they may have neglected to make sufficient use of it in their theoretical constructions" (Goldenweiser, 1916: 531; see also 1925a: 220). The aim was demarcating their work from others. Nevertheless, to some anthropologists, "so far all attempts to explain particular culture traits as due to the unity of the human mind have been abortive" (Wissler, 1916: 198). "When men lay down the dictum that all widely separated similarities are due to a common humanity (…)", suggested Mason, "they have substituted dogmatism for science" (Mason, 1895a: 116).

the variety? Diffusion is not mere imitation or "mechanical additions" (Boas, 1924: 344) but is in itself invention (or inventive). Diffusion is a "stimulus to new inner development" which produces new "mixed cultural types". [4] Second, the causes for this diversity are multiple, and are not only psychological, but also geographical, demographical and social. All in all, the process of cultural development is historical, a view shared by Clark Wissler (Wissler, 1916).

To Boas and the diffusionists, only a comparative method and not speculative philosophy can resolve the issue of invention *versus* diffusion, or "the long-continued controversy between the theory of their [universal traits of culture] independent origin and that of their transmission from one part of the world to another" (Boas, 1904: 30). One should "renounce the vain endeavor to construct a uniform systematic history of the evolution of culture", stated Boas (Boas, 1896: 280; see also Boas, 1924). [5]

Yet, if history is to be taken seriously, diffusionists had to admit the existence (although perhaps rare) of parallel inventions, and they did. Boas applied his above argument on cause-effect (multiple causes produced similar results) to this case too: parallelism or similarity occurs through independent thought or development because unlike causes or 'historical' factors produce similar effects. The phenomenon came to be called "convergence" (Boas, 1911; Lowie, 1912; Goldenweiser, 1913; Dixon, 1928). Society "starts with very different inventions and finally by mere evolution comes to have similar forms" (Wissler, 1923: 100).

[4] An early writer on diffusion as creative is the British anthropologist W.H.R. Rivers, to whom the "intermixture" of people creates a (new) culture (Rivers, 1911).

[5] To diffusionists the problem is not evolutionism, contrary to what is often suggested, but evolutionary schemes (Lowie, 1946). Cultures evolve, but not as part of biological (or psychological) evolution. Evolution yes, but through diffusion. "The fact that many fundamental features of culture are universal, or at least occur in many isolated places, interpreted by the assumption that the same features must always have developed from the same causes, lead to the [wrong] conclusion that there is one grand system according to which mankind has developed everywhere; that all the occurring variations are no more than minor details in this grand uniform evolution" (Boas, 1896: 275). To diffusionists, evolution is rather a matter of history, contingency and accident – origin is only an "incident" (Goldenweiser, 1925a: 227) –, while psychic unity means definite stages of culture. There is certainly a general psychological equipment in every man, the "same kind of inventive activity", as Wissler put it, but there are differences in degree (Wissler, 1913). Some evolutionary anthropologists would consequently revise the theory on "psychic unity" and talked instead of a "state of preparedness": similar needs and similar means "make independent origins more probable" (Wallis, 1930).

The idea of convergence would get a warm reception among anthropologists. It went hand in hand with another idea: the 'principle of limited possibilities' (Goldenweiser, 1913). Convergence is really the emergence of a limited number of traits and (similar) patterns in every society. Patterns are limited in number or possibilities due to many factors: history, psychology and techniques. A "general pattern gives direction to change and limits the degree of deviation" – although it is "broad enough that individual variation is allowed for" (Herkovits, 1945: 162-63). The promoters of convergence present the idea as a historical fact rather than an evolutionary principle. However, some critics have argued that convergence is a "challenge" to diffusionism: "it says in effect that a trait may have a distribution due to events not dependent upon diffusion" (Wissler, 1923: 105-106).

The Diffusion Controversy:
Two Theses

- Invention
    - Man invents the same way everywhere. Thus the parallelism and independent invention. Invention is explained by:
        - Psychic unity.
        - Evolution (definitive stages)
- Diffusion
    - Man is non-inventive; the inventions that exist diffuse among societies.
        - Parallelism exists, but as a historical phenomenon (convergence), not a unilinear or evolutionary one.
    - Diffusion is either (mere) imitation, or (creative) adaptation (acculturation).

From the above discussion, one may observe that 1) a controversy developed that hinged on an opposition – or perceived opposition – between invention and diffusion, and 2) an

intermediate position taking both invention and diffusion into account was emerging: a) imitation (diffusion) is itself invention (or inventive), b) both invention and diffusion exist; they are historical phenomena and must be documented empirically.

In 1927, American anatomist G. E. Smith published *Culture: The Diffusion Controversy*, a collection of four essays from both sides of the controversy (Smith et al., 1927). [6] The document starts with Smith explaining the "two conflicting views as to the process (…) of civilization": one, "in any community civilization can and did grow up and develop quite independently"; the other, invention "was made in one definite place and became diffused" (p. 9-10). Then Smith presents his then-well-known and controversial theory on civilization coming from one center, Egypt. The diffusionist B. Malinowski follows with a paper in which he qualifies the contrasting views as extreme and misleading (p. 28). [7] According to Malinowski, invention is continuous and there are many independent inventions. However, similarities between inventions concern form (p. 33-34) and not the details of techniques of production, material or uses. Diffusion is not imitation or transmission, but "adaptation, transformation and re-invention" (p. 31, 41-42). To Malinowski, mere "diffusion never takes place: it is always a readaptation, a truly creative process" (p. 46). Goldenweiser concludes the document with views similar to Malinowski's.

In the decade following the publication of *The Diffusion Controversy*, a new concept (first suggested in the late 1800s; for example, see Mason, 1895a) came into vogue among diffusionists: acculturation. In 1936, the US Social Science Research Council (SSRC) appointed a committee to analyze both the term, and studies on, acculturation. A memorandum to this end was published in *The American Anthropologist* (among others), under the authorship of Robert Redfield, Ralph Linton and Melville J. Herskovits (Redfield et al., 1936). No final report was issued but two books did appear and, in a sense, they can be regarded as surrogate final reports. These are *Acculturation: The Study*

[6] A precursor to this publication was *Is Civilization Contagious?*, a debate between Smith and Malinowski in *The Forum* (1926).
[7] In a third paper, H. J. Spinden opposes the prosaic school (uniformity, psychic unity) to the romantic school (diffusion; man as not inventive).

of Culture Contact (1939) by Herskovits – a prolific author on acculturation in subsequent years – and *Acculturation in Seven American Indian Tribes* (1940) by Linton. Again in 1953, the US SSRC held a seminar on acculturation (Siegel et al., 1954; Barnett, 1954).

From these exercises, acculturation came to be defined as cultural change through (direct or indirect) contact of societies – a somewhat controversial definition among anthropologists. Acculturation is defined as "the study of cultural transmission in process", rather than the study of similarities and differences (Herskovits, 1947: 525-27). It "comprehends those phenomena which result when groups of individuals having different cultures come into continuous first-hand contact, with subsequent changes in the original cultural patterns of either or both groups" (Redfield et al, 1936: 149).

One of the emphases of acculturation studies is selective and creative adaptation: acculturation is "neither a passive or colorless absorption (…). It is both "creative and destructive": adjustments, reorganizations, reinterpretations, syncretisms and fusions of inventions occur between two cultures, and disintegrations and conflicts such as those between "progressives and conservatives" develop (Siegel et al., 1954: 985-87). To the US SSRC, "the very act of copying alien traits entails some modification of them since no copy is perfect reproduction" (Siegel et al., 1954: 985). The receiving culture "function[s] as selective screens": it accepts some elements from another culture and rejects others (Siegel et al., 1954: 984-85). Acculturation is not a one-way process from one society to another. To emphasize this, researchers contrasted acculturation to other concepts like change, diffusion, assimilation, incorporation, adoption, imitation, borrowing and transfer. Acculturation is a specific kind of diffusion. It is bidirectional; it is reciprocal give and take; it involves interchanges with re-workings, reinterpretations and selective adaptation. A transmitted cultural trait never retains its whole identity. Diffusion is invention.

