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A Review of Theories of Invention and Innovation

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by

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ABSTRACT

This paper reviews existing theories of invention and innovation putting them at the center of the understanding of cultural change. After a survey of different categories of inventions and innovations, it introduces a taxonomy relying on the origins of invention and innovation highlighting individual qualities, social environments, resource access and incentives for problem solving. Following this taxonomy, different theories are analyzed and compared. Features of theories are evaluated with respect to their explanatory power. Conclusively, historical trends of theories are outlined as well as some preliminary results regarding different points of directions of existing theories.

Keywords: Innovation theory, innovation, invention

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I. Introduction

How does new stuff come about? This is one of the more important questions addressed within the history of science and technology. In fact, it is one of the more important questions addressed within the human and social sciences overall. Broadly speaking, there are only two possibilities for cultural change. In any context, new cultural elements have either to be transferred from other cultures or contexts or to be developed, i.e. invented and spread, within the culture itself. Interesting enough, mathematical modeling has shown that cultural innovation is the force that drives cultural accumulation in general.[1]

The problem of how new culture—and most of all new technology—is created has been thoroughly studied within many different academic fields. Thus, the history and theory of inventions has a multi-faceted and long tradition. Problems connected to how and in what contexts inventions arise have been analyzed and the results have been generalized in order to create theories regarding suitable contexts and environments for targeted individuals. The aim of this study is to review the factors engaged in theories explaining invention and innovation. This does not entail an account for each and every observation made regarding the reasons for an invention to appear at a specific place in a specific time. Instead, it is an attempt to map different types of ideas of why inventions and innovations emerge with variable frequencies over time and space. This is a bird's-eye view of the explanations employed in existing theories of invention.

Before existing theories are reviewed, however, it is important to clarify certain points of departure and simple definitions. First of all, the problems of defining the concept of invention has been stressed by many researchers, an insight that has caused still more of them to refrain from it altogether.[2] Although we will be dealing with theories of technical inventions, the definition of the concept will be the broadest possible. Here invention is assumed to mean: anything human-made different from anything already existing. More specifically it is defined as: "any thought, behavior, or thing that is new because it is qualitatively different from existing forms. Strictly speaking, every [invention] is an idea, or constellation of ideas; but some [inventions] by their nature must remain mental organizations only, whereas others may be given overt and tangible expression."[3] Note that this definition does not delimit inventions to technical novelties. Instead, any type of news introduced to any type of practice such as literature or art may be called an invention. Also note that inventions as defined here is not delimited to material objects and artifacts, but may well include thoughts and theories as well as social institutions and organizations.

A more important distinction of invention is achieved by contrasting it to the concept of innovation. While innovation is usually used to denote the process that takes place when a product or a process is developed, from idea to market, the concept of invention only denotes the process that takes place when new ideas or solutions are generated *per se*.[4] Thus, invention usually is assumed to precede innovation, which in its turn is assumed to precede implementation, i.e. the process that takes place when a product or a process is adjusted and further developed to fit market conditions.

It has correctly been pointed out that inventions may be abundant in a specific culture without ever being developed into innovations. One often cited example is ancient China where a lot of

[1] Magnus Enquist, Stefano Ghirlanda & Carl-Adam wachtmeister, "The evolution of cumulative cultural evolution", Working paper Dec. 2005, Department of Zoology, University of Stockholm.
[2] S.C. Gilfiillan, *The Sociology of Invention*, first publ. 1935 (Cambridge, Mass., 1970), 23.
[3] Homer G. Barnett, *Innovation: The Basis of Cultural Change* (New York, 1953), 7.
[4] Joe Tidd, John Bessant & Keith Pavitt, *Managing Innovation: Integrating Technological, Market and Organizational Change*, 2nd ed. (New York, 2001), 38.

techniques such as paper, gunpowder, printing etc was invented but never implemented on a broader scale. Thus it is possible to have inventions in abundance and still lack innovations. Nevertheless, inventions are a necessary precondition for innovations.[5]

In contrast to innovations—a concept with a more obvious and easily verifiable condition, namely the arrival of a product on a market—inventions lack a corresponding condition when defined as broadly as above. According to our definition, any idea is to be called an invention if it is uniquely new. In order to delimit inventions to those of direct or indirect historical importance for technical change, it becomes compelling to introduce additional delimiting conditions or distinctions.

