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Search for a Common Ground in the Fogs of Innovation Definitions

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Abstract

The second half of the twentieth century saw a dramatic rise in scholarly attention to the Concept of Innovation in a range of different scientific disciplines: from economy, sociology and psychology to management sciences. In this analysis we investigate the work of those innovation scholars active in the Domain of Innovation Research that shows a bewildering heterogeneity of definitions of the notion of innovation. After identifying the much noted need for clarity in definitions, we observe the need for a common ground. We tried to find what all those definitions have in common and identified a range of different groups in Change & Novelty-thinking; from the combination-thinking and invention-thinking to the idea-thinking and result-thinking. But the confusion persisted. To find a common ground we turn to the Domain of Systems applying the 'function' concept: the product-function, the organizational function and the production function. There we can define stepwise changes in the function, the first derivative of a function, as innovation. To conclude we propose a generic definition of innovation. In the appendix an example is given of how we used the generic definition in our case study research related to the General Purpose Technology of Electricity.

Keywords

Definition of innovation, technological innovation, innovation, history of technology.

JEL: O30, O39

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Introduction

Scholars looking at the real world, try to explain the phenomena they are interested in. They develop their views and theories based on their observations. When ‘Schools of Thought’ develop from their shared views and theories, the need arises for a common language. Language in which the same terms are used for the same subject: the classic need for definitions. Already in 1906, the economist Henry L. Moore (1869-1958) wrote:

“Economic terms seem to pass in their historical development through a series of stages which, without pretension to rigidity, may be described as follows: first, no definition is given, but it is assumed that everyone has a sufficiently clear idea of the subject to make a formal definition unnecessary; second, a definition is attempted and a number of exceptional forms are noted; third, with the further increase of data, the relative importance of the various forms changes, confusion in discussion is introduced, logomachy¹ takes the place of constructive investigation; fourth, a complete classification of the forms embraced under the original term is made, and problems are investigated with reference to these classes. The bewildering vagueness of economic theory is largely due to the fact that the terms used are in all of these stages of development.” (Moore, 1906, p. 212)

In the early twentieth century, we find scholars thinking about the combination of technical progress and economic progress. The economic historian Abott Payson Usher (1883-1965) published his *A History of Mechanical Inventions* (Usher, 1929), an analysis about technical progress resulting from mechanical inventions. Mixing the notions of discovery and invention, from that historic analysis of the real world he developed his theory of *cumulative synthesis*. A theory that was about the activities of the inventor and his Act of Skills combined with his Act of Insight, and is still of value in our days (Molella, 2005).

In the same period of time, the economist Alois Schumpeter (1883-1950) published *The Analysis of Economic Change* (Schumpeter, 1935), soon to be followed by his ground-breaking *Business Cycles* (Schumpeter, 1939). His theory of economic development was based on three elements: the process of innovation, the entrepreneur as innovator, and credit/capital. Innovation, clearly distinguished from invention, was a ‘new combination’. As an economist, he was using again their favorite ‘production function’:

¹ Logomachy: a meaningless verbal battle of words.

“We will simply define innovation as the setting up of a new production function. This covers the case of a new commodity, as well as those of a new form of organization such as a merger, of the opening up of new markets, and so on. ... Innovation combines factors in a new way, or that it consists in carrying out New Combinations.” (Schumpeter, 1939, p. 84).

As it was about economy, in Schumpeterian economic growth the entrepreneur dominated more than the inventor: the entrepreneur was the innovator, the agent of innovation. This brought the human element in the equation. After earlier philosophical explorations into the laws of imitation and invention (Tarde, 1903), this was the dawn of the development of a different kind of innovation theories developed by economists, sociologists and psychologists and managerial scholars.

The historian Usher and economist Schumpeter were not the only scholars observing invention and innovation. Also the sociologist William Fielding Ogburn (1886-1959) looked at innovation, creating his theory of social change, that saw invention as a new combination of exiting cultural elements (Ogburn, 1922). He did not bother to much about its definition. The sociologist Seabury Colum Gilfillan (1889-1987), after a historic analysis of the invention of ships (Gilfillan, 1935a), wrote *The Sociology of Invention* (Gilfillan, 1935b). However, there was quite some confusion notable:

“The definitions given to inventions vary considerably, even if not so greatly as in the case of the steam engine, and there is no way out of the arbitrary assumption of one definition. The best we can do, if we seek accuracy, is to try to make clear what definition we are using.” (Gilfillan, 1945, p. 77).

Moreover, the economist Vernon Ruttan (1924-2008), later commenting on the contributions of Usher and Schumpeter, observed not much later:

“The distinction between exactly what is meant by invention in contrast with innovation, and innovation in contrast with technological change, is usually less clear.’ This absence of any clear-cut analytical distinction among concepts which have been assigned such important places in current economic discussion is particularly disturbing.” (Ruttan, 1959, p. 596).

Not withholding this confusion created by the fogs of semantics, after the mid-century the *Domain of Innovation Research*—from the large emperical Innovation Studies to individual investigations—rose in the attention of the *innovation scholars*, resulting in stark rise in publications by economist, sociologists and psychologists, and the management scholars. From the nineteenth century interest in discovery, followed by early twentieth-century interest in invention, we came to the increasing interest in (technological) innovation after World War II (Figure 1).

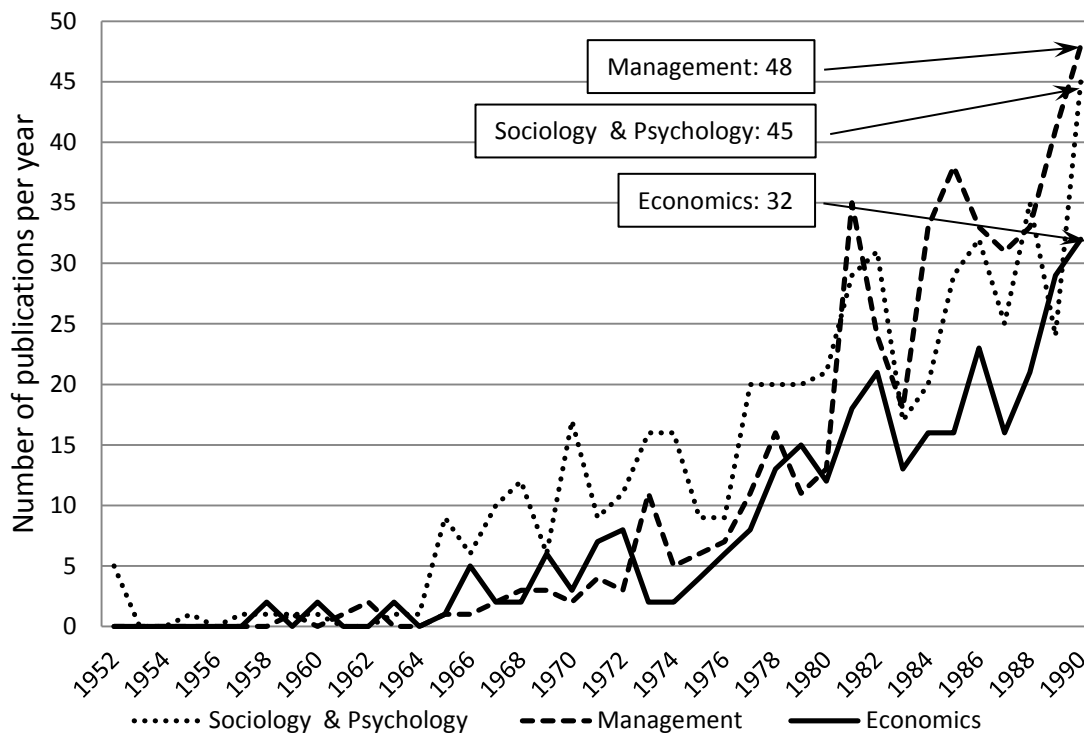


Figure 1: Number of publications on innovation (articles, 1952-1990).

Number of publications with the word innovation in the title. The search was restricted to subject areas: Business, Management & Accounting; Social Sciences; Economics, Econometrics & Finance; Multidisciplinary; Psychology.

Source: Scopus query (TITLE(Innovation) AND DOCTYPE(ar) AND SUBJAREA(MULT OR ARTS OR BUSI OR DECI OR ECON OR PSYC OR SOCI) AND (LIMIT-TO(SUBJAREA,"SOCI") OR LIMIT-TO(SUBJAREA,"PSYC"))) (Accessed 2014)

The need for a common ground

That state of confusion being the case, one can even wonder why a definition would be needed at all for the scholars studying 'innovation'. Obviously, quite some innovation-theories have been developed, hundreds of books have been written with views about innovation, all without any attempt to create an explicit definition at all. Why would a definition be important? One reason is that innovation research is not just a jolly academic exercise, it is relevant to theory building and the creation of innovation policies. As illustrated by George Downs and Lawrence Mohre, who were looking at organizational innovation:

"Unfortunately, the theoretical value of the research that has been done is problematic. Perhaps the most alarming characteristic of the body of empirical study of innovation is the extreme

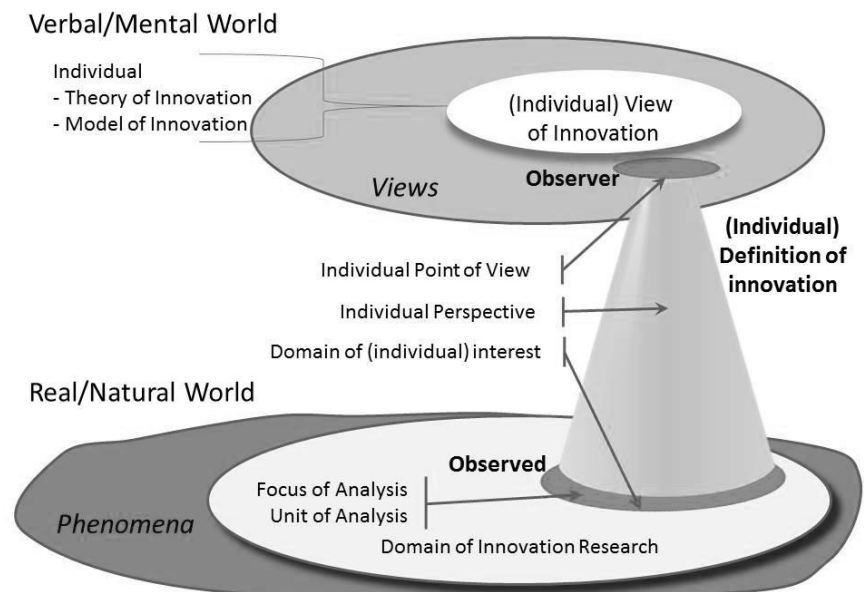
variance among its findings, what we call instability. Factors found to be important for innovation in one study are found to be considerably less important, not important at all, or even inversely important in another study. This phenomenon occurs with relentless regularity.” (G. W. Downs, Jr. & Mohr, 1976, p. 700).