A. L. Kroeber has expressed the same idea differently, suggesting the concept of "stimulus diffusion" (stimulus is a term borrowed from Boas, 1924). While ordinary

diffusion is adoption, stimulus diffusion is "procreation" (Kroeber, 1940: 20). When a culture encounters a trait complex or system (as opposed to a specific trait), the receiving culture not only copies it but "develop(s) a new content" (Kroeber, 1940: 1). "Diffusion is not something that operates automatically" (Kroeber, 1940: 19). There are selective factors at work. It is a blend of diffusion and invention.

Anthropologists then, at least some of them, took into account both invention and diffusion, in the sense that diffusion was inventive or a source of invention. Many other diffusionists explicitly held a general belief combining invention and diffusion. To Mason, "every one of these propositions [invention and diffusion] is true under certain conditions" (Mason, 1895a: 105). Certain kinds of similarity are explained by independent origin, others by diffusion, and the "boundary line is not definitely fixed" (Mason, 1895a: 113). To R. B. Dixon, "no one of these theories is a panacea"; it is a matter of history (Dixon, 1912: 55). To A. A. Goldenweiser, invention ("originality") and diffusion have "equal theoretical status" (Goldenweiser, 1916: 532) and are "heuristic tools" (Goldenweiser, 1925a: 247). To Carl Wissler, invention, convergence and diffusion all contribute to culture (Wissler, 1923: 194). To B. Malinowski, "diffusion and invention have equal shares (…), always mixed, always inseparable" (in Smith *et al.*, 1927: 30). To L. A. White, "one process originates, the other spreads" (White, 1945: 342).

A Resolution?

The diffusion controversy placed invention and diffusion in opposition to each other, authors discussing their own preference with only a few (critical) words concerning the other alternative – although as early as 1895 some like Mason discussed at length how both play a part in cultural change (Mason, 1895a). With time, both invention and diffusion came to be discussed seriously together, with whole chapters devoted to each in the same book. At the same time, both invention and diffusion came to be discussed as stages or steps of a linear sequence in the process of cultural change, above all among American anthropologists.

In 1923, Kroeber's *Anthropology* devoted a chapter to invention ("Parallels"), followed by one on "Diffusion". Like most anthropologists, Kroeber started by discussing the invention *versus* diffusion controversy, whose existence stems, according to the author, from lack of data to document independent invention, which limits the latter to a "mysterious" principle. To Kroeber, "truly independent or convergent invention" is currently more a principle than a reality. There are always differences between parallel inventions, and the variety of details "would not recur together once in a million times" to prove independent invention. "Partial convergence" or "incomplete parallelism", perhaps; common origin, certainly. "To wage an abstract battle as between two opposite principles is sterile", stated Kroeber. Both invention and diffusion "supplement" each other. "Diffusion and imitation undisputedly do take place" and "independent developments are more or less intertwined with disseminations". Diffusion leads to "modifications" (invention) and "independent starts" are often "merged or assimilated by diffusion" (Kroeber, 1923: 220).

Kroeber was certainly one of the first anthropologists to discuss both sides of the controversy, devoting chapters to arguments from each side. Kroeber's solution to the controversy was that invention and diffusion merge and blend in the same process. It was left to others to develop a further solution: a sequence in which invention and diffusion follow each other:

Wissler, 1923	invention → diffusion
Dixon, 1928	discovery → invention → diffusion
Linton, 1936	discovery → invention → diffusion

The same year that Kroeber's *Anthropology* appeared, Carl Wissler published *Man and Culture* (1923). In a chapter on invention ("How Traits Are Acquired?"), Wissler framed the invention *versus* diffusion controversy as being between two fictitious theses. To

Wissler, (independent) invention, as “the result of an evolution from a crude stone age, through a bronze age, into one of iron and steel”, is “a fatalistic view”. He attributed this view to Tylor (Wissler, 1923: 101). On the other hand, (diffusion or) imitation, the thesis that “nothing is ever invented twice” (Wissler, 1923: 102), is an “equally absurd” view, unless one accepts that no imitation is “identical” to the original. Wissler then devoted two long chapters to diffusion, which is either natural (random migrations) or directed and purposeful (conquest).

The next step in Wissler’s argument was a chapter on “Culture Building”. Here, Wissler offered a “sequence” invention → diffusion as a solution to the controversy. To Wissler, invention is “the beginning of culture”: “It is an invention that marks the beginning of a culture element (…). [Invention] is the basic phenomenon in culture” (Wissler, 1923: 186). “Unfortunately this subject still awaits serious investigation (…). It is to psychology and sociology to trace out the intricate path” (Wissler, 1923: 184-85).

To Wissler, invention is followed by diffusion: “the prevailing mode of acquiring culture has always been to imitate” (Wissler, 1923: 206). To the author, diffusion is not mere imitation but “borrowing and re-borrowing of traits is the rule” (Wissler, 1923: 208). While discussing factors contributing to diffusion, Wissler placed the emphasis on leadership, in which a model or “pattern” functions as a “lead”. This pattern constrains or “inhibits” others possibilities; it “exercises a kind of selective function”. It is “reduplicated and elaborated” among societies, thus explaining convergence between cultures. To Wissler then, it is the emergence of patterns that explains parallelisms.

Next came a further sequence in R. B. Dixon’s *The Building of Cultures* (1928). Again, Dixon starts with the “long-standing controversy” regarding how to explain “similar cultural traits which occur in widely separated areas” (Dixon, 1928: 33; see also 182s). To Dixon, “it is indisputable that every culture trait must have arisen by discovery or invention at least once. There has always and necessarily been a first time” (Dixon, 1928: 35). In a chapter entitled “Discovery and Invention”, Dixon devotes himself to definitions, distinguishing invention from discovery on the basis of “purpose”, and

suggesting that the two are sequential steps or "stages": (accidental) discovery, then (purposeful) invention. Dixon discusses the factors composing each stage at length. Discovery is a compound of opportunity, observation, appreciation plus imagination. Invention, which he distinguished as either entirely new or an improvement (a direct borrowing from H. S. Harrison), [8] is either accidental or "directional" (again, a direct borrowing, this time from sociologist L. Bernard's dichotomy empirical/projected (Bernard, 1923). The factors involved here are genius, needs, available knowledge and opportunities. [9]

Having discussed discovery and invention, Dixon turns to diffusion. Diffusion is the third step of Dixon's sequence: discovery → invention → diffusion. To Dixon, discovery or invention is made by individuals and "is without result and sterile unless it is adopted" by other individuals. "Without its diffusion beyond the discoverer or inventor the new trait remains merely a personal eccentricity, interesting or amusing perhaps, but not significant" (Dixon, 1928: 59).

Following Wissler's distinction between natural and directed diffusion, Dixon devotes two long chapters to diffusion, distinguishing diffusion according to whether it is primary

[8]In a series of articles, Harrison distinguished mutations (independent inventions) – a phenomenon of modern times mainly (organized research) – and variations (subsequent small changes or forms) (Harrison, 1926a; 1926b; 1930a). Mutations are more or less what some would call today 'revolutionary' inventions.