By applying such a broad definition, it soon becomes clear that inventive processes take place more often than usually assumed. In fact, any type of solution to any type of daily problem is an invention in the terminology used here. And why shouldn't it be? Although resources, both material and personal, are on a very different scale in large corporate laboratories in comparison to what humans in general are able mobilize for their personal use, the basic vision of possibilities for change in existing conditions are the same.[6]

Along more traditional lines, and simultaneously more delimiting, are the definitions of invention and innovation given by the philosopher of science Jon Elster. He defines innovation as "the production of new technical knowledge" while invention is said to be "the generation of some scientific idea, theory or concept that may lead to an innovation when applied to a process of production" and diffusion is "the transfer of an existing innovation to a new context".[7] The definition is weak since the daily use of the concept of invention is much broader and may well denote technologies that are neither based on scientific ideas, theories or concepts, nor ever applied to a production process. One such invention could be the technique to light a fire, something that was developed long before science existed and led to innovations such as a heating device, without having ever been applied to a process of production (whatever that may be). Still, science has often been referred to as a very, perhaps the most, important basis for inventions and innovations. In order to avoid problems of what can be considered to be scientific knowledge in contrast to other forms of knowledge and in order to avoid discussion about such categorizations as applied science, basic science etc., it is usually a good idea to simply define science as any set of information, a perspective that of course gives the concept of science a very different meaning than it has in everyday speech.

In the literature, it is common to introduce distinctions between different types of inventions and innovations such as radical versus conservative (incremental) or independent versus routine regarding perceived extent of change, where the former denotes inventions leading to radically new forms of systems and behavior such as the telephone or the automobile and the latter denotes inventions or innovations that in one way or another improve existing systems and behavior.[8] Generally, radical inventions are supposed to be created through changes on the supply side and conservative (incremental) as reactions on the demand side. Another common distinction is often made between product and process inventions (or innovations) regarding what is changed, where product inventions are seen as a new thing or service, while process

[5]William J. Baumol, *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism,* (Princeton, 2002), 9-10.
[6]Homer G. Barnett, *Innovation: The Basis of Cultural Change* (New York, 1953), 3.
[7]Jon Elster, *Explaining Technial Change: A Case Study in the Philosophy of Science* (Cambridge, 1983), 93.
[8]For a thorough discussion on distinctions, see: Rosanna Garcia & Roger Calantone, "A critical look at Technological innovation typology and innovativeness terminology: A literature review", *The Journal of Product Innovation Management* 19 (2002), 110-132. See also: Richard A. Wolfe, Organizational Innovation: Review, critique and suggested research directions", *Journal of Management Studies* 31 (1994), 405-431.

inventions are seen as changes in the ways in which they are created and delivered.[9] An important result regarding this distinction is that it seems as if the rate of product innovations are high and the rate of process innovations low in the early phases of a new industrial sector or product class. Later though, it seems as if this is reversed so that product innovations become less frequent and process innovations more so.[10] When a broader stance is taken, however, as is done here, it is more rewarding to make a distinction between consumer goods and capital goods. These concepts can be defined in different ways, but one standard definition is based on the competence needed in order to use the goods. Consumer goods are those where the buyer can use the product without having to mobilize extra competence, while capital goods are those where that is necessary.[11]

From an epistemological perspective, it may be important to make distinctions between inventions and discoveries. Some historians and sociologists, most of them may be called constructivists, claim that there is no difference since both inventions and scientific findings (discoveries) must be accepted through formal or informal processes under human control in order to acquire recognition. Constructivists tend to ignore or at least play down possible external constraints on human activities such as inventing and discovering.

Realists, on the other hand, view external constraints as crucial when analyzing how inventions as well as discoveries are made. Among realists in general, external constraints are seen as the ultimate test for the recognition of scientific results in the same way external constraints limit the number of possible solutions to a specific problem or the number of ways a specific function may be realized technically.[12] From this perspective, there is no principal difference between a discovery and an invention.