And Alex Roland, facing a similar problem looking at technical change, sometime later concluded: *“Lack of definition, I believe, accounts for much of the confusion and many of the problems of terminology in the extant literature.”* (Roland, 1992, p. 82). But it was about more than avoiding confusion obstructing theory-building: *“Technology and innovation policies must in fact be founded upon a clear, consistent and robust research framework, rather than combining policy measures suggested by two different scientific paradigms.”* (Castellacci, 2008, p. 986). So, definitions are important and the core of scholarly work.

Why a Definition of Innovation?

When we try to characterize scholarly work—in short—, it is about observing phenomena in the real world, defining the focus and unit of analysis, interpreting the findings, drawing conclusions, and creating an individual view, concept, theory and model. In the verbal world of the *Domain of Innovation Research* these efforts would create a particular View of Innovation (VOI), followed by a Theory of Innovation (TOI), a Model of Innovation (MOI) all based on a (theoretical) Definition of Innovation (DOI). That View (VOI) is based on a Point of View and on a Perspective (Figure 2). If needed, to measure their observations of innovation instances, an operational Definition of Innovation is added.

Next, when a group of Innovation Scholars agree on a common view often



Adapted from: Watt, J.H.; van den Berg, S.: *Research Methods For Communication Science* (2002)

Figure 2: The individual View of Innovation (VOI) being based on the individual Definition of Innovation (DOI).

based on the VOI of a dominant author (eg. The Diffusion Theory based on the View from Everett Rogers, the New-Combination definition of Alois Schumpeter), they create a specific *School of Thought on Innovation* (SOTOI) using his DOI and its derivatives (Figure 3).

So, one could conclude and state that the use of a Definition of Innovation (DOI) is a dominant issue is the Domain of Innovation

Research. That is why, in this contribution to the *Body of Knowledge of Innovation Research*, we will focus on the Definitions of Innovation (DOI) that were developed in the second half of the nineteenth century. In the first segment we will try to find what all those definitions have in common. As it does not seem to make sense to create, next to the dozens of existing definitions, another specific definition, we will try in the second segment to define the contours of a generic definition in a more conceptual way. A definition that can be used by innovation researchers active in the Domain of Innovation Research.

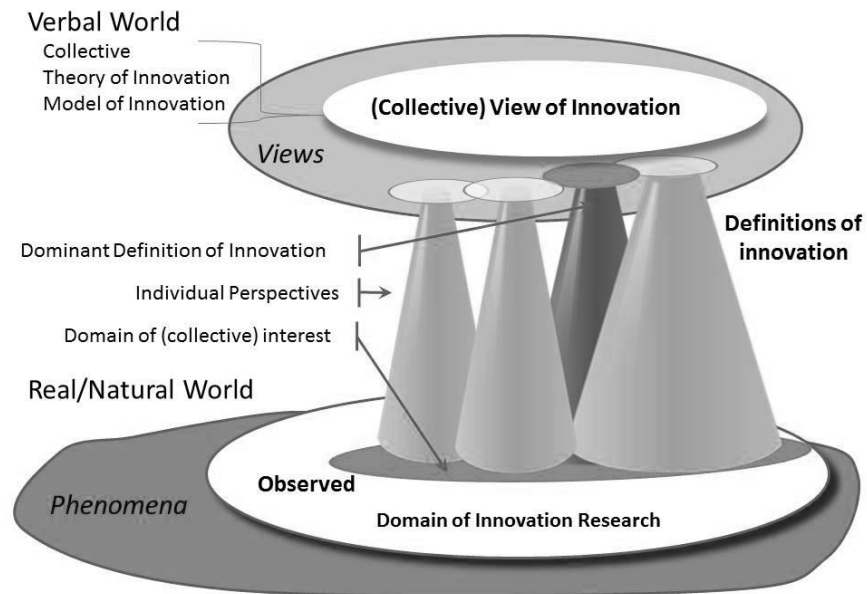


Figure 3: The place of Definitions of Innovation in collective Views of Innovation in the Domain of Innovation Research.

1. Finding a road into dissolving fogs

After analyzing the definitions of innovation found in scholarly literature (Kooij, 2013)², our preliminary conclusion was that innovations are about *changing 'something old' into 'something new' by 'anything'*. Thus, innovation is about 'Change'. As trivial as this looks, the 'something' can be a product, process, organization. So, scholars talk about 'product innovation', 'process innovation', 'organizational innovation'. The change can be a big change (a 'basic', 'radical', 'macro' or 'revolutionary' innovation) or a small change ('incremental', 'micro' or 'evolutionary' innovation). Sometimes the change can be disruptive to the existing equilibrium (the 'disruptive innovations'), other times it can indicate a minimal adaptation ('incremental' and 'imitation innovations'). Or, it can be simply the combination of existing technology in novel ways: 'architectural innovation' in systems. Moreover, the 'anything' can be a product, an individual having an idea, a group or a society: ie the 'innovating organization' and 'innovative society'. The reference for determining the novelty was 'something old'; the preceding technical, economic or social equilibrium. This shows us a road for further analysis.

Change & Novelty-Thinking

Innovation is about change; as the change observed by the before mentioned innovation scholars Usher, Schumpeter, Ogburn and Gilfillan in real life. Such as Technical Change, Economic Change and Social Change. Change that is the transition from one equilibrium to the next equilibrium (eg in economy), but it is more as it has a creative dimension. It is the opposite of 'change & destruction' that accompanies a transition and was observed by Schumpeter. He labeled that combination as 'creative destruction' (Schumpeter, 1942).

Implicitly and explicitly, innovation is about 'something new'. So, the definitions found practically all relate to the novelty-element. "[...] **new** solutions to a problem that currently faces the organization." (Cyert & March, 1963, p. 278); "*The implementation of **new** procedures or ideas, whether a product of invention or discovery, will be referred to [...] as innovation.*" (Evan & Black, 1967). "*We define innovation as the earliness or extent or use by a given organization of a given **new** idea, where 'new' means only **new** to the adopting agent, and not necessarily to the world in general.*" (G. W. Downs & Mohr, 1979, p. 385). Thus, innovation is about change and novelty.

Originally Change & Novelty became related to technological progress. The **notion of invention** was already earlier considered to be about change and novelty leading to new ideas based on knowledge:

² The first 1988-study gave some 76 definitions. We extended our study into definitions in 2014 and found some 250 different definitions.

“An invention must be defined as the combination of several ideas; and which ones are involved, and which are more important, is always the question. [...] invention is a new combination from the ‘prior art’ i.e. ideas previously known [...].” (Gilfillan, 1935b, pp. 6, 28-29). An interpretation that can be observed over time: *“Invention, defined as activity directed toward the discovery of new and useful knowledge about products and processes, [...].”* (Schmookler, 1957, p. 321). *“[...] an invention is an original solution resulting from the synthesis of information about a need or want and information about the technical means with which the need or want may be met.”* (Utterback, 1971, p. 77)

So, innovation is about change and novelty, and about ideas based on knowledge. This preliminary conclusion was not too satisfactory, so we delved again into the definitions. Qualitative looking at how this broad interpretation is translated into definitions, we found groups of scholars writing about innovation who have defined innovation in different ways.

Common grounds for a definition

As stated, the definitions found agree on the basic-element that innovation is about ‘change’ and about ‘novelty’. But, the pain is in the details, as becomes obvious as we analyze the definitions that evolved after the 1950s and try to combine them in similar groups of thinking (aka Views).

Combination-thinking

Many scholars based their work, implicit or explicit, on their view on innovation and many definitions relate to **new combinations** originating from the early 1900s. Though Schumpeter distinguished between ‘invention’ and ‘innovation’: *“It should be noticed at once that that concept [‘Innovation’] is not synonymous with ‘invention.’...”* (Schumpeter & Fels, 1939, p. 80), we see the same ‘combination’ approach we already noted in Schumpeter’s New Combination, appearing in the discussion of the concept of invention. For example by the economists.

Usher defined invention as a **combination of old and new**: *“Practically, we characterize as an invention only some concept or device that represents a substantial synthesis of old knowledge with new acts of insight.”* (Usher, 1955, p. 530). It meant combining these ‘acts of insight’, the unlearned activities, with the ‘acts of skill’, the learned activities: *“Acts of skill include all learned activities whether the process of learning is an achievement of an isolated adult individual or a response to instruction by other individuals of the same or different species of organisms. Inventive acts of insight are unlearned activities that result in new organizations of prior knowledge and experience.”* (Usher, 1955, p. 526). His impressive description of mechanical inventions from 1929 includes electric lighting and reciprocating steam engines (Usher, 1929).

Kutnetz defined an invention to be a **combination of existing knowledge**: “[...] *an invention be a combination of available and existing knowledge concerning properties of the material universe, with the implicit distinction between invention and discovery,[...]*” For him discovery was close to invention: “[...] *discovery is viewed as a process of unveiling something already existing, implying an indefensible theory of scientific knowledge. [...] And yet it must be recognized that scientists in "discovering" their theories are in fact "inventing" them.*”(Kuznets, 1962, p. 20). He also referred to examples like Watt’s condenser, Faraday’s work related to the electric generator, concluding that “*Some inventions, representing as they do a breakthrough in a major field, have a wide technical potential in the sense that they provide a base for numerous subsequent technical changes. [...] what might be called subsidiary invention.*” (Kuznets, 1962, p. 25). Thus, hinting at clustering of invention, just like Schumpeter: “*First, that innovations do not remain isolated events, and are not evenly distributed in time, but that on the contrary they tend to cluster, to come about in bunches, simply because first some, and then most, firms follow in the wake of successful innovation.*” (Schumpeter & Fels, 1939, p. 98)

Nelson defines innovation as a **combination of old and new ideas**: “*An invention may be defined as a new combination of new or old elements-things or ideas. [...] for our purposes it is well to define the term narrowly so as to include only, patentable inventions.*” (Nelson, 1959, p. 103). His definition of inventions is even expanded by adjectives when he speaks about ‘revolutionary, breakthrough and basis inventions’. And, again, the clustering of inventions is stipulated: “*A basic invention is usually followed by a number of improvement inventions.*” (ibidem, p.104).