[9] The distinction between invention and discovery is commonplace among anthropologists. To F.A. Seely, discovery "brings to light the material facts, and the natural laws". Invention "applies" discovery to useful purposes (Seely, 1885: 151; see also Seely, 1883). To O.T. Mason, discovery is "finding out" (knowledge) and invention is "artificiality" or the "modification" of the discovery for "industrial purposes" (Mason, 1895d: 17). To H.S. Harrison, discovery is "new knowledge of natural forces, and of the nature and reactions of material substances under varying conditions". Invention is "applied discoveries" (Harbison, 1930b: 107). All three anthropologists talk of discovery and invention in terms of "stages" and "steps" (and "process" in the case of Seely). For example, to Harbison, there is "First [primary] discovery", then "applied discovery" or invention ("the exploitation of the knowledge gained"). Yet, Harbison does not study the diffusion stage. Nevertheless, diffusion is mentionned as a stage "between the first inkling of the possibility of a crossmutation, and the carrying out of the transfer and adaptation ... It must be accepted as highly probable that in early times especially, man needed frequent repetition of a suggestion before he adopted it" (Harbison, 1930b: 117-18). Harbison goes further and suggests that discovery is not necessary to invention in his days, because of "foresight" or (voluntary) "design" (combination) "unaffected by discovery in its first conception". "An invention proper ... may be defined as a single mutational step which owes its origin not to discovery, but to a combining of structures or devices already in existence". The combination "is preceeded subjectively by the action of the mind" (the inventive faculty) (Harrison, 1930a: 729).

or secondary. Primary diffusion is diffusion in the group or area of the discoverer-inventor, while secondary diffusion is diffusion between societies. To Dixon, "demonstration and persuasion" and "imitation and fashion" are the two main factors explaining the process of diffusion. Personality, conformity to the culture, people's inertia and customs are also discussed. Dixon explains that the mechanism of diffusion is contacts, during which "modifications and improvements" are made, to the extent that "in time the original trait may become considerably changed" (Dixon, 1928: 63) and even disappear.

Like Kroeber and Wissler before him, Dixon discusses the diffusion controversy. He negates (extreme) diffusionism as an option in the diffusion controversy. Like Wissler, he believes that there are rather three empirical cases: independent invention, diffusion and convergent evolution. Similarities are "in fact only seeming and not real, in that the phenomena were originally quite independent and dissimilar, but in the course of their historical development, they gradually converged until what had started out as two or more unlike traits, finally came to have close superficial resemblances" (Dixon, 1928: 183).

Six years after Dixon, Ralph Linton published *The Study of Man* (1936), with specific and separate chapters devoted to both invention and diffusion. Like Wissler and Dixon, Linton believed that it is only by discovery and invention "that new elements can be added to the total content of man's culture" (Linton, 1936: 304). Also like Dixon, Linton starts by defining his concepts. In line with Dixon, Linton distinguishes discovery from invention. However, the distinction rests not on the purpose or motivation of the individual, but on the implications or significance of the invention: employing knowledge "in a new way to achieve a particular end" (Linton, 1936: 306). Like Dixon again, Linton discusses the factors responsible for invention. Some are related to the inventor – rewards (economic, but also prestige) and psychology (deviance) – others to the invention itself (culture of society like available knowledge and receptivity).

To Linton, inventions are of two kinds: basic and improved. Basic invention "opens up new potentialities for progress" and is destined "to become the foundation of a whole series of other inventions". Basic inventions "imply a considerable departure from the status quo". They usually come from conscious and "organized" activity (laboratories). Improved invention is rather "a modification of a preexisting device" (Linton, 1936: 316-19). Following sociologists W. F. Ogburn and S. C. Gilfillan, Linton suggests that "the bulk of cultural progress has probably been due to the less spectacular process of gradual improvement" (Linton, 1936: 318). Basic inventions are the result of "a long series of improving inventions".

A Universal Solution

As well as inventing an invention-diffusion sequence to explain stages of culture, anthropologists went deeper into the analyses and imagined further stages or steps. For example, to Linton, diffusion includes three steps: presentation (through contact or acculturation, with exchanges and fusion), acceptance (based on utility and compatibility, themselves dependent on people's subjective judgments and the interests and prestige of the inventor) and integration. [10] Invention has stages of its own as well. However, the analyses of these stages come from others than anthropologists – and often remain of a psychological nature. [11] One such early analysis is that of economic historian Abbot P. Usher. Invention is analyzed as starting from an (indefinite) idea and composed of steps or phases [12] – which is then tested and developed into a design, and finally 'operationalized' in a (commercialized) product.

[10] Integration is "the mutual adjustment [adjustment is a term from sociologist W. F. Ogburn] between culture elements" (Linton, 1936: 348): "the receiving society develops new interpretations for it [the culture trait] and shapes it to serve new ends" (Linton, 1936: 347). To Linton, "disintegration ["disruptive effects"] and reintegration go on side by side" (Linton, 1936: 354), in the sense that societies reach "cultural accommodation", that is, "both the new trait and the preexisting traits are progressively modified until they have been brought into agreement" (Linton, 1936: 355). However, there always remained inconsistencies, incompatibilities and ambivalences (Linton, 1936: 358). "Perfect adjustment is never reached" and serious conflicts emerge when the core of a culture is affected (Linton, 1936: 359-63).

[11] Psychological theories of invention and imagination go back to the seventeenth century. For the twentieth century, mention should be made of philosophers like J. Dewey and H. G. Mead with their stages involved in thinking, and of psychologists and *Gestalt* theories.

[12] Elaboration of the concept → primary synthesis → critical revision.

Over the twentieth century, imagining (causal) sequences combining invention and diffusion to explain the process through which culture changes, society develops and technology evolves became a kind of business of its own. Psychologists, sociologists, historians, business schools and economists developed sequences similar to those of the anthropologists. The steps imagined are many and diverse depending on the discipline concerned, as many as the stages imagined in evolutionism (see Appendix 2). From the 1920-30s particularly, such sequences would become popular to explain technological innovation as a process: management (e.g.: Mees, Holland, Stevens, Bichowsky, Furnas), economics (e.g.: Epstein, Usher, Maclaurin, Kuznets, Mansfield, Utterback) and sociology (e.g.: Bernard, Ogburn, Gilfillan, Rogers). In the late 1940s-early 1950s, the linear model of innovation crystallized these ideas into a theory, called a model by later students of technological innovation: from pure research to applied research then development.

Sociologists usually stress the diffusion phase, as Everett Rogers did (Rogers, 1962). [13] Diffusion begins with an innovative individual (as leader) who adopts something new early on. The invention subsequently gets adopted by other individuals, then groups, firms and whole countries. In contrast, most of the economists stop at commercialization, with few concerns about diffusion in the larger society. One such sequence from economists, which has become a convention, is that introduced by Edwin Mansfield in 1968. Mansfield frames his discussion in terms of the following sequence: invention → innovation → imitation → diffusion (Mansfield, 1968b). To Mansfield, "until recently our knowledge of the imitation (diffusion) process did not extend far beyond Schumpeter's simple assertion that one a firm introduces a successful innovation, a host of imitators appear on the scene" (Mansfield, 1968a: 133). Mansfield's stages, including diffusion, are entirely concerned with firms, with no concern for the society at large. For example, imitation is *use* of a new technology by a firm and diffusion is the subsequent *substitution* of the old technology for a new one within firms.

[13] Awareness → interest → evaluation → trial → adoption.

In spite of Mansfield's original framework to the then-emerging field of technological innovation studies, [14] such sequences first appeared in the early 1950s in the writings of economist Yale Brozen (Brozen, 1951), [15] economic historian W. Rupert Maclaurin (Maclaurin, 1949; Maclaurin, 1953) [16] and a couple of others. Maclaurin first concentrated on the steps leading to commercialization, which gave rise to and became known as the linear model of innovation. Then in 1953, he added the diffusion step to what he called a "sequence" and imagined a series of statistics for measuring each of the steps of the process of innovation, from invention to diffusion. [17]

A few years earlier, Yale Brozen published a paper titled "Invention, Innovation, Imitation", first produced for a conference on "Quantitative Description of Technological Change" in 1951 (Brozen, 1951). Maclaurin's paper on statistics was presented at this conference too. Brozen's discussion of the sequence remains fuzzy but is the very first one to bring the three terms together. 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). Imitation here is diffusion, a term introduced into the study of innovation by the French sociologist Gabriel Tarde (Tarde, 1890) and often used in place of diffusion until the 1970s (e.g. Edwin Mansfield).