But most realists hold market success to be an additional judge when it comes to evaluate whether inventions can be said to work satisfactorily. Since market conditions are internal to human activities, the differences between the processes preceding the acceptance of a discovery—ultimately checked against constraints external to human activities—and of an invention—primarily checked against constraints external to human activities and secondarily checked against constraints internal to human activities—become significant. Thus, it can hardly be viewed as a surprise to come to the conclusion that the issue of similarity and difference between invention and discovery is to a large extent decided by the basic epistemological assumptions made.

In general, theories of invention don't predict how inventions will occur, even less so when.[13] This is understandable since such a theory would not only be stronger than social theory commonly is, but it could also, strictly speaking, be used to predict historical change. Instead, theories of invention usually point out factors that are viewed as important in order to understand why some environments seem to be more dynamic than others.

[9]Joe Tidd, John Bessant & Keith Pavitt, *Managing Innovation: Integrating Technological, Market and Organizational Change*, 2nd ed. (New York, 2001), 8.
[10]James M. Utterback & William J. Abernathy, "A Dynamic Model of Product and Process Innovation", *Omega* 3 (1975), 639-656.
[11]There are many alternative definitions of capitalist goods such as: Goods which are used to make other goods which satisfy more immediate demands. The weakness with this definition is that it for instance excludes fighter aircrafts.
[12]Stephen Cole, *Making Science: Between Nature and Society* (Cambridge, Mass., 1992).
[13]In fact, this is impossible since their prediction would imply their existence and hence disqualify them as inventions.

II. A taxonomy of theories of invention

Even if the concept of invention is defined in broadest possible way, the scope of the theories that can be generated with respect to the phenomenon can be narrowed down. Theories of invention may be classified according to how they explain the emergence of inventions. Most commonly, they propose that (technical) inventions occur in the context of problem-solving as in neo-classical economic theory. Other theories point out individual creativity that can be spurred by organizational and social conditions.[14]

Traditionally, the individual's abilities have often been stressed, especially in theories developed in romantic contexts stressing the importance of the individual when explaining cultural change. These types of theories are still common today.[15] This perspective can be contrasted to those where organization and social environment are focused.[16] The distinction between theories of processes going on inside the heads of individual actors and processes generated by the interaction of individuals is not absolute. Most theories blend components from both categories. However, it is striking how often the scope of a theory of invention mainly falls within one of the two categories.

Another dividing principle that can be used in order to characterize theories of invention is whether invention is assumed to be mainly a process of problem-solving or if access to resources is focused. In the first case, systematic methods and analytical approaches are generally stressed while the other usually point out the importance of different resources such as technical equipment, knowledge of relevant natural phenomena etc.

In this context, it is important to point out that the distinctions made here are theoretic, not empirical. That means that in each single case, an invention may be accounted for by stressing problem-solving activities as well as the resources at hand. In addition, the individual efforts involved may be paralleled to the social environment in which they occur. Thus, no matter of the data used, the perspectives outlined here can always be found in the empirical material studied. There are no inventions without individual efforts and social environment. There are no inventions without resources and problems to be solved.