Type of change-thinking

In the 1960s, some scholars related innovation as **just a change**: “*By innovation is meant the generation, acceptance, and implementation of new ideas, processes, products or services. Innovation therefore implies the capacity to change or adapt.*” (Thompson, 1965, p. 2); “*When an enterprise produces a good or a service or uses a method or input that is new to it, it makes a technical change. The first enterprise to make a given technical change is an innovator. Its action is innovation.*” (Schmookler, 1966, p. 2).; “*Innovation is a fundamental change in a significant number of tasks.*” (Wilson, 1965, p. 196). “*An innovation is the adoption of a change which is new to the organization and to the relevant environment.*” (Knight, 1967, p. 478).

Later in time, some scholars related innovation as a **relative change**: “*The process of innovation is (1) a response to either a need or on opportunity, that is, it is context dependent; (2) depends on creative effort and, if successful, results in the introduction of a novelty; (3) brings about or induces the need for further change. Something can be new only in relation to some frame of reference. In the innovation*

phase it is the current state of the art." (Kelly & Krantzberg, 1978, p. 6); As 'change' is relative to something else, a point of reference is needed. For example the 'state of the art' that was in fact the technical equilibrium of 'something old'. More specifically, the point of reference could be the organization and its environment that implemented the innovation: *"An innovation is the adoption of a change which is new to the organization and to the relevant environment."* (Knight, 1967, p. 478). More broadly speaking, and later in time, the point of reference could be 'anything' that innovated: *"I define innovation as a process through which new ideas, objects, and practices are created, developed or reinvented, and which are new for the unit of adoption."* (Walker, 2008, p. 592).

Some scholars related innovated as a **qualitative change**: *"An innovation is here defined as any thought, behavior, or thing, that is new because its qualitatively different from existing forms [...] a comprehensive term covering all kinds of mental constructs, whether, they can be given sensible representation or not."* (Barnett, 1953, p. 7); *"Innovation takes place via a process whereby a new thought, behavior, or thing, which is qualitatively different from the existing forms, is conceived and brought into existence."* (Robertson, 1967, p. 14).

Origin-thinking

Some scholars related innovation as the consequence of some external **origin**, like inventions: *"An invention, when applied for the first time, is called an innovation."* (Mansfield, 1968); *"[...] the practical implementation of an invention"*. (Wilson, A.H., 1968); *"Technological innovation: [...] initiated by: discovery/invention, phase 1: adoption, phase 2: refinement or aborted, phase 3, generalization [...], terminated by: diffusion/supersession."* (Archer, 1971, p. 1). *"Thus, innovation will be defined to refer to an invention which has reached market introduction in the case of a new product, or first use in a production process, in the case of a process innovation."* (Utterback, 1971, p. 77). *"The process by which an invention or idea is translated into the economy."* (Twiss, 1974).

That origin was not only seen as an invention, it could also be something called an **idea**: *"[...] the actual installation of a new idea in a going concern."* (Alderson, 1965, p. 59); *"Technological innovation represents the conversion of the idea into new or improved products, processes, and their dissemination into general use."* (Uhlmann, 1976, p. 20); *"Process by which, from an idea, an invention or the identification of a need, a product, technology or service is developed that is accepted commercially."* (Gee, 1981), (de Castro & del Pino, 2010, p. 49); *"A technical innovation can be the implementation of an idea for a new product for a new service or the introduction of new elements in an organization's production process or service operation."* (Damanpour & Evan, 1984, p. 394).

Type of Size-thinking

So, innovation was a change that had an effect, and an origin, but it stayed a foggy situation. When Change & Novelty became related to economic progress, also in the realm of invention, the distinction between **incremental** and **radical** changes was introduced: *"I define micro-inventions as the small **incremental** steps that improve, adapt, and streamline existing techniques already in us, reducing costs, improving form and function, increasing durability, and reducing energy and raw material requirements. Macro-inventions, on the other hand, are those inventions in which a **radical** new idea, without clear precedent, emerges more or less ab nihilo. [...] The essential feature of technological progress is that the macro-inventions and micro-inventions are not substitutes but complements."* (Mokyr, 1990, p. 13). One gets the impression that Mokyr is talking about innovations rather than inventions.

Other scholars had already made a simple distinction: *"Product innovation involves the development of **radically** or **incrementally** new products."* (Johne, 1984, p. 2). Or, they hinted at what would be called a **basic** innovation: *"In many instances the industry life cycle can be associated with a **basic** innovation, that is to say, an innovation, which gave rise to fundamentally new products and production processes."* (Duijn, 1977, p. 554); *"Technological **basic** innovations produce new markets and industrial branches whereas nontechnical **basic** innovations open new realms of activity in the cultural sphere, in public administration, and in social services. **Basic** innovations create a new type of human activity."* (Mensch, 1979, p. 47). Whatever the case, the element of radical was introduced: *"An innovation is the initial market introduction of a new product or process whose design departs **radically** from past practice. It is derived from advances in science, and its introduction makes existing knowledge in that application obsolete. It creates new markets, supports freshly articulated user needs in the new functions it offers, and in practice demands new channels of distribution and aftermarket support. In its wake it leaves obsolete firms, practices, and factors of production, while creating a new industry."* (Abernathy & Clark, 1985, p. 6);

Type of Subject-thinking

Innovation was the change of something: the subject of the definition. For many innovation scholars, the phenomena they observed were the new products: sometimes it were the basic innovations of the steam engine, the telephone and telegraph, etc. Sometimes it were the product-improvements classified as incremental innovations. They often included the manufacturing process in their observation: *"[...] new or better **products** and **processes**."* (Koprowski, 1967, p. 79); *"[...] **products** produced by organizations (among which service-oriented), that, when first adopted, represented a new program, that is, an innovation."* (Hage & Aiken, 1970, p. 140); *"Innovation is the process of applying a new idea to*

create a new **process** or **product**.” (Galbraith, 1982, p. 6); “Product innovation involves the development of radically or incrementally new **products**.” (Johne, 1984, p. 2). Also later in time, the organization was seen as the subject of innovation: “Innovation may be viewed as a change to the organizational systems that traverse between radical and incremental rates of change. Innovation may be viewed as driven from a planned and unplanned perspective and can be characterized as being between process and product focused.” (Flynn, Dooley, O'sullivan, & Cormican, 2003, p. 6).

The definition might have been focusing on a single subject, or they covered the whole range of subjects: “1. Jede *anderung von Bedeutung in den Interaktionen oder Wechselwirkungen der Unternehmung mit der naturlichen und socialen Umwelt* uber: a) die *Einfuhrung neuer oder verbesserter **Produkte** und Dienstleistungen auf den Markt*, b) die *Anwendung neuere oder verbesserter Produktionsverfahren* und c) die *Beseitigung der schadlichen Aufswirkungen der Verfahren, Produkte und Dienstleistungen auf die naturlichen und socialen Umwelt*. 2. In der *inneren Struktur der Unternehmung durch Anderungen der Organisationsstruktur*. 3. In den *Subsysteme der Unternehmung, realisation einer, neuen Product-Markt-Kombinationen*.” (Hinterhuber, 1975, p. 26); “There are three stages of innovation: innovation as a **process**, innovation as a discrete item including, **products**, programs or services; and innovation as an attribute of **organizations**.” (Kimberly, 1981, p. 108).

Process-thinking

All these definitions had a product, process (or even organization) as the subject. However, in some definitions ‘innovation’ was not considered to change a ‘thing’, but it was an activity, as in ‘to innovate’. It referred to the **process of implementing** the change: “Innovation is the **process** of bringing invention into use.” (Schon, 1967); “Innovation takes place via a **process** whereby a new thought, behavior, or thing, which is qualitatively different from the existing forms, is conceived and brought into existence.” (Robertson, 1967); “Innovation is the **process** of introducing new ideas to the firm which result in increased firm performance.” (Rogers, 1998); “Technological innovation is a complex activity which proceeds from conceptualization of a new idea to a solution of the problem and then to the actual utilization of a new item of economic or social value [...] it is not a single action but a total **process** of interrelated sub processes.” (Myers & Marquis, 1969): “Innovation is the **process** of applying a new idea to create a new process or product.” (Galbraith, 1982). “I define innovation as a **process** through which new ideas, objects, and practices are created, developed or reinvented, and which are new for the unit of adoption.” (Walker, (2005). It was sometimes defined as a process related to inventions and markets: “Innovation is the process of adopting and distributing a particular invention to different **markets** and its

acceptance by entrepreneurs" (Griliches, 1957, p. 522). All these process-oriented definitions indicate the interest of scholars in trying to understand the nature of the innovation-process.

Result-thinking

Some scholars related innovation to the **result of the change**. Innovation —then called invention— had to be successful. That successfulness was also related to the marketplace or the organization:; "[...] *the **commercial** introduction of an invention.*" (Maclaurin, 1953); "*The innovation stage occurs, when, and if, the invention is first **commercially** introduced by a firm.*" (Davies, 1979); "*Thus, innovation will be defined to refer to an invention which has reached **market** introduction in the case of a new product, or first use in a production process, in the case of a process innovation.*" (Utterback, 1976); "*An invention only becomes an innovation when it is transformed into a **socially** usable product.*" (Martin, 1984). "*Invention is the first occurrence of an idea for a new product or process. Innovation is the first **commercialization** of the idea*". (Fagerberg, (2003). These invention-oriented definitions represent the meaning of innovations as (technological) inventions that are used, adopted, and commercialized by industry (Godin, 2008, p. 31).

This result-thinking thinking broadened, as innovation had to be **successful**: "*Innovatie is het met **succes** invoeren van iets nieuws*" (Translation: "Innovation is the successful introduction of something new") (Beckers, 1974, p. 18). This even became an element in the official OECD-definition: "*Innovation consists of the **successful** production, assimilation and exploitation of novelty in the economic and social spheres.*" (OECD, 2003, p. 5).