Finally, Warren Scoville, a third member of the historical school of innovation, fully aware of the diffusion controversy in anthropology, brought the study of diffusion into innovation studies as an object of study *per se*. In several papers produced in the early

[14] One year before Mansfield, Richard Nelson and his colleagues from RAND put their analysis into a more or less similar sequence (Nelson et al., 1957: chapter 5).
[15] Invention → innovation → imitation.
[16] Pure science → invention → innovation → finance → acceptance or diffusion.
[17] Pure Science: major contributions, classified by field, country, and over time; prizes, awards and medals; budget; forecasts on commercial applications; Invention: patents (major/minor); research workers (because they are correlated with the volume of inventions); records of inventions by firms; Innovation: inquiry over time industry by industry on annual sales volume, productivity figures, investments for new/minor products and new firms/established (great) corporations; Finance (capital supply): number of new firms launched each year, their capital investments; new plant construction; Acceptance (or diffusion): growth curves for a wide variety of products and services under different types of conditions, by region, between cultural groups, length of time required for mass acceptance.

1950s, Scoville looks at the mechanisms of diffusion of technology (contact, migration) (Scoville, 1951; 1952) – a concern he shares with Fritz Redlich, a student of Schumpeter (Redlich, 1953). [18]

By Mansfield's time, the sequence invention-innovation-diffusion was becoming, in slightly different forms, "conventional" as Arthur D. Little put it in 1963 (A. D. Little, 1963) (for early examples of uses, see OECD, 1966; 1971), "accepted without question" by historians of technology (Staudenmaier, 1985: 55), [19] part of the (emerging evolutionary) economists' *credo* [20] and regularly attributed to Schumpeter (see below).

Mention has to be made of a new term (step) in the above sequence – innovation –, as distinct from invention. In the early twentieth century, anthropologists made little use of the word innovation, like sociologists, economists and others. In fact, the word was only beginning to acquire a positive sense (Godin, 2012b), and entered regularly into discourses only in the late 1940s-early1950s, including discourses in anthropology. Nevertheless, to anthropologists, invention is innovation or one kind of innovation. At the opposite end, to the economists, invention is not innovation and must be distinguished from innovation. Economists regularly cite Schumpeter as source of the argument (but see below). [21] Innovation is the commercialization of invention. First there are inventions, then their commercialization or innovation.

[18] One more researcher needs to be mentioned: Elting E. Morison, a founder of the MIT's Program on STS in 1976. In a 1950 paper Morison studies the" process of innovation" (the continuous-aim firing technology) as a "sequence of events" or "chronological account of innovation" in three steps: development of an idea, introduction, reception (Morison, 1950).

[19] Historian of technology John Staudenmaier calls the sequence or rather a variant of the sequence (invention-development-innovation) indiscriminantly as "tripartite model", "three dimensional model" and "three-stage model".

[20] "Most social scientists would probably accept the sequence in which the three terms – invention, innovation, and technological change – are ordered" (Ruttan, 1959: 596).

[21] E. M. Rogers attributes the distinction to sociologist W. F. Ogburn and anthropologist R. Linton: "Since the writings of Ogburn (1922) and Linton (1936), most scholars have made a distinction between invention and innovation. Invention is the process by which a new idea is created or developed, while innovation is the process of adopting an existing idea" (Rogers, 1978: 4). Yet, such a distinction is found, under many different forms, among several writers before Schumpeter and the authors that Rogers names: Jeremy Bentham, Lester Ward and Josiah Stamp.

The distinction, although foreign to anthropologists (except for Dixon), contributed to giving innovation a privileged place on researchers' agendas, as well as on the policy agendas of governments (economic policy), and came to be, to many, a spontaneous understanding of what innovation is, eclipsing the broader anthropologists' meaning. In fact, semantically, innovation is either a substantive (novelty), a verb (introducing novelty into the world) or a process (from invention to diffusion) (Godin, 2012b). Today – in fact since Maclaurin in the late 1940s-early 1950s (Maclaurin, 1950) [22] –, technological innovation is studied as a process, from invention to diffusion (or rather commercialization).

Given the affinity of ideas on sequence between economists and anthropologists, it is worth asking what intellectual linkages, if any, exist between the two disciplines that could explain the similarity of their theories. Was there a direct borrowing by economists from anthropology? Or was the sequence an idea "in the air", shared under different forms by a multiplicity of researchers in a diversity of fields? For example, Paul Stoneman suggests that many concepts of the time points to a triple sequence. "The Schumpeterian trilogy" states Stoneman, "can be matched to other concepts used in the literature" (Stoneman, 1995: 4): 1. the distinction between science and technology: "science is associated with the early stages in the trilogy, say invention, whereas technology is often associated with later stages of the trilogy" (Stoneman, 1995: 4); 2. the research and development (R&D) process "broken down into basic and applied research and development ... In terms of the Schumpeterian trilogy, basic research will relate closely to the invention process, applied research and development will relate to the innovation stage" (Stoneman, 1995: 5). [23] In spite of these intellectual affinities, Stoneman attributes the "trilogy" to one individual – Schumpeter.

[22] In 1959, economist Vernon Ruttan claimed that "neither Schumpeter nor the growth economists [like Robert Solow] have given explicit attention to the process by which innovation – technological and organizational change – is generated" (Ruttan, 1959: 599). This requires a theory of innovation which is, according to Ruttan, absent from Schumpeter.

[23] Stoneman (1995) gets the point right: many concepts in the literature point to a trilogy. Yet Stoneman attributes the trilogy to Schumpeter: "The Schumpeterian trilogy can be matched to other concepts used in the literature" (Stoneman, 1995: 4). By this, Stoneman refers to 1. the distinction between science and technology: "science is associated with the early stages in the trilogy, say invention, whereas technology is often associated with later stages of the trilogy" (p. 4); 2. the research and development (R&D) process "broken down into basic and applied research and development ... In terms of the Schumpeterian trilogy,

Mansfield and other economists made no references to the diffusion controversy among anthropologists. One exception was the economic historian W. C. Scoville who, as an early student of the diffusion of technology, began his discussion with the controversy (Scoville, 1951). The authors who used the sequence in the following decades also made no reference to anthropologists, attributing the sequence's origin to J. A. Schumpeter. [24] Yet to Schumpeter, invention is distinct and has little to do with innovation. Invention is an act of intellectual creativity and "is without importance to economic analysis", while innovation is an economic decision: a firm applying or adopting an invention (Schumpeter, 1939: 84-85). [25] Schumpeter was only putting into print an old representation of innovation. Innovation is action (introducing something new into the world) while invention is purely mental (discovering or inventing something new). Just to take one example, in the late eighteenth century the English philosopher Jeremy Bentham distinguishes between "operation upon matter" ("making known the discoveries to the world"), which is the task of "projectors" (the technological innovators of the time), and "operation upon mind" (talent, or genius as others call it) (Bentham, 1793-95: 49). French sociologist Gabriel Tarde has held the same representation. He distinguishes theoretical invention (scientific discoveries) and practical invention (industrial inventions) (Tarde, 1902).

Despite this distinction, and to a certain extent in contradiction to it, in the second half of the twentieth century, invention was theorized as being at the origin of innovation. The linear model of innovation suggests that innovation starts with science or basic research.