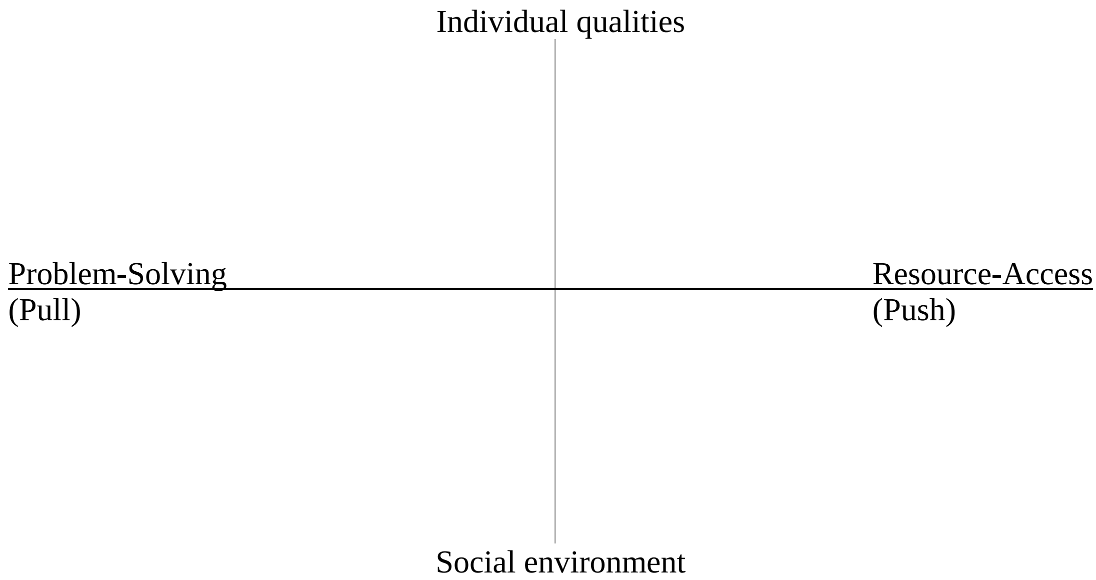
These different theoretical principles can be summed up in a graph as the one below where the dichotomical pairs have been arranged along two different axes. The plane they span can then be used to classify existing theories regarding inventions. This type of graphs is not an invention, but a practiced way of mapping objects of analysis. In fact, innovations themselves has been mapped in this way according to their effect on technology, disruptive making existing competence obsolete or conserving it, and market-user relations, creating new markets or conserving old relations.[17]

[14]See for example: Larry R. Vandervert, "The Neurophysiological Basis of Innovation", in: *The International Handbook on Innovation*, ed., Larisa V. Shavinina (Amsterdam, 2003), 17-30; Larisa V. Shavinina & Kavita L. Seeratan, "On the Nature of Individueal Innovation", in: *The International Handbook on Innovation*, ed., Larisa V. Shavinina (Amsterdam, 2003), 31-43.

[15]For a review of the idea of the individual, see: Robert Friedel, "Perspiration in Perspective: Changing Perceptions of Genius and Expertise in American Invention"; in: *Inventive Minds: Creativity in Technology*, eds., Robert J. Weber & David N. Perkins (Oxford, 1992), 11-26.

[16]Wiebe E. Bijker, *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (Cambridge, Mass., 1995).

[17]William J. Abernathy & Kim B. Clark, "Innovation: Mapping the winds of creative destruction", *Research Policy* 14 (1985), 3-22.



The perhaps best known theories of invention are those regarded by Elster in his analysis of how technical change has been explained.[18] Here, neo-classical theories of economy, Joseph Schumpeter's theory of the entrepreneur, evolutionary economic theories and Marx theories of productive forces and relations of production are compared. In conclusion, the observation is made that neo-classical theory stresses the social environment (market conditions) before the individual capitalist and problem-solving before access to resources. Hence, it should be placed in the lower left quadrant.

Schumpeter, on the other hand, stresses the individual entrepreneur and his or her ability to bring together economic, technological and scientific expertise and use these to get prime-mover advantages on new markets.[19] True, Schumpeter's theory is more complex since it also includes the access to risk capital, something that in its turn depends on the condition of markets. Still, this theory belongs in the upper right quadrant because of its strong focus on the individual's initiatives.

From the perspective of the above graph, evolutionary theories depart from the notion that a company can be viewed as an phenotype that is fitted to the ever changing economic environment although fitness here is defined as profitability. And if the firm corresponds to the phenotype, then routines within the firm corresponds to the genotype of a particular firm.[20] In most evolutionary models, the company employs scientific methods and information as well as other means to make processes and products fit existing (market) conditions better. If mapped on the figure above, evolutionary models should be placed in the middle of the upper half since resources make the changes possible, while problems, or at least the desires of an external environment, usually drive the allocation and application of these resources.[21]

Finally, Marx argues that capitalists innovate because they are forced to do so by competition, and they are able to innovate because they can draw on a stock of inventions, i.e. on science.[22] This view is in principle similar to that of evolutionary economic theory. On the other hand,

[18] Jon Elster, *Explaining Technial Change: A Case Study in the Philosophy of Science* (Cambridge, 1983).
[19] Ibid., 126.
[20] Richard R. Nelson, "Recent Evolutionary Theorizing About Econoimc Change", *Journal of Economic Literature* 33 (March 1995), 48-90.
[21] Maureen McKelvey, *Evolutionary innovations: The Business of Biotechnology* (Oxford, 1996).
[22] Quoted from: Jon Elster, *Explaining Technial Change: A Case Study in the Philosophy of Science* (Cambridge, 1983), 166.