Then, there was those scholars that observed the **impact of the change** on economy or technology by a specific substantial or even radical type of change: "[...] *far reaching **basic changes**.*" (Sachs, 1963, p. 207); "[...] *a **drastic change** to something different.*" (Casinco, 1963, p. 674). Changes that resulted in disturbance: "*The implementation of a new idea in connection with a product, process or system which creates a **substantial** economic and/or social disturbance in the relevant environment into which is introduced, thereby necessitating a process of extensive adaptations and imitations.*" (Tinneland, 1973, p. 26). "[Radical innovations are] ***fundamental** changes that represent revolutionary changes in technology. They represent clear departures from existing practice.*" (Dewar & Dutton, 1986, p. 1422)

Still a foggy situation

Clustered by their way of thinking, expanding on the Change & Novelty-concept, different scholarly groups of similar thinking about definitions can be recognized. Some definitions showing a crossover effect as they represent several ways of thinking. However, the confusion stays, and this first analysis

gives reason to conclude that the early, pre-1950s, meaning of invention is quite similar to the meaning of innovation in the late twentieth, early twenty-first century. An impression supported when we are reading about the examples of invention/innovation given by those early scholars. Already in 1922, the sociologist William Fielding Ogburn writes, without giving a trace of a definition, extensively about inventions. In his listing of 148 inventions claimed by more than one person, we find as the examples of electrical inventions the Leyden Jar, the self-exciting electromotor, the telegraph and the telephone (Ogburn, 1922 Appendix). Seabury Colum Gilfillan describes his examples the same way, and even mentions the clustering of inventions: “[...] *the mighty flood of inventions made since in the steamboat and steamship, adapting them to different waters and vastly improving them, without which steamboats would be totally unknown today [...]. The most striking true trait of invention is evolution-the great inventions are enormous and never ceasing aggregations of countless inventions of detail, improvements whose weight and total worth contribute the main value of invention.*” (Gilfillan, 1945, p. 68). Followed by: “*To sum up concerning the invention of wheeled transportation, I repeat that it was never of much consequence until supplemented by numerous other inventions - horseshoes, the modern harnesses, abundant good roads, and great improvements in the cart and wagon, culminating in that marvelous light vehicle of spidery grace, the American buggy.*” (ibidem p.79). Notwithstanding these observation, he certainly struggles with a definition: “*What do we mean by the steam engine, or its invention? Does it include the prior atmospheric or Newcomen engine, a fair substitute for pumping? Does it include the boiler, the cylinder lubricant, accurate lathe, modern metallurgy, or various other inventions which have been vital to the vast progress of the steam engine since Watt's day, and even to his building it?*” (ibidem p.76). Gilfillan describes inventions we would consider today more to be in the realm of innovations. So, could it be that the earlier used concept of ‘invention’ equals today’s concept of ‘innovation’? Could it be that the earlier used ‘discovery’ would be our today’s ‘invention’? That this is all the result of a kind of word-inflation?

We saw that invention and innovation are interlinked, either in time (invention → innovation), either in interpretation (invention + something = innovation). Even more, ‘invention’ could be a specific form of ‘innovation’ (invention ∈ innovation): “*Invention then becomes that special subset of technical innovation on which patents can be obtained.*” (Ruttan, 1959, p. 603). This interesting interpretation could lead to the conclusion that, whatever definition differences between the concept of ‘invention’ and the concept of ‘innovation’, they are related to the same phenomenon we call Change & Novelty.

2. The common ground

One could wonder if there can be found a common ground to this heterogeneity in definitions of Change & Novelty that goes beyond *changing 'something old' into 'something new' by 'anything'*. Can the process-thinking (ie innovation as a process) be combined with views of the product-thinkers (ie innovation as a new product or production process)? Can the origin-thinking find a common ground with impact-thinking? Would that create something like: *"Innovation is composed of two parts: (1) the generation of an idea or invention, and (2) the conversion of that invention into a business or other useful application..."* (Roberts, 2007). Or, combining improvement and radical innovations, *"[...] we define incremental (first or lower order) innovation as low in breadth of impact and comprising the following broad categories: procedural (management-determined innovations in rules and procedures); personnel-related (innovations in selection and training policies, and in human resource management practices); process (new methods of production or manufacturing); and structural (modifications to equipment and facilities and new ways in which work units are structured). We define radical (higher or second-order) innovation as major in scope and breadth, involving strategic innovations or the creation of new products, services, or markets."* (Koberg, Detienne, & Heppard, 2003, pp. 23-24).

We do not have the impression that, after the presented analysis of the heterogeneity, adding another specific definition serves our objective of creating clarity. Another approach is needed. Just like in earlier times of the Scientific Revolution the natural philosophers, investigating the fogs of the 'Nature of Matter' turned to the abstract language of mathematics, we will apply the abstract language of systems. Therefore, we have to leave the Domain of Innovation Research and transform our definition problem to the Domain of Systems Research.

A Systems based Definition

Clearly, the common denominator for all those definitions was 'change' and 'novelty' and they had in common that the change happened in 'something'. The before mentioned 'something' can actually—in abstract terms—considered to be a 'system'. A system with an inner structure (i) and input-variables (x) and a control (c) that determines its function (Y). A system that acts like a black box: $Y=f(x,i,c)$ (Figure 4, top). This approach obviously may need some clarification.

About systems and their function

We will consider the use of the system concept in three different situations: the product as a system, the organization as a system, and the economy as a system. Each results in its own function.

1. **Products:** A system can be a (complex) physical product: eg a bike/ automobile/ train/airplane with many subsystems (eg the power-unit of the motor). Each (group of) product(s) has its specific function: the **product function**: $Y=f(x)$. Like the bike/car/train that has a

transportation function, the watch that performs the *timekeeping function*, the calculator the *calculation function*,

the telephone has a *communication function*, the smartphone adds to that *information functions*. It is a system with internal variables (I) that give the product its properties: like the technology-variable indicating how it was made (eg the electronic watch), the materials-variable for the materials that were used (eg metal, plastic, electronic parts), the design-variable for the design (eg swatch-like style) that was applied. Often the system can be controlled by changing its control-variables (C): eg in a car the steering wheel and the gas pedal, the remote control for the control of the television. The system at a given moment in time is in a steady state (n): eg it is a specific model of a car, watch, television, etc.: $Y=f(x,i,c)_n$ (Figure 4, top).

Ultimo it is a system with properties that constitute its behavior³; the way it reacts to changes in its input-variables (I) and control-variables (C) over time. For the user of the product, it is black box:

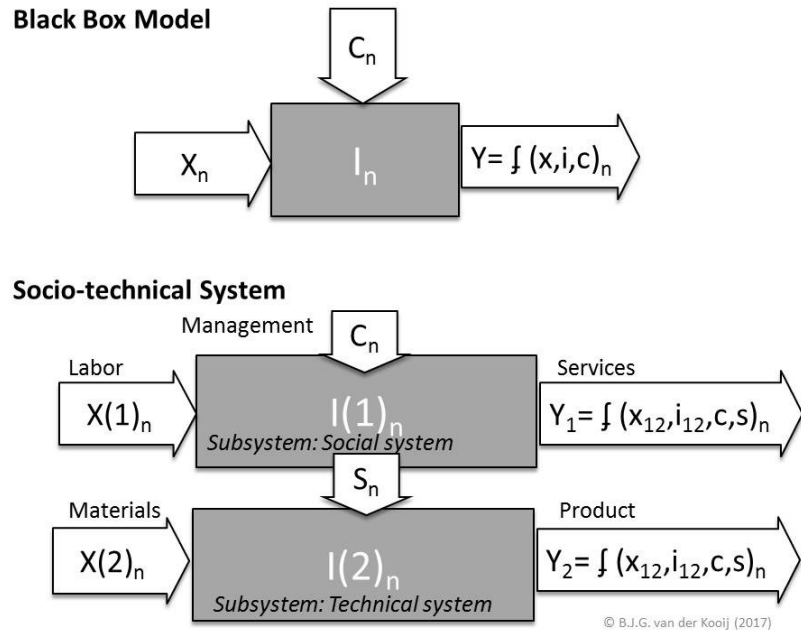


Figure 4: The Black Box model (top) and the model of a Socio-Technical System.

The top shows the system as a Black Box model. The bottom shows a model of a Socio-technical system.

³ Behavior is defined as the predetermined transitions from state to state over time, as the response to external stimuli.

where its inner constitution is invisible and only its normal⁴ behavior is notable: $Y(t) = f(X, I, C)$.

However, there is more, so let's zoom in on the composition of the product function.

The product function is realized by a technology. Therefore, 'technology' (T) is a component of the product function. In addition, the product function is a response to a *primary functional need*: eg the need for the function 'timekeeping' by a watch. In short: one wants to know the time and needs a watch to determine the time. But the need can also be of a secondary nature: one does not need to know the time, but the esthetics of the design of the watch response to a *secondary need* like design and added functionality ("I like high-tech watches", "A need to watch my heartbeat rate during sporting activities"). And one can image that people who buy a watch to show how rich they are, in fact are indicating there are other needs too, thus indicating *tertiary needs*. Without the need (be it a primary, secondary or tertiary need) there would be no product. If needs changes, the product changes. Being an incremental shift in needs (watch: fashion/design), or a more drastic change in need (watch: aviators needed an easy portable watch, thus the wristwatch evolved from the non-mobile and traditional timepieces). So, 'functional need' (N) is a component of the product function. This results in the concept of the product function $P=f(T,N)$, combining the factors of technology (T) and functional need (N). As the sum of functional needs creates a market ($M=\sum N$), this factor represents the market⁵: i.e. the watch market.

2. **Organizations:** The 'system' can be a specific construct: eg the socio-technical system. These systems are also consisting of entities (e.g. individual people, departments) with their interconnections (corporate infrastructures, networks), together creating a *function* with *variables*. A system that realizes an **organizational function**: again $Y=f(x)$. Like the organizational system that realizes a *service-function* (eg the repairs done in a garage, the work done by accountants), a *manufacturing function* (eg as done by the food/ cars/ appliances industry), a *safety-function* (eg police), a *logistic function* (eg postal, internet) (Figure 4, bottom). Again, let's zoom in on the organizational function.

Organizations use a technology: 'knowing how to make things'. Thus, technology (T) is a factor of the 'organizational function'. But there is more as a firm is organized in a certain way; it can be organized for mass production, for engineering, etc., resulting in a specific organizational

⁴ Normal is defined as behavior being related to the state of the system when it is in its equilibrium and performs the function for which it is designed.