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basic research will relate closely to the invention process, applied research and development will relate to the innovation stage" (Stoneman, 1995: 5).

[24] Siegel, 1962: 445 (on the necessity to breakdown "the Schumpeterian triple sequence (invention, innovation, and imitation" into more stages; in his comments to Siegel's paper, T.S. Kuhn again refers to (Siegel's) attribution of the sequence to Schumpeter); Mansfield, 1968a: 133 (on the "Schumpeter's simple assertion that one a firm introduces a successful innovation, a host of imitators appear on the scene"); Rosenberg, 1976: 67; Georghiou *et al.*, 1982: 1; Stoneman and Diederen, 1994: 918; Stoneman, 1995: 2-4 (on "Schumpeter trilogy"); Alter, 2000: 14; Lefebvre, 2007: 357.

[25] To be sure, there is a sort of triple sequence in Schumpeter's theory. Yet, it is not the one commonly attributed to him. Schumpeter's sequence is innovation, imitation, impacts: 1. Emergence of new "combinations" (innovations) and entrepreneurs in clusters; 2. "Copy" in ever-increasing numbers (and which compete); 3. "Effects" on the economy (disturbances, booms in specific industries, absorption and incorporation of the new things, adaptation of the economic system, new equilibrium) (Schumpeter, 1934: 223-233).

This theory gave rise to studies by the dozens on measuring the link between science or research and development (R&D) and innovation. The theory also continues to feed policies and remains in the background of many alternative models of technological innovation.

With regard to diffusion, the concept was not part of Schumpeter's vocabulary either. British economist Chris Freeman talks of the "Schumpeterian concept" of "diffusion" (Freeman, 1994: 480). Yet Schumpeter is rather concerned with "imitation" and followers among entrepreneurs, not diffusion (a term he uses only once) of technological innovations through the economy and society, namely in the market sense. Schumpeter did not study diffusion, but jumped from innovations to their effects on the economy (business cycles) (see footnote 23 above). Schumpeter may have had the "idea" of diffusion, but not the "concept". As Ruttan puts it: "Schumpeter's major interest was not in explaining the process of innovation but in discovering the effect of variations in the rate of both technological and organizational changes on economic growth and development" (Ruttan, 1959: 606).

Mythology, or attribution of (false) originality, is abundant in the literature on technological innovation. Another attribution concerns the linear model of innovation. To many, Vanevar Bush is the father of the linear model of innovation, a story shown to be false but which persist in the literature nevertheless (Godin, 2006; 2008; 2011). Equally, Bengt-Ake Lundvall attributes the concept "national system of innovation" to Freidrich List in the nineteenth century. But it is one thing for an individual writer (List) to have invented or used a concept similar to ours, and another to give rise to a research tradition, which List did not (Godin, 2010). Finally, there is the origin of the study of innovation, which is attributed to economists and to Schumpeter. Historian of technology John Staudenmaier states that "the term 'innovation' appears to have originated in a tradition of economic analysis" – Schumpeter and Jacob Schmookler – (Staudenmaier, 1985: 56) while Norbert Alter suggests that one may find "la trame fondatrice de la réflexion sur l'innovation" in Schumpeter (Alter, 2000: 8). These are just two examples. Many other

authors could be cited. In fact, the term, as well as thoughts on innovation, are centuries older than that (Godin, 2012b).

The sequence invention-diffusion as used in the study of technological innovation today has obvious analogies with the sequence from anthropology. There are many other such analogies. The anthropological concept of independent or parallel invention has also been influential. Sociologists have attempted to measure "multiple discoveries" and have used the numbers to determine whether invention is individual genius or a social phenomenon (Kroeber, 1917; Ogburn and Thomas, 1922; Stern, 1927; Merton, 1957; 1961; 1963b; Kuhn, 1959). The concept "parallel efforts" developed by economists from the US RAND Corporation in the late 1950s, as a strategy and policy option for dealing with the riskiness of research and development (R&D), is another adaptation of the anthropological concept of parallel invention (Nelson, 1961; Klein, 1962; see also Merton, 1963a; 1965). The sociologist S. C. Gilfillan also suggested the concept of "equivalent" inventions that appear in functional groups (Gilfillan, 1935: 12, 137) and sociologist W. F. Ogburn shared Gilfillan's view with his concept of "convergence" of technologies. Both concepts gave rise to the more recent notion of "clusters". Many other concepts from the studies of technological innovation have analogues in anthropology. Gaps and "convergence" (of economies) due to the diffusion of technology is one (Godin, 2002). "Path-dependency" (Arthur, 1994) is also an analogue to the principle of limited possibilities in anthropology. And "re-invention", as theorized by E. M. Rogers, for example (Rice and Rogers, 1980; see also Rothwell, 1986; Rothwell and Gardiner, 1985 and 1988, on re-innovation), also has a precursor in anthropology.

Whether the economists' and social researchers' concepts are the result of diffusion and (conscious or unconscious) borrowing from anthropology or independent and parallel invention is difficult to determine. At the very least, they point to a community of ideas. [26] When researchers started looking at technological innovation in the twentieth century, ideas (and terms) such as sequence, stages and process were much "in the air" – as much

[26] With regard to economists, note the analogy between the sequence invention, innovation, diffusion and the classic economic triad: production, circulation, consumption. I thank Jan Kosloswki for pointing this out to me.

as evolutionism was, in anthropology as well – and this was also the case with the idea of the linear model of innovation (Godin, 2011): in philosophy and history (social evolutionism), in psychology (mental development), in biology (life-cycle), and scientists' discourses (pure science gives applied research; see Kline, 1995). Then, anthropology, sociology, management (studies of organizations), policy and economics also espoused the idea.

Conclusion

There exist not one, but two sequential models of innovation in the literature. One is the "linear model of innovation", known by that name. The model is the result of the cumulative work of several researchers over many decades (Godin, 2006; 2008; 2011). It comes from management and economics, and their concern with studying the origin of, and the factors responsible for, invention (Mees, 1920; Holland, 1928; Maclaurin, 1947; Furnas, 1948).

The other model, of which the linear model of innovation is only one part or step, is that of innovation as a process of invention followed by diffusion. The early thoughts on such a model, or rather theory (at the time no-one talked of models), come from anthropologists – and sociologists like F. S. Chapin. [27] This paper has documented the contribution of this theory as a solution to a controversy that pitted invention against diffusion in anthropology.

Over time, many solutions to the diffusion controversy were offered. I have concentrated on those solutions that, to varying degrees, reintroduced invention into anthropology (although rarely explicitly admitted as such), or at least into the study of diffusion. One such solution was convergence, widely discussed among anthropologists. Another was defining diffusion as creative borrowing (invention). Through the contact and mingling of two forms, suggested Boas, new types arise (Boas, 1924: 344). Acculturation studies took the suggestion seriously: "culture contact is not a mere mechanical transference of traits"

[27] Invention → Accumulation → Selection → Diffusion (Chapin, 1928).

(Malinowski, 1939: 32). "Fundamental in the diffusion process", suggested M. J. Herkovits, "is the manner in which cultural borrowings are reworked as they move from people to people". "The acceptance of what comes from the outside is never a total acceptance (…). Reworking is the rule and reinterpretation inevitable" (Herkovits, 1945: 156, 157).

Still another solution was the development of sequential theories: invention → diffusion. Many authors from many disciplines made use of such sequences from the 1920s to today, and this gave rise to the study of innovation as a process over time, from invention to diffusion. What started as two analytical concepts (invention and diffusion) became a dichotomy, and then was transformed into a sequence.