Marx also introduces the concepts of forces of production and relations of production arguing that forces of production (often interpreted as science and technology) over time always depart from being in correspondence with the relations of production. This process implies that forces of production sooner or later will become in contradiction to the relations of production. These contradictions may take many forms such as crisis or lead to too many restrictions on changes in the forces of production. The general problem for those interested in Marx' theory of invention is that the factors behind the changes in forces of production are described differently in different texts by Marx. In some, it is claimed that contradiction between forces and relations of production only appear when all productive forces for which there is room (within a set of relations) have been developed.[23] In other texts, innovative activities are regarded as springing from the inner sources of being of individuals. If so, the problem is not creating incentives for innovation, but removing obstacles.[24] It seems that marxian theory comes in many different shapes and colours. This makes it hard to specify a location for it on the map.[25]

III. The individual inventor and organizational innovation

The results emanating from historical studies of individual inventors point to the importance of systematic searches for both problems and potential solutions in the invention process. Systematic searches of problems almost automatically lead to specialization in order to be efficient. The problems may be acquired from journals or patent statistics while the solutions may come from scientific findings communicated through journals or a highly skilled staff assigned to keep track of scientific developments. In addition, historian of technology, Thomas P. Hughes, has stressed the ability to reason metaphorically, i.e. to understand the similarities that are necessary to take into account and the dissimilarities that can be ignored.[26] A feature making the individual inventor more inclined to radical or independent inventions in comparison to larger organizations with a large number of employees which typically have routinized the innovation process, is the lack of restricting hierarchies directing inventive thinking to certain well-known problems promising high profits for a patented solution.[27]

Another idea that has been presented as a common feature among successful individual inventors is their exclusive combination of knowledge in one specific field that proves to hold some interesting clues to the solution of an important problem in another field. Many individual inventors testify of the efficiency of such an advantage. For example, the Wright brothers used their experience as bicycle mechanics and constructors in order to solve the problems of steering airplanes.[28] Another example comes from the development of plastics. The inventor of bakelite, the chemist Leo Baekeland, had learnt of the key problems, problem-solving methods, goals, theories and tacit knowledge of a so-called technological frame, i.e. a set of the issues and knowledge in common for a relevant social group and structuring the interactions between the individuals of that group.[29] When he then equipped with one

[23]Ibid., 211-212.
[24]Ibid., 216.
[25]For a view of Marx as a neo-classical thinker, see: Nathan Rosenberg, "Marx as a student of technology", in: *Inside the Black Box: Technology and Economics* (Cambridge, Mass., 1982), 34-51.
[26]Thomas P. Hughes, "How Did the Heroic Inventors Do It?", *American Heritage of Invention and Technology* 1:2 (1985), 18-25.
[27]William J. Baumol, *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism*, (Princeton, 2002).
[28]Tom D. Crouch, "Why Wilbur and Orville? Some Thoughts on the Wright Brothers and the Process of Invention", in: *Inventive Minds: Creativity in Technology*, 80-92.
[29]Wiebe E. Bijker, *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (Cambridge, Mass., 1995), 141.

technological frame became a member of another relevant social group connected to another technological frame, it turned out that his experiences could be used in order to solve problems of the new technological frame using insights he had already acquired elsewhere. The same type of ideas have also been proposed to be valid on a cognitive level where the ability to invent to some extent also depends on genetic inheritance.[30]

A more general approach to the same type of idea has been adopted by the social psychologist Johan Asplund. But instead of claiming that inventions of solutions to problems appear in the minds of individuals with experience from different frames or fields, he claims that problem-solving always takes place in the interaction between people.[31] This thought is not original and appears in many different contexts. Inventions emerge when individuals combine their insights from different frames regardless of if the combination appears within the mind of one individual who has been able to collect experiences itself or in the interaction between several individuals with different, but complimentary experiences. On a larger scale, the same ideas appear when inventive cultures or civilizations are discussed below.