⁵ Which factor is dominant demand on the situation and results in the discussion of the dominance of technology-push effect versus the market-pull effect.

structure. So, organizational structure (S) is a factor of the ‘organizational function’. Next, the organization is composed out of people; individual persons performing a specific task. Like the manufacturing tasks of operating a machine, creating a member of the production force (P_p) with his activities (A_p). Or the managerial tasks of coordination work, creating members of management (P_m) with their specific activities (A_m). And last but not least, in respect to business creation, we have the entrepreneurial activity (A_e) as a factor (internal in the existing firm, or external in creating new economic activity). The totality of the individual persons creates the workforce of the firm and their activities. In a more abstract description, ‘labor’. This created another factor of the ‘firm function: the workforce (L) consisting out of people (P) and their activities (A): $L = \sum P, A$ where $P = P_p + P_m$ and $A = A_p + A_m + A_e$. This results in the concept of the organizational function $O = f(T, S, P, A)$, combining the factors of technology (T), organization (S), people (P) and their activities (A).

3. **Economy:** The ‘system’ can also be a non-physical construct : eg the social system, the political system, the economic system. These systems are also consisting of entities (e.g. organizations, institutions) with their interconnections (infrastructures, networks), together creating a *function* with *variables*. These systems also have their own range of internal variables: the ‘culture’-variables, the ‘technology’-variables. They also show a behavior as the result of changes in the input-variables and control-variables. Again, the system can be seen as a black box: where its inner constitution is invisible and only its behavior over time is notable: $Y(t) = f(L, N, K)$. The system performs — in its equilibrium— its normal behavior. The economic system (aka the economy) realizes ‘economic production’, converting resources into wealth. The economic system thus realizes a **production function**. Zooming in on the economic production function we observe:

The production function relates the output (Y) of the economic system to the inputs or factors of production: land (N), labor (L), capital (K). Such as $Y = f(L, N, K)$ (ie labour, land, and capital). Or when technology (T)

became important: $Y = f(L, N, K, T)$ (ie labour, land, capital, technology). Over time, the economist using the (economic)

Table 1: The black box model applied to the production function

Black box model	$Y = f(I)_t$
Inputs: labor (L), land (N)	$Y = f(L, N)$
Inputs: labor, capital, land, capital (K)	$Y = f(L, N, K)$
Technology influencing labor	$Y = f(K, AL)$
Technology influencing capital	$Y = f(AK, L)$
Technology as exogenous external constant	$Y = A f(K, L)$
Technology (T) as endogenous factor	$Y = f(L, N, K, T)$

production function have been looking at different inputs. First, it were the French Physiocrats focusing on the wealth transfer of land. Then, the classical British economist considered the wealth created by merchants in the form of capital. Then came the wealth created by industry where technology became a factor; first as an exogenous constant, later as input variable. As a result, the economic production function changed considerably over time (Table 1).

About Steady State, Equilibrium and Change

As this is not the place to dwell on the basics for applying the General Systems Theory to our topic of Change & Novelty, we leave it here with these examples of systems and their functions, and observe Schumpeter's (economic) definition of innovation "*as the setting up of a new production function*". He relates to innovation that indicates the departure from the steady state of the economic equilibrium, and starts the transition into a new state with a new equilibrium. That transition for a system is the process of Change & Novelty.

Thus, the before mentioned Change & Novelty for a system indicates a transition in the function over time: $Y(t) = f(X)$. It can be the result of changes in the state of its existing internal variables (I_n) from one state to a new state⁶, but it also can be the addition of new variables⁷. That transition can be a range of small—stepped changes—over a period of time, that add up to a bigger change. Alternatively, the transition can be one big step in a short time, representing a discontinuity in the function.

Thus, we start to define an *innovation* as 'a change in a system with a stepwise character'. As the step is big the change becomes a discontinuity that is 'radical/fundamental', as the step is small the change becomes 'incremental/imitation'. If the step has a high degree of novelty (different from the existing) it is 'revolutionary', if the step is close to the existing it becomes 'evolutionary'. To adjust for the often used expressions of *basic innovation* versus *incremental innovation*, we will define a *basic innovation* as 'a large, revolutionary change in a system' with an impact outside the system itself. In the same context we consider an *incremental innovation* as a 'small, evolutionary change in a system', regarding the system itself (Figure 5).

⁶ Colour is a variable of many product-functions (eg cars). The variable 'colour' can have many predetermined states (eg red, green, blue, etc.). A change in that variable normally does not change the product-function. That was the case when, next to black, colours were added as an option by the manufacturers, and it changed in the product-function.

⁷ Such as the addition of the variable 'Technology' (A) in the before mentioned Production function: $Q = f(L, C, N, A)$. Or in the case of the product function: the addition of 'smart' functions to automobiles, telephones and televisions. Such as the internet-access of the smart television, enabling 'Video on Demand', access to internet, etc..

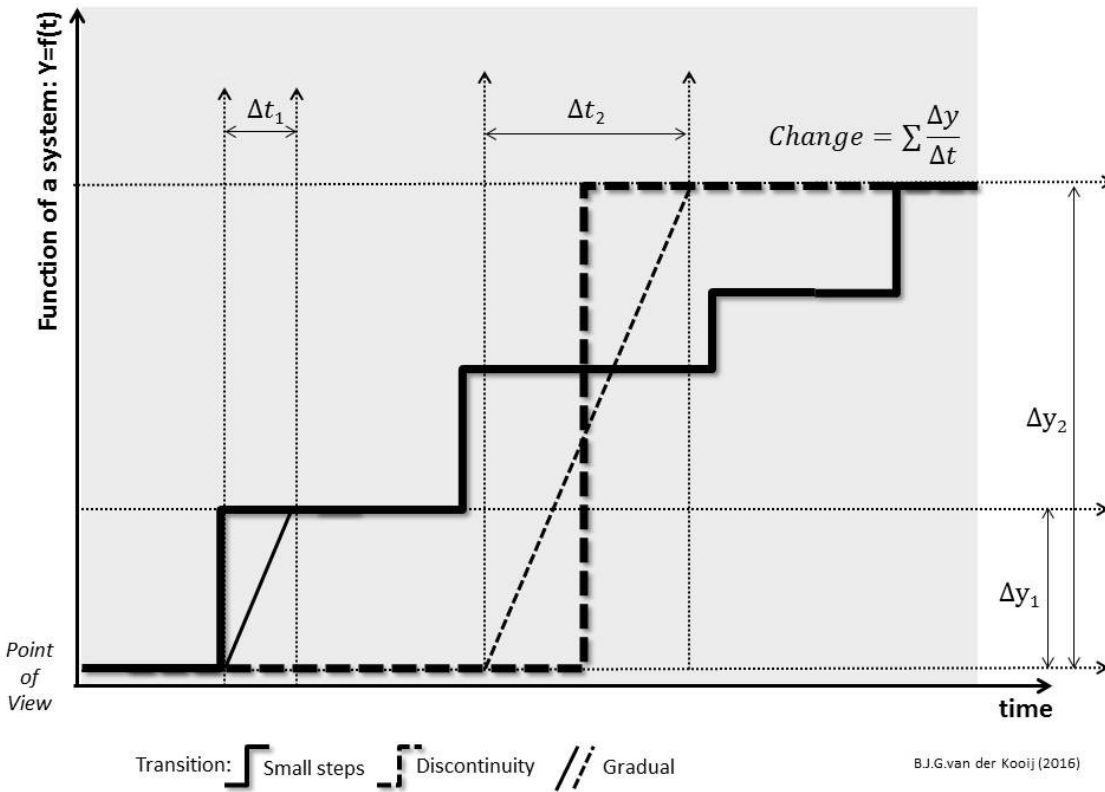


Figure 5: Graphical representation of our system based definition. Small steps as incremental change, large steps creating a discontinuity.

The graph illustrates the stepped changes (ie evolutionary change: $\Delta y/\Delta t$, solid line) that result in a discontinuity (i.e revolutionary change: $\sum \Delta y/\Delta t$, dotted line).

That change also has to be seen within a certain timeframe. Changes are related to the time it takes to realize the transition; it can have an explosive character when the change Δy takes place in a short time ($\Delta t \approx 0$), or it can take a long(er) time ($\Delta t > 0$), the transition is then gradual. Whatever the situation, the time-aspect is important and has to be addressed. Change itself can be represented by the first derivative of the function Y : $Y' = \Delta y/\Delta t$. In the case of small steps the same transition is the sum of the individual steps: $Y' = \sum \Delta y/\Delta t$.

In the same spirit, we define 'inventing' as the creation of a new system. An 'invention' is the creation of a new system, maybe with some variables borrowed from the 'old thing'. Sometimes a system with a completely a new function (eg the telephone for voice-communication versus the telegraph for coded information), sometimes a system that is realizing an old function in a totally different way (eg the wireless telegraph as substitute for a cabled telegraph, the amplifying function of vacuum triode versus

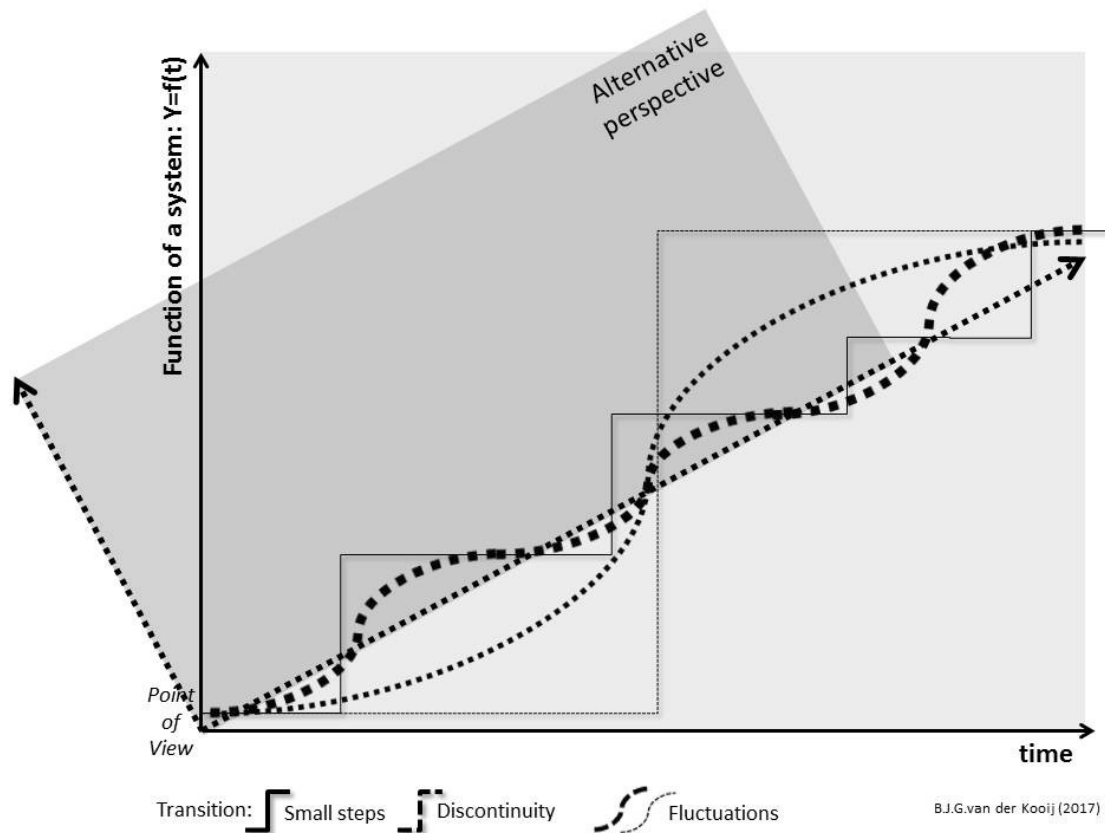


Figure 6: Graphical representation of our system based definition when the perspective changes.