Yet, the coupling of the two concepts into one theory did not prevent researchers from favouring one term over the other. Most anthropologists ended up with a preference for diffusion, as Boas did. [28] A similar preference for diffusion existed among sociologists. Before the sociology of science and technology developed, sociologists concentrated on studying diffusion, with little concern for how invention comes about (exceptions are Gilfillan and Hornell Hart). Classical economists too emphasized use or diffusion (often called imitation, following Mansfield) of technological invention in industrial production (called technological change). At the opposite end, management and policy-oriented specialties like "innovation studies" focused on invention (many opening what they called the "black box" of invention), thus strengthening, perhaps unconsciously, a linear view of innovation. Yet, today the pendulum has swung back again: invention (or R&D) is said to play a minor role in innovation. Innovation is the diffusion (adoption to the sociologist; commercialization to the economist) of invention.

[28] To Wissler, despite his stress on invention as "the beginning of culture" (Wissler, 1923: 186), diffusion is the rule: because of our "high value upon originality" we forget that "we are largely imitators" (Wissler, 1923: 206). To Kroeber, "imitation is the normal process by which men live and invention is rare, a thing which societies and individuals oppose with more resistance that they are aware of, and which probably occurs only as a result of the pressure of special circumstances" (Kroeber, 1923: 239). To Dixon, "much of the variety [of human culture] is due to diffusion" (Dixon, 1928: 57). To Linton, "there is probably no culture extant to-day which owes more than 10 per cent of its total elements to inventions made by members of its own society" (Linton, 1936: 325). "All cultures have grown chiefly by borrowing" (Linton, 1936: 323).

References

Arthur D. Little Inc. (1963), *Patterns and Problems of Technical Innovation in American Industry*, report submitted to the National Science Foundation, C-65344, Washington.

Arthur, W. B. (1994), *Increasing Returns and Path Dependence in the Economy*, Ann Arbor (Michigan): University of Michigan Press.

Balconi, M., S. Brusoni and L. Oresnigo (2010), In Defence of the Linear Model: An Essay, *Research Policy*, 39: 1-13.

Barnett, H. G. (1954), Acculturation: An Exploratory Formulation – Comment, *American Anthropologist*, 56 (6): 1000-1002.

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

Bentham, J. (1793-95), *A Manual of Political Economy* [1843], Available at http://oll.libertyfund.org/index.php?option=com_staticxt&staticfile=show.php%3Ftitle=1922&Itemid=27.

Bernard, L. (1923), Invention and Social Progress, *American Journal of Sociology*, 29 (1): 1-33.

Boas, F. (1887), The Occurrence of Similar Inventions in Areas Widely Apart, *Science*, IX (224): 485-86.

Boas, F. (1896), The Limitations of the Comparative Method of Anthropology, in F. Boas, *Race, Language and Culture*, New York: Macmillan: 270-80.

Boas, F. (1904), The History of Anthropology, *Science*, 20, 1904: 513-24; reprinted in F. Boas, *A Franz Boas Reader*, University of Chicago Press, 1982: 23-36

Boas, F. (1911), Méthode des Ethnologie, *Science*, 34 (884), 8 December: 804-10.

Boas, F. (1924), Evolution or Diffusion, *American Anthropologist*, 26 (3): 340-44.

Bowler, P. J. (1983), *Evolution: the History of an Idea*, Berkeley: University of California Press.

Bowler, P. J. (1989), *The Invention of Progress: The Victorians and the Past*, Oxford: Basil Blackwell.

Brozen, Y. (1951), Invention, Innovation, and Imitation, *American Economic Journal*, May, pp. 239-257.

Burrow, J. W. (1968), *Evolution and Society: A Study in Victorian Social Theory*, Cambridge: Cambridge University Press.

Chapin, F. S. (1928), *Cultural Change*, New York: The Century Co.

Dixon, R. B. (1912), The Independence of the Culture of the American Indian, *Science*, 35 (889), 12 January: 46-55.

Dixon, R. B. (1928), *The Building of Cultures*, New York: Charles Scribner.

Freeman, C. (1994), The Economics of Technical Change, *Cambridge Journal of Economics*, 18: 463-514.

Furnas, C. C. (ed.) (1948), *Research in Industry: Its Organization and Management*, Princeton: D. Van Nostrand.

Gilfillan, S. C. (1935), *The Sociology of Invention*, Cambridge (Mass.): MIT Press.

Gladwin, H. S. (1937), Independent Invention versus Diffusion, *American Antiquity*, 3 (2): 156-60.

Godin, B. (2002), Technological Gaps: Quantitative Evidence and Qualitative Arguments, *Technology in Society*, 24: 387-413.
Godin, B. (2006), The Linear Model of Innovation: The Historical Construction of an Analytical Framework, *Science, Technology, and Human Values*, 31 (6), November: 639-667.
Godin, B. (2008), In the Shadow of Schumpeter: W. Rupert Maclaurin and the Study of Technological Innovation, *Minerva*, 46 (3): 343-360.
Godin, B. (2010), *National Innovation System: A Note on the Origins of a Concept*, Working Paper, Project on the Intellectual History of Innovation, Montreal: INRS
Godin, B. (2011), The Linear Model of Innovation: Maurice Holland and the Research Cycle, *Social Science Information*, 50 (3-4): 569-581.
Godin, B. (2012a), Innovation Studies: The Invention of a Specialty, *Minerva*, 50 (4): 397-421.
Godin, B. (2012b), *καινοτομία: an Old Word for a New World, or the De-contestation of a Political and Contested Concept*, Montreal: INRS. Available at http://www.csiic.ca/innovation.html. Published in Karl-Erik Sveiby, Pemilla Gripenberg and Beata Segercrantz (eds.), *Challenging the Innovation Paradigm*, London: Routledge, 2012: 37-60.
Goldenweiser, A. A. (1913), The Principle of Limited Possibilities in the Development of Culture, *Journal of American Folklore*, 26 (101): 259-90.
Goldenweiser, A. A. (1916), Diffusion vs. Independent Origin: A Rejoinder to Professor G. Elliot Smith, *Science*, 44 (1137), 13 October: 531-33.
Goldenweiser, A. A. (1925a), Cultural Anthropology, in H. E. Barnes (ed.), *The History and Prospects of the Social Sciences*, New York: Knopf: 210-54.
Goldenweiser, A. A. (1925b), Diffusionism and the American School of Historical Ethnology, *American Journal of Sociology*, 13 (1): 19-38.
Harris, M. (1968), *The Rise of Anthropological History: A History of Theories of Culture*, New York: Thomas Y. Crowell.
Harrison, H. S. (1926a), Inventions: Obtrusive, Directional, and Independent, *Man*, 26, July: 117-21.
Harrison, H. S. (1926b), Variations and Mutations in Invention, *Man*, 26, September: 154-58.
Harrison, H. S. (1930a), Evolution in Material Culture, *Nature*, 126 (3184), 8 November: 726-29.
Harrison, H.S. (1930b), Opportunism and the Factors of Invention, *American Anthropologist*, 32: 106-25.
Herskovits, M. J. (1945), The Processes of Cultural Change, in R. Linton (ed.), *The Science of Man in the World Crisis*, New York: Columbia University Press: 143-70.
Herskovits, M. J. (1947), *Man and His Works: The Science of Cultural Anthropology*, New York: Alfred Knopf.
Holland, M. (1928), Research, Science and Invention, in F. W. Wile (ed.), *A Century of Industrial Progress*, American Institute of the City of New York, New York: Doubleday, Doran and Co.: 312-34.