In addition to these ideas regarding individuals' abilities to invent, there is a vast number of psychological theories of how the mind can be set to generate new ideas.[32] One pick of these ideas may include Edward de Bono's claim that creativity stems from the ability to recognize patterns and arguing for lateral thinking in order to boost creativity.[33] Other usually include the importance for the individual to depart from a challenge or a problem, to document the ideas that pop up, to work on ideas that are within the realm of one's competence etc.[34] Yet another set of theories come in the form of tool kits with specific strategies for the individual or the organization that wants to be innovative.[35] These have in common the insight that innovative activities can be systematized on an individual or organizational level.

Just as theories of individual inventors tend to list desirable personal qualities or working methods common among successful inventors, theories regarding innovative organizations tend to list corresponding features among firms and other types of organizations. Such features may include specialization, professionalism, knowledge resources etc. as shown in an analysis of determinants for organizational innovation.[36] Although organizational innovation was defined differently here, as adoption rather than production of innovations, the determinants analyzed are similar to those usually mentioned in studies of organizational production of innovation.[37] In addition to the sheer listing of determinants, conclusions regarding organizational innovation may also include observations determinants' different importance in different types of organization or for different types of innovation.

For the purposes here, though, it is enough to note that all the determinants analyzed can usually only be decided upon internally within the firm, for example through recruiting policies, decision-making processes, external relations etc. Of course, this does not prevent

[30]C. Scott Findlay & Charles J. Lumsden, "The Creative Mind: Toward an evolutionary theory of discovery and innovation", *Journal of Social and Biological Systems* 11 (1988), 3-55.
[31]Johan Asplund, *Genom huvudet: Problemlösningens socialpsykologi* (Göteborg, 2002).
[32]A popular example is: Mihaly Csikszentmihalyi, *Flow: The Psychology of Optimal Experience* (New York, 1990).
[33]Edward de Bono, *Lateral Thinking: Creativity Step By Step* (New York, 1970).
[34]See for example: Robert Epstein, "Generativity theory and creativity", in: *Theories of creativity*, eds., M. A. Runco and R. S. Albert, (Newbury Park, CA, 1990), 116-140.
[35]See for example: Peter F: Drucker, "The Discipline of Innovation"; *Harvard Business Review* 81 (August 2002); Jacob Goldberg et al., "Finding Your Innovation Sweet Spot", *Harvard Business Review* 82 (March 2003), 120-129.
[36]Fariborz Damanpour, "Organizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators", *The Academy of Management Journal* 34:3 (September 1991), 555-590.
[37]See: Joe Tidd, John Bessant & Keith Pavitt, *Managing Innovation: Integrating Technological, Market and Organizational Change*, 2nd ed. (New York, 2001), 49.

firms in different industrial sectors to have different principal activities and thus different technological specialties, which in turn affects how they innovate.[38] However, the strong trend towards internally decided determinants within research on organizational innovation makes the theories in this field similar to those of individual invention where the determinants listed as having positive influence on the capacity to invent are created and implemented by the individual exclusively, irrespective of if the positive traits are inherited genetically or picked up and applied in the course of life, an issue that is seldom addressed in these theories at all. In this sense, both theories of individual inventors and theories regarding innovative organizations are internalist in relation to their respective object.

Another similarity between theories of individual inventors and theories regarding innovative organizations is the focus on the individual and organizational qualities that promote rather than prevent innovation. In the analysis of determinants for organizational innovation mentioned above, ten out of thirteen determinants were considered positive for the ability to innovate or adopt innovations in an organization.[39] When considering theories of individual inventors, the stress on positive qualities is even stronger.

In conclusion, theories regarding individual inventors and their prerequisite as well as theories regarding organizational innovation tend to list desirable qualities of the respective object: Systematic, specialized, ability to reason metaphorically, experience from different technological frames, ability to recognize patterns etc. etc. when it comes to individuals; Specialization, professionalism, functional differentiation, slack resources etc. etc. when it comes to organizations. In addition, these theories tend to leave out features of the individual's or organizations' characteristics that restrict creativity and instead tend to stress features that promote it, although they are almost always viewed as neither necessary, nor sufficient in order for the individual or organization to actually be so creative that it results in inventions or innovations. In this simple sense, theories of individual and organizational creativity tend to be constructive rather than restrictive. Taken together, the theories regarding individual and organizational production and handling of novelties tend to list correlations between specific internally chosen determinants and other entities such as organizational type or innovation type rather than external conditions. To sum up, theories within these fields seem to aim at supplying successful routines for innovation management more than anything else.