From the same Point of View, changing the axes another Perspective results in a different interpretation of the same phenomena.

that of the semiconductor transistor). Sometimes it regards only *knowledge* (the understanding or know-what), in other cases it regards the *knowhow* of technology, the way to make thing, a method, a procedure, a technique (i.e. the time-function of the mechanical watch being replaced by the electronic watch). Or, it results in a *physical object*; a component or the total system.

About Point of View and Perspective

That change in a system is seen from a specific perspective: the perspective of the creator, the perspective of the user, the perspective of the scholar observing the phenomenon. Changing the perspective, changes the interpretation: the innovation in the original perspective become a mere fluctuation in the other perspective (Figure 6). When that perspective is not defined, as can be observed in many scholarly research, the interpretation becomes fuzzy.

One has to realize that Change is a relative concept as it depends on a) the Point of View (POV) and b) the perspective of the observer; represented by the coordinate system in Figure 5. An observer,

regarding the transition of a system from the same point of view, but now using a different perspective, can have another interpretation of the same phenomenon. In Figure 6 this is illustrated by rotating the coordinate system to create an alternative perspective. From the same Point of View the original change—either stepped or as a discontinuity—can now be observed as a range of fluctuations.

A Generic Definition

When we apply the concept of Change and Novelty in the Domain of Systems, we create a better understanding of the notion of innovation. Now, innovation is the change in a system and its function:

Innovation is a discontinuity that appears as a stepwise change in the function of a system.

So a **product innovation** is a stepwise change in the ‘product system’: for example the timekeeping function of the mechanical watch that now is realized in the electronic watch. The **process innovation** is a stepwise change in the production function like an assembly line: for example the assembly of electronic watches with the microelectronic technology that realizes the production of electronic systems (LSI) used in electronic watches. The **organizational innovation** is the stepwise change in organizations that develop, make and market products like (electronic) watches. For example the changes implemented by existing manufacturers (i.e. traditional mechanical watch industry) or the new startup of manufacturers (i.e. electronic industries) that use the new technology to realize new products.

Innovation is related to changing the type, number and properties of the variables of the function.

Changing the values of the variables themselves is not an innovation.

As the function of a system does exist out of different variables, a change in the number of, the type and properties of these variables constitutes an innovation. The variable can be the technology in which it is made (eg the electronic technologies applied on the time-function created the electronic watch). Or the variable can be the adding of functionality: such as the addition of a camera and video function, and mobile access to data that made a smartphone out of the mobile phone. Just the change of a value of a variable does not encompass a stepwise change resulting in an innovation. Take the example of a specific automobile where the existing variables of the product function — like ‘body color’, ‘headlight shape’, ‘upholstering material’, etc.- are changed. Creating an automobile with another color, another form of headlight, with leather seats, is not an innovation but a design change. But changing the fuel system (electricity instead of fossil fuels), adding the electronic motor management function, and the intelligent safety functions are examples of changing or adding variables to the system.

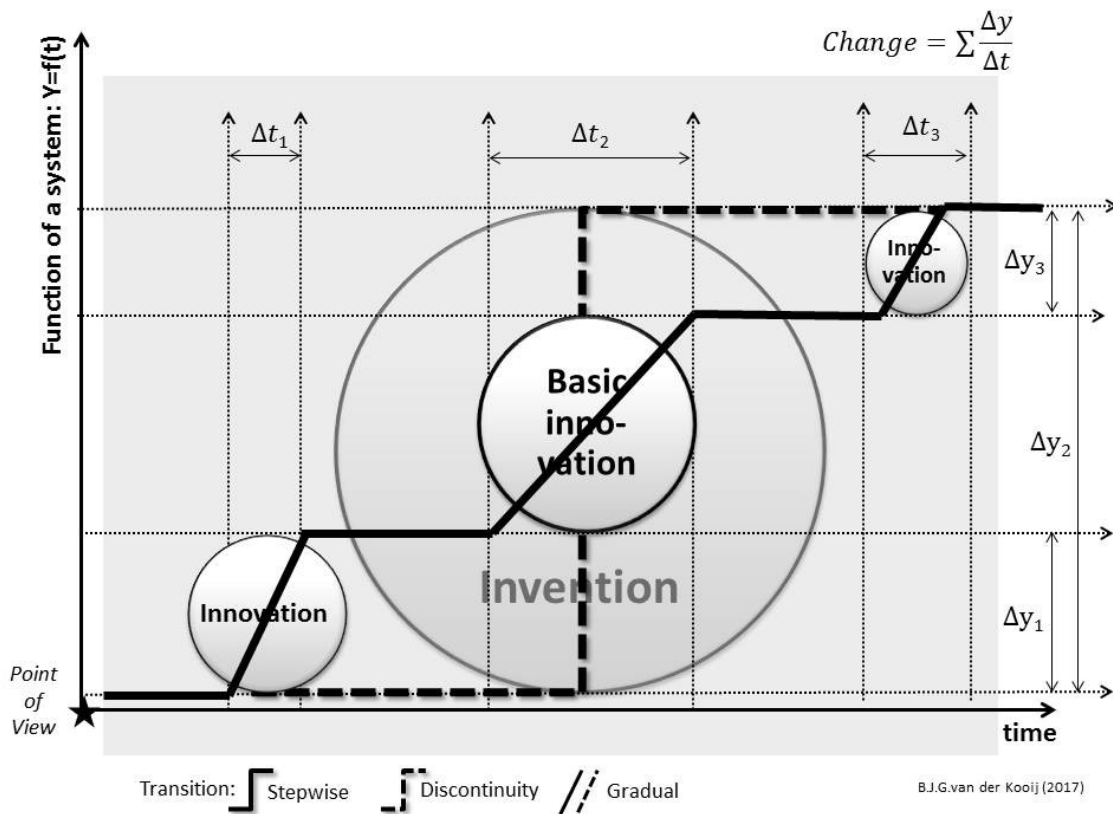


Figure 7: Graphical representation of stepwise changes creating innovation and invention.

Seen from the Point of View the small and large steps in a Cluster of Innovations represent the changing of system variables and/or adding of system variables.

Invention is the creation of a new system: That can be a complete new function, or it can be an existing function where a new system realizes an existing function in a new way.

The function of flight (like a bird) was the basis of a new mechanical system: the invention of airplanes. The electric telegraph had the same function as the Pony Express and the Semaphore; it transmitted the written word over considerable distance. But it did it in a new way (in code with electricity as carrier) based on the early electro-mechanical technologies. Seen on a shorter timeframe with a different resolution, an invention can be the result of separate innovations that represent a discontinuity (Figure 7).

Innovation is the result of a process of change and novelty. Innovation is the result of human activity that appears in the form of a random or organized process. On an individual level the (random) activities of the inventor/innovator constitute the process. On the level of organizations it are the

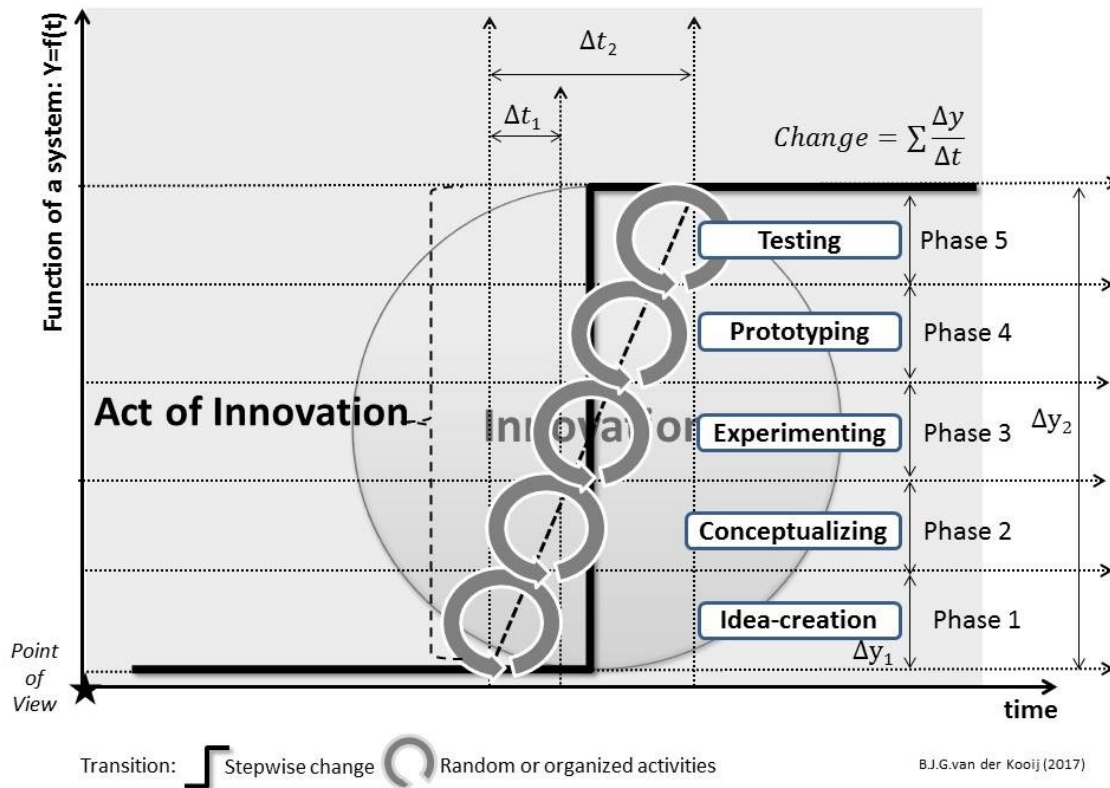


Figure 8: Graphical representation of the stepwise changes resulting in the Act of Innovation.