Klein, B. H. (1962), The Decision Making Problem in Development, in US National Bureau of Economic Research (1962), *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton: Princeton University Press: 477-508.
Kline, R. (1995), Construing Technology as Applied Science: Public Rhetoric of Scientists and Engineers in the United States, 1880-1945, *Isis*, 86, pp. 194-221.
Koepping, K.-P. (1983), *Adolf Bastian and the Psychic Unity of Mankind: The Foundations of Anthropology in Nineteenth Century Germany*, Queensland: University of Queensland Press.
Kroeber, A. L. (1917), The Superorganic, *American Anthropologist*, 19 (2): 163-213.
Kroeber, A. L. (1923), *Anthropology*, New York: Harcourt, Brace and Co.
Kroeber, A. L. (1930), Diffusionism, in E. R. A. Seligman and J. S. Johnson (eds.), *Encyclopedia of the Social Sciences*, New York: Macmillan: 139-42.
Kroeber, A. L. (1940), Stimulus Diffusion, *American Anthropologist*, 42 (1): 1-20.
Kuhn, T. S. (1959), Energy Conservation as an Example of Simultaneous Discovery, in M. Clagett (ed.), *Critical Problems in the History of Science*, Madison: University of Wisconsin Press: 321-56.
Lefebvre, P. (2005), Innovation et Invention, in M. Borlandi, R. Boudon, et al. (eds.), *Dictionnaire de la Pensée Sociologique*, Paris: PUF.: 357-59.
Linton, R. (1936), *The Study of Man*, New York: Appleton Century Crofts.
Lowie, R. H. (1912), On the Principle of Convergence in Ethnology, *Journal of American Folklore*, 25 (95): 24-42.
Lowie, R. H. (1946), Evolution in Cultural Anthropology: A Reply to Leslie White, *American Anthropologist*, 48 (2): 223-33.
Maclaurin, W. R. (1949), *Invention and Innovation in the Radio Industry*, New York: Macmillan.
Maclaurin, W.R. (1950), The Process of Technological Innovation: the Launching of a New Scientific Industry, *American Economic review*, 40: 90-112.
Maclaurin, W. R. (1953), The Sequence from Invention to Innovation and its Relation to Economic Growth, *Quarterly Journal of Economics*, 67 (1): 97-111.
Malinowski, B. (1939), The Present State of Studies in Culture Contact: Some Comments on an American Approach, *Africa: Journal of the International African Institute*, 12 (1): 27-48.
Mansfield, E. (1968a), *Industrial Research and Technological Change*, New York: Norton.
Mansfield, E. (1968b), *The Economics of Technological Change*, New York: Norton.
Mason, O. T. (1887), The Occurrence of Similar Inventions in Areas Widely Apart, *Science*, IX (226): 534.
Mason, O. T. (1891), The Birth of Invention, in Patent Centennial Celebration, *Proceedings and Addresses: Celebration of the Beginning of the Second Century of the American Patent System in Washington*, Washington: Gedney Robert.
Mason, O. T. (1895a), Similarities in Culture, *American Anthropologist*, 8 (2): 101-117.
Mason, O. T. (1895b), *The Origins of Invention: A Study of Industry Among Primitive Peoples*, London: Walter Scott.
Mason, O. T. (1908), Mind and Matter in Culture, *American Anthropologist*, 10 (2): 187-96.

Meek, R. L. (1976), *Social Science and the Ignoble Savage*, Cambridge: Cambridge University Press.
Mees, C. E. K. (1920), *The Organization of Scientific Research*, New York: McGraw Hill.
Merton, R. K. (1957), Priorities in Scientific Discovery, in N. W. Storer (ed.), *The Sociology of Science: Theoretical and Empirical Investigations*, Chicago: University of Chicago Press, 1973: 286-324.
Merton, R. K. (1961), Singletons and Multiples in Scientific Discovery, in N. W. Storer (ed.), *The Sociology of Science: Theoretical and Empirical Investigations*, Chicago: University of Chicago Press, 1973: 343-70.
Merton, R. K. (1963a), Multiple Discoveries as Strategic Research Site, in N. W. Storer (ed.), *The Sociology of Science: Theoretical and Empirical Investigations*, Chicago: University of Chicago Press, 1973: 371-82.
Merton, R. K. (1963b), Resistance to the Systematic Study of Multiple Discoveries in Science, *Archives européennes de sociologie*, 4: 237-82.
Merton, R. K. (1965), The Environment of the Innovating Organization: Some Conjectures and Proposals, in G. A. Steiner (ed.), *The Creative Organization*, Chicago, Graduate School of Business: 50-65.
Morison, E.E. (1950), A Case Sutdy of Innovation, *Engineering and Science Monthly*, 13 (7): 5-11.
Nelson, R.R. (1961), Uncertainty, Learning, and the Economics of Parallel Research and Development Efforts, *Review of Economics and Statistics*, 43 (4): 351-64.
Nelson, R. R., M. J. Peck and E. D. Kalachek (1967), *Technology and Economic Growth and Public Policy*, Washington: Brookings Institution .
Nisbet, R. A. (1969), *Social Change and History: Aspects of the Western Theory of Development*, London: Oxford University Press.
Nisbet, R. A. (1980), *History of the Idea of Progress*, New York: Basic Books.
OECD (1966), *Government and Technical Innovation*, Paris: OECD.
OECD (1971), *The Conditions for Success in Technological Innovation*, Paris: OECD.
Ogburn, W. F. and D. S. Thomas (1922), Are Inventions Inevitable? A Note on Social Evolution, *Political Science Quarterly*, 37 (1): 83-98.
Redfield, R., R. Linton and M. J. Herskovits (1936), Memorandum for the Study of Acculturation, *American Anthropologist*, 38 (1): 149-52.
Redlich, F. (1953), Ideas: Their Migration in Space and Transmittal Over Time: A Systematic Treatment, *Kyklos*, 6 (4): 301-22.
Rice, R. E., and E. M. Rogers (1980), Reinvention in the Innovation Process, *Science Communication*, 1: 499-514.
Rivers, W. H. R. (1911), The Ethnological Analysis of Culture, *Science*, 34 (874), September 29: 385-97.
Rogers, E. M. (1962), *Diffusion of Innovations*, New York: Free Press.
Rothwell, R. (1986), Innovtion and Re-Innovation: A Role for the User, *Journal of Marketing Management*, 2 (2): 109-23.
Rothwell, R., and P. Gardiner (1988), Invention, Innovation, Re-Innovation and the Role of the User: A Case Study of British Hovercraft Development, *Technovation*, 3: 167-86.

Rothwell, R., and P. Gardiner (1988), Re-Innovation and Robust Design: producer and User Benefits, *Journal of Marketing Management*, 3 (3): 372-87.
Ruttan, V.W. (1959), Usher and Schumpeter on Invention, Innovation, and Technological Change, *Quarterly Journal of Economics*, 73 (4): 596-606.
Scoville, W. C. (1951), Spread of Techniques: Minority Migrations and the Diffusion of Technology, *Journal of Economic History*, 11 (4): 347-60.
Scoville, W. C. (1952), The Huguenots and the Diffusion of Technology, *Journal of Political Economy*, Part I, 60 (4): 294-311 and Part II, 60 (5): 392-411.
Schumpeter, J. A. (1939), *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*, Volume 1, New York: McGraw Hill.
Seely, F.A. (1883), An Inquiry into the Origin of invention, *Transactions of the Anthropological Society of Washington*, 2: 70-90.
Seely, F.A. (1885), The Genesis of Inventions, *Transactions of the Anthropological Society of Washington*, 3: 147-71.
Siegel, B. J., E. Z. Vogt, J. B. Watson and L. Broom (1954), Acculturation: An Exploratory Formulation, *American Anthropologist*, 56 (6): 973-1000.
Smith, G. Elliot (1916), The Origin of the Pre-Columbian Civilization of America, *Science*, 44 (1128), 11 August: 190-95.
Smith, G. E., and B. Malinowski (1926), Is Civilization Contagious?, *The Forum*, 76: 171-85.
Smith, G. Elliot *et al.* (1927), *Culture: The Diffusion Controversy*, New York: Norton & Co.
Stewart, J. H. (1929), Diffusion and Independent Invention: A Critique of Logic, *American Anthropologist*, 31 (3): 491-95.
Stocking, G. W. (1968), Matthew Arnold, E. B. Tylor, and the Uses of Invention, in G. W. Stocking, *Race, Culture and Evolution*, Chicago: University of Chicago Press, 1982: 69-91.
Stoneman, P. (1995), *Handbook of the Economics of Innovation and Technological Change*, Oxford: Blackwell.
Stoneman, P., and P. Diederen (1994), Diffusion and Public Policy, *Economic Journal*, 104 (July): 918-30.
Tarde, G. (1890), *Les lois de l'imitation*, Paris: Seuil, 2001.
Tarde, G. (1902), L'invention, moteur de l'évolution sociale, *Revue internationale de sociologie*, X: 561-74.
Teggart, F. J. (1949), *The Idea of Progress: A Collection of Readings*, Berkeley: University of California Press.
Tylor, E. B. (1870), *Researches into the Early History of Mankind and the Development of Civilization*, London: John Murray, Second edition.
US National Bureau of Economic Research (1962), *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton: Princeton University Press.
Usher, A. P. (1929), *A History of Mechanical Inventions*, New York: Dover, 1988.
Wallis, W. D. (1930), Independent Origins of Similar Culture Traits, in W. D. Wallis, *Culture and Progress*, New York: McGraw Hill: 149-68.
Watson, J.B. (1953), Four Approaches to Cultural Change: A Systematic Assessment, *Social Forces*, 32 (2): 137-45.