IV. Social and technological environments

Apart from these ideas, there is a considerable lack of theories of invention that depart from the individual inventor. In comparison, it is far more common to take the environment as point of view when analyzing necessary and even sufficient conditions for inventive activities. A historian who has stressed the existing technological level as the most important environment when analyzing new ones is Lewis Mumford. More specifically, he has discussed how dominating construction materials have limited the possible alternatives for technicians of different times. His periodization of Western culture into an eotechnical era, dominated by natural materials such as wood, fibers etc, in a paleotechnical era, dominated by metals, and a neotechnical era, dominated by composites and combinations of materials, have become a classic among historians of technology.[40] In order to explain invention, however, Mumford becomes less original and for the eotechnical era, he insists that existing technologies and knowledge production were important generators for new technologies, while consumption of

[38]K. Pavitt, M. Robson & J. Townsend, "Technological Accumulation, Diversification and Organisation in UK Companies, 1945-1983", *Management Science* 35 (1989), 81-99.
[39]Damanpour, "Organizational Innovation".
[40]Lewis Mumford, *Technics and Civilization* (1934). See also: Leo Marx & Roe Smith, eds., *Does Technology Drive History?* (1994).

luxuries among the wealthy laid the foundations for markets and demand when it spread to other layers of society. Hardly a very original thought in the shadow of Karl Marx and Werner Sombart.

Environments can be of very many different kinds. Most common are of course the market environment, i.e. those relations that can be used in order to answer questions like: What do consumers and other potential buyers want, how much are they willing to pay for it and how much will it cost to invent, innovate and sell it? Parameters like these may be said to constitute the economic environment.

Departing from the economic environment, others such as economic historian Nathan Rosenberg, have tried to develop concepts that more specifically point out certain features of the economic environment such as the existing technologies and its institutions. In reaction to attempts to establish theories in which scientific and technological change were entirely endogenous to economic forces, he stressed their exogenous character.[41] To some extent, scientific and technological changes are endogenous to economic factors, not the least in a world where new technologies and scientific results to a large degree depend on material resources such as laboratory equipment. On the other hand, Rosenberg argues, economic demand does not entirely decide what knowledge is acquired and what is not. There is an independent and non-negligible supply-side of science and technology changing along lines determined by other factors than economic that "imposes significant constraints or presents unique opportunities which materially shape the direction and the timing of the inventive process".[42] His conclusion is that the cost of invention is different in different industries, but that it in general declines progressively since science and technology are cumulative entities.

These ideas led to the introduction of the concept of path-dependency.[43] Technological change is path-dependent in the sense that inventions are produced in a historical context that severely limits the alternatives available for solving a specific problem or developing an idea for any other reason, no matter how strong the (market) incentives may be. The emergence of an invention can only be understood through an analysis of existing pool of knowledge, its possibilities and its limitations. From this perspective, existing technologies to a large extent determine what will come, both in defining the problems that are to be solved and supplying the solutions possible. It is hardly bold to conclude that the concept of path-dependency works well when trying to explain the dynamics behind conservative inventions, but usually is less satisfactory when explaining inventions that can be called radical.

Another strain of thought developed from the insight that existing (scientific) knowledge is a crucial component for expanding the restrains on invention is the so-called linear model.[44] The general idea that empirically based and systematically produced knowledge as well as confirmed theories can be used to further technological change as well as for example finding resources is old and have roots in the early seventeenth century. However, the more specific linear model of how scientific knowledge could be exploited orderly in steps to produce