The Act of Innovation is a phase-wise activity (here labelled for illustration) that realizes the conversion from idea to artefact.

organized activities of (groups) in the organization. We call this process the individual/collective *Act of Innovation* that is the basis of the innovation it creates. (Figure 8)

Going back to the Domain of Innovation, the preceding brings us to the contours of a generic definition of innovation that could be formulated abstractly as:

An innovation is a change in the function of a system that, from a certain point of view and in a certain perspective, has a stepwise character. It is the result of a process of human activity.

The system can be a product, process, organization or society, depending of the focus of analysis and the unit of analysis the innovation researcher is applying. The point of view and perspective are determined by the observer. That goes also for the steps that can be small – resulting in incremental changes— or large, resulting in discontinuities.

Conclusion

Up till present time, notwithstanding the massive attention to the phenomena of innovation in the Domain of Innovation Research, the concept of innovation is shrouded in nebulae. Based on a multitude of Views (VOI), a broad range of theories (TOI) and models (MOI) in parts of the domain have emerged. Subsequently, innovation scholars use a broad range of definitions (DOI), the cornerstones of their scholarly work, showing a massive heterogeneity. As the observation of the confusion in the field of economic research due to a lack of definitions, also applies in the field of innovation research, attention has to be paid to this definition-heterogeneity.

It seems that a first step to clear the fogs around the Concept of Innovation can be found in using a system-based generic definition. It is to the individual scholar to specify the system and its function, his point of view and his perspective. But that is already part of scholarly work when he does research in the real world and defines his *point of view* and the *perspective* he uses for observing the phenomena at hand, as well as his *focus of analysis* and *unit of analysis*. (Figure 2).

Appendix: An Example of research into the Nature of Innovation

As part of our study of the Nature of Innovation, we have been investigating the Clusters of Innovations that are part of the *General Purpose Technology* of Electricity (GPT-E). A meta-technology carried by engines like the electric motor and dynamo, electric light and the communication engines telegraph, telephone and wireless⁸. We called these engines that are so essential in the GPT-E, the *General Purpose Engines* (GPE) (Kooij, 2015e).

Our focus of analysis was the cluster around the *Basic Innovation* (eg Edison's incandescent lamp, Morse's telegraph, Bell's telephone, Marconi's wireless) with the preceding contributing innovations and with the subsequent improving innovations (Figure 9). Our unit of analysis was the innovation as identifiable by a patent or a reading. As the basic innovation we considered the innovation which patent

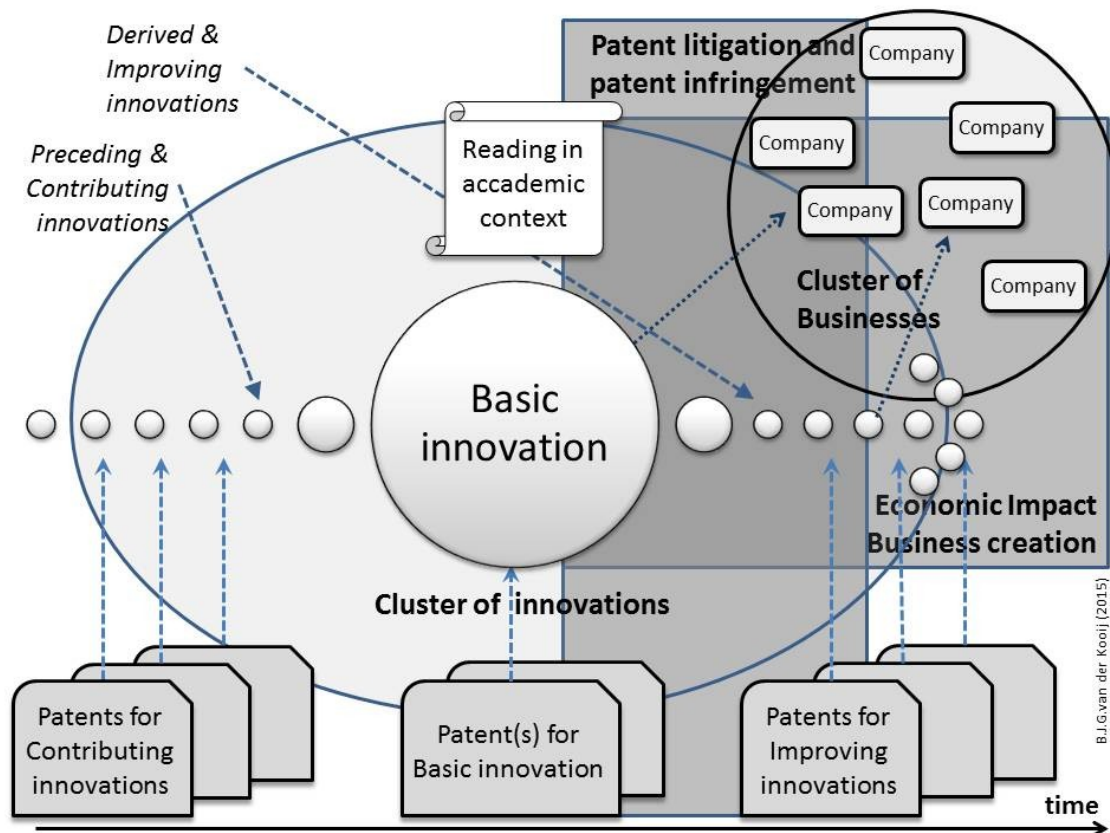


Figure 9: Cluster of Innovations with the Basic Innovation at its core.

⁸ Published as case studies in the *Invention Series*, which are available through Amazon. Open Access articles on our findings are available at the Delft Repository: <https://repository.tudelft.nl/islandora/search/author:%22Van%25C+der%25C+Kooij%252C%25C+B.J.G.%22?collection=research>

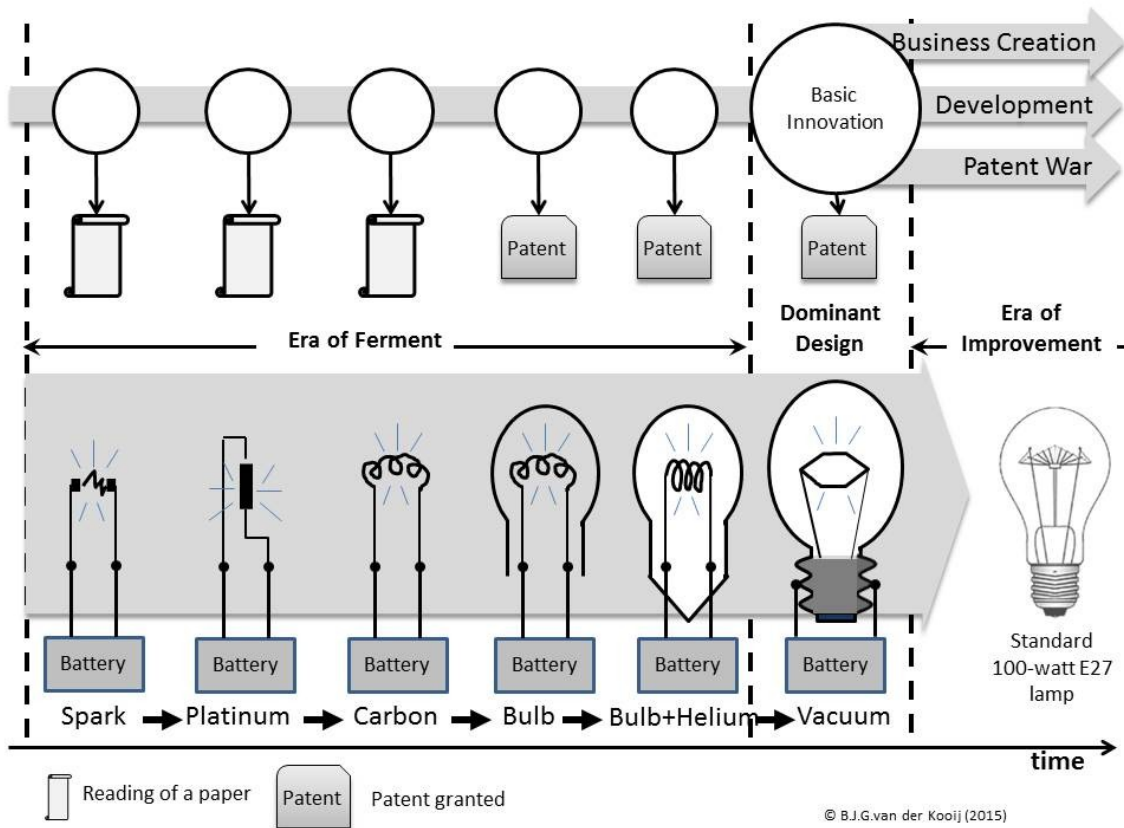


Figure 10: The stepwise change in the function 'incandescent light' leading to the Dominant Design as Basic Innovation in the Cluster of Innovations.

was mostly contested and that had the greatest impact (economically) by business creation, and (technically) when it became the Dominant Design (Anderson & Tushman, 1990).