White, L. A. (1945), Diffusion vs. Evolution: An Anti-Evolutionist Fallacy, *American Anthropologist*, 47 (3): 339-56.
Wissler, C. (1913), The Doctrine of Evolution and Anthropology, *Journal of Religious Psychology*, 6 (3): 223-37.
Wissler, C. (1916), Psychological and Historical Interpretations for Culture, *Science*, XLIII (1102), February 11: 193-201.
Wissler, C. (1923), *Man and Culture*, New York: Thomas Y. Crowell.

Appendix 1.

Some Theories on Evolutionary Stages

- Antiquity
  - Aristotle
    - From family to community to polis
    - From aristocracy to oligarchy to democracy
  - Hesiod (metallic ages – races): golden, silver, bronze, iron

- Enlightenment (philosophers)
  - French (Turgot, Condorcet, Comte, Saint-Simon): intellectual categories
    - e.g.: Comte: theological, metaphysical, positive (scientific)
  - Scottish (Robertson, Mill, Smith, Millar, Gibbon): economic categories
    - Four stages theory: hunters, shepherds, farmers, traffickers
    - Smith: agriculture, manufacture, commerce

- Origin of Life
  - Biology (comparative anatomy, embryology)
    - Model of the embryo (birth, growth, maturity)
  - Biogeography (Wallace, Hooker)
    - Cyclical models (add decline to the embryo model)
  - Morphology (Huxley, Haeckel, Lancaster, Sedgwick, MacBride)
    - Tree of life
  - Paleontology (Owen, Mivart, Osborn): from fossils
    - Fish, reptiles, mammals, humans

- Origin of Human
  - Archeology (Worsaae, Thomsen, Lubbock, Mortillet)
    - From Ape to Cro-Magnon, Neanderthal, Pithecanthropus, Savage (as link between ape and human), White man
    - From stone to bronze to iron (technology)
  - Anthropology (Morgan, Tylon, Frazer)
    - From savagery to barbarism to civilization (first in historian W. Robertson)

- Origins of society
  - Spencer (social evolutionism)
    - Law of universal evolution (biology, psychology, society)
    - From inorganic to organic to superorganic (also: Kroeber)
    - Social change as geometric (from homogeneity to heterogeneity)
  - Ellwood (19??): From organic, to social, to cultural
  - Chapin (1928): From tools, to language, to institutions
  - Hart (1931): From hunting, to agriculture, to metal (technology)
  - Sorokin (1947): From sensate culture, to ideational, to idealistic
  - Parsons (1966): From primitive to intermediate to modern society
  - History
    - Sombart: pre-capitalism, early capitalism, fully developed capitalism, late capitalism
    - Rise and fall of civilizations
      - O. S. Spengler, *The Decline of the Wes*t
      - A. J. Toynbee, *Study of History*
    - Mumford: eotechnic, paleotechnic, neotechnic, biotechnic
    - From empiric (individual inventor, trial and error) to scientific (industrial laboratories; organized R&D)

- Economics
    - Stueart: pastoral, agrarian, exchange
    - Marx on modes of production
        - Slavery, feudalism, capitalism, socialism
        - Craft, manufacture, modern industry
    - Schumpeter: Craft, factory, big firm
    - Rostow (1960): Traditional society, transitional stage, take off, drive to maturity, high mass consumption

Appendix 2.
Sequences of Innovation

Anthropologists and Sociologists

Seely (1885)	Discovery, invention
Tarde (1890)	Invention, opposition, imitation
Ogburn (1920)	Invention (and diffusion), maladjustment (lag)/adjustment
Bernard (1923)	Formula, blue print, machine [29]
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 [30]
Gilfillan (1937)	Thought, model (patent), first practical use, commercial success, important use
US National Resources Committee (1937)	Beginnings, development, diffusion, social influences
Ogburn and Nimkoff (1940)	Idea, development, model, invention, improvement, marketing
Ogburn (1941)	Idea, plan, tangible form, improvement, production, promotion, marketing, sales
Ogburn (1950)	Invention, accumulation, diffusion, adjustment
Rogers (1962)	**Innovation**, diffusion, adoption Adoption = Awareness, interest, evaluation, trial, adoption [31]
Rogers (1983)	Needs/problems, research, development, commercialization, diffusion and adoption, consequences

[29] For social invention, the stages are: theory, rules, organizations and institutions.
[30] Diffusion is composed of three steps: presentation, acceptance and integration.
[31] From Beal and Bohlen (1955).

Management and Economists [32]

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 [33]
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, service engineering [34]
Furnas (1948)	Exploratory and fundamental research, applied research, development, production
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
Brozen (1951a)	Invention, **innovation**, imitation
Brozen (1951b)	Research, engineering development, production, service
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
Enos (1958)	Invention, development, application
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
Scherer (1965)	Invention, entrepreneurship, investment, development
Hollomon (1965)	perceived need, invention, **innovation**, diffusion or adaptation
Schmookler (1966)	Research, development, invention
Hollomon (1967)	invention, **innovation**, diffusion
Allen (1967)	Research, development, investment, construction, production, distribution
Shepard (1967)	Idea generation, adoption, implementation
Mansfield (1968; 1971)	Invention, **innovation**, imitation, diffusion

[32] 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.

[33] 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).

[34] The last term was added in 1949 (Maclaurin, 1949).

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 (1969)	Invention and discovery, **innovation**, adoption and diffusion
Goldsmith (1970)	Pure science, applied science, development, design, production, marketing, sales and profits
Utterback (1971)	Idea generation, problem-solving, implementation, diffusion
Mansfield et al. (1971)	Applied research, preparation and specification, prototype or pilot plant, drawing, tooling and facilities, manufacturing start-up
Rothwell and Robertson (1973)	Idea generation, project definition, problem solving, design and development, production, marketing
Brewer (1973)	initial introduction, reaction or rejection, partial incorporation, diffusion
Zaltman (1973)	Initiation, implementation
Utterback (1974)	Generation of an idea, problem-solving or development, implementation and diffusion
Rowe and Boise (1974)	Knowledge accumulation, formulation (of an innovation), decision, implementation, and diffusion
Rowe and Boise (1974)	Knowledge accumulation, formulation, decision, implementation and diffusion
Kuznets (1977)	Preconception, innovation, diffusion