The innovation itself was the stepwise change that was the result of the Act of Innovation (Figure 8) under investigation. In the case of the incandescent lamp we used as the function the 'light-emission of a heated wire'. We found different moments in time when a 'step' occurred in its development trajectory. The innovation identifiers were either Readings of patents (Figure 10). This method of identifying stepwise changes in functions, was used in all case studies

However, we did more. As we both investigated the Content and the Context we analyzed extensively the techno-economic and the socio-political environment of the cluster. Each characterized by their Technical Change, Economic Change, Social Change, Political Change and Scientific Change over time. We related those dynamics to the Cluster of Innovations by creating the techno-economic environment and the socio-political environment (Figure 11). Thus we could analyze the techno-economic impact of the

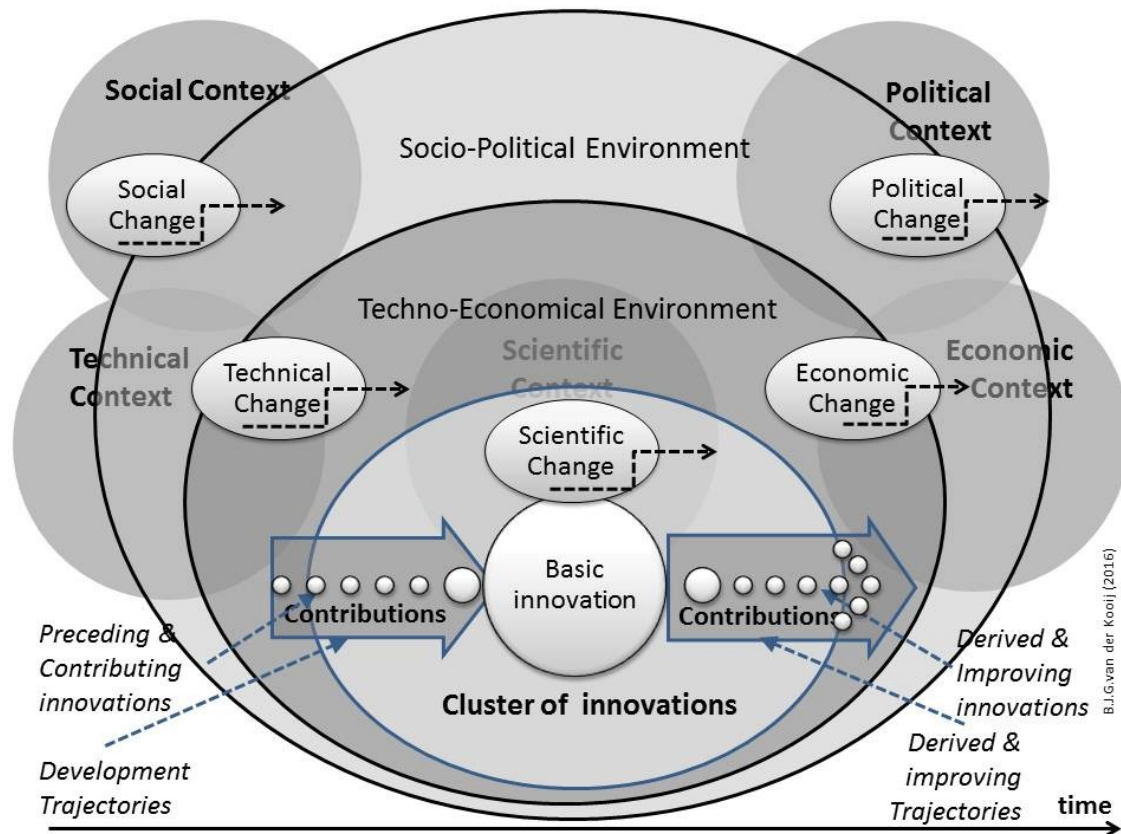


Figure 11: The Context for the Cluster of Innovations with the Cluster of Innovations and the Basic Innovation at its core.

basic invention (ie business creation) and its techno-economic conflicts (ie patent wars). And the mechanism behind Change & Novelty where human behavior is involved (Kooij, 2017c).

By defining the innovation as a stepwise change in a function (eg emission of visible light from the heated incandescent wire) we were able to distinguish (a) steps identified by readings/patents along the development trajectory of that function, and (b) the dominant design that was the big step in the function. Take for example the development trajectory of the incandescent lamp (Figure 10). Patented contributions from several people over time could be identified before the breakthrough contribution of Thomas Edison. After this innovation became the dominant design, a range of (patented) improvements could be identified. The cluster of Innovation could be constructed (Figure 12) with its contributing trajectories and with the improvements that followed the basic invention. (Kooij, 2015c)

A similar approach was followed for other functions identifiable in the GPT-E. The function of rotative motion was used to analyze the development of the GPE's electro-motor and electric dynamo (Kooij,

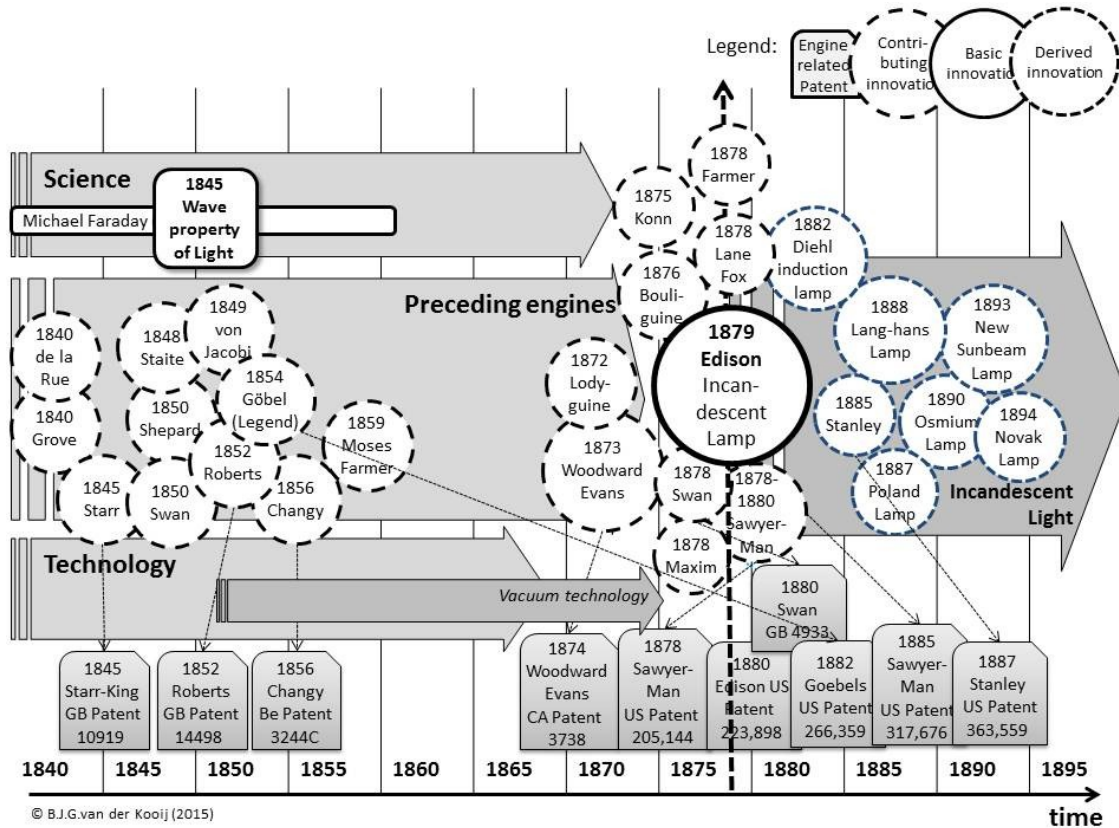


Figure 12: The Context for the Cluster of Innovations with the Basic Innovation at its core.

Figure created by author in case study.

2015d). The communication function was used in specific forms; the cabled transmission of the written (and coded) word (Kooij, 2015b) and the spoken word (Kooij, 2016b), and the wireless transmission of the written word (Kooij, 2017b).

As the spawning of the GPT-E was such an important factor in the Industrial Revolution (Figure 13) (Kooij, 2015a) (Kooij, 2017a), we analyzed the context of the Industrial Revolution separately (Kooij, 2016a). With the totality of these case studies in the GPT of Electricity, we analyzed the *History of Electric Inventions* in a uniform and well-defined way. Stimulated by Usher and his *History of Mechanical Inventions* (Usher, 1929).

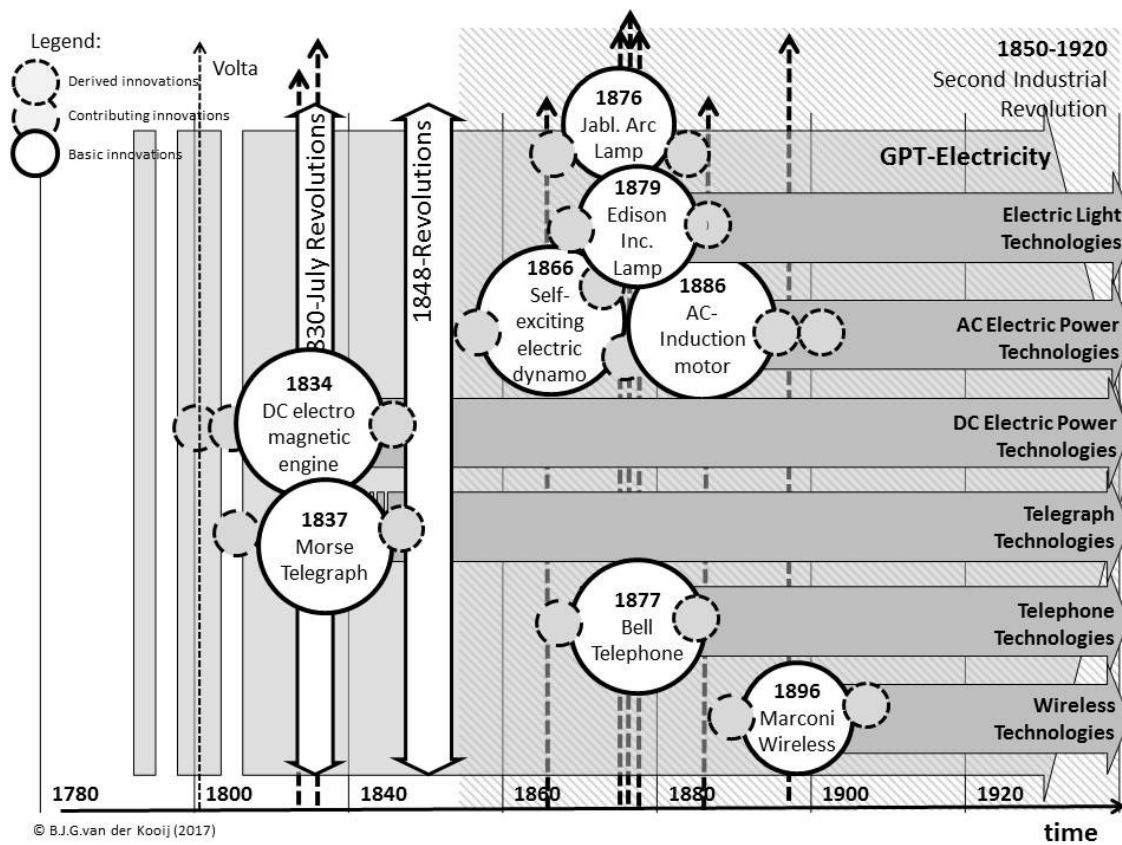


Figure 13: The GPT-E and its spawning technologies in relation to the Industrial Revolution.

Figure created by author in case study.

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