[41] Nathan Rosenberg, "Science, Invention and Economic Growth", *The Economic Journal* 84 (March 1974), 90-108.
[42] Ibid., 95.
[43] Paul A. David, "Path-Dependence: Putting the Past Into the Future of Economics" (1988).
[44] Keith Pavitt, "Academic Research, Technical Change and Government Policy", i: *Science in the Twentieth Century*, eds., John Krige & Dominique Pestre (Amsterdam, 1997), 143-158. A critical discussion of the concept is given in: David Edgerton, "`The linear model´ Did not Exist: Reflections on the History and Historiography of Science and Research in Industry in the Twentieth Century", in: *The Science-Industry Nexus: History, Policy, Implications*, eds., Karl Grandin, Nina Wormbs & Sven Widmalm, Nobel Symposium 123 (Sagamore Beach, MA, 2004), 31-57; David A. Hounshell, "Industrial Reesearch: Commentary", in: *The Science-Industry Nexus: History, Policy, Implications*, eds., Karl Grandin, Nina Wormbs & Sven Widmalm, Nobel Symposium 123 (Sagamore Beach, MA, 2004), 59-65.

inventions and later innovations was developed in the wake of World War II and the construction of the atomic bombs where masses of scientists were involved in producing the knowledge necessary in order to build the bombs. Behind the linear model was usually the view that scientific knowledge constituted a pool of knowledge which could used, or applied, for inventions at will. The larger the pool of scientific knowledge, the better the possibilities to develop new technologies. This conclusion has more or less explicitly been the strongest argument for large-scale funding of basic research, i.e. research conducted without an aim to solve specific problems, throughout modernity.

One more specific feature of existing technologies that, in combination with market forces, may create enormous pressure for inventive activities is what Hughes name reverse salients and Hirschman denote bottlenecks.[45] No matter how the idea is labeled, the common denominator is the notion of a crucial problem that, if solved, will generate profit with high certainty. Hughes points out that technology always exists in relations to other technologies in systems that only work as well as its weakest link. If a link of a system seems to functionally lag behind other parts, there will be very high (demand-driven) incentives to improve or replace it with something that continues to match the output of other parts of the system.

This neo-classical idea, however simple, almost automatically leads to the notion of the invention as something closely dependent on what other technological solutions there are present. In fact, from this perspective, existing technologies in general and weak links, or dysfunctions of different kinds, of technological systems in particular, can be said to define what is to be viewed as an invention. This is especially true in a time and culture as our own when almost the whole world is defined and controlled through technologies.[46] In this sense, inventions are in effect new ways to increase human control.

More specifically, innovations may be viewed as supplying new and more alternatives for action such as increasing the possibilities for inventions as well as other human endeavours like finding natural resources. From this perspective, environment supplies humans with a possibility space to act in and the more human controlled technologies that occupy the possibility space, the better are the conditions for invention and innovation. Thus innovation leads to better possibilities for new innovations in a positive feedback process. But the notion of possibility space may also be made more complex by observing it from the individual's perspective. From this angle, it may often seem to shrink rather than expand in high-tech society due to spill-over effects of new technologies:

> Business economists [---] have failed to observe that as the carpet of 'increased choice' is being unrolled before us by the foot, it is simultaneously being rolled up behind us by the yard. We are compelled willy-nilly to move into the future that commerce and technology fashion for us without appeal and without redress. In all that contributes in trivial ways to his ultimate satisfaction, the things at which modern business excels, new models of cars and transistors, prepared foodstuffs and plastic *objets d'art*, electric tooth-brushes and an increasing range of push-button gadgets, man has ample choice. In all that destroys his enjoyment of life, he has none. The environment about him can grow ugly, his ears assailed with impunity, and smoke and fuel gases exhaled over his person. He may be in circumstances that he will never enjoy a night's rest at home without planes shrieking overhead. Whether he is indifferent to such an invasion of his privacy, whether he suffers it stoically or painfully, whether he is resigned or furious, there is under the present dispensation practically nothing he can do about it.[47]

[45]"Thomas P. Hughes, "The Dynamics of Technological Change: Salients, Critical Problems, and Industrial Revolutions", in: *Technology and Enterprise in a Historical Perspective*, eds., Giovanni Dosi, Renato Gianetti & Pier Angelo Toninelli (Oxford, 1992), 97-118; Albert O. Hirschman, *The strategy of economic development* (1958) or *Developments Projects Observed* (1968).
[46]Jacques Ellul, *The Technological Society*, Fr. original 1954, (London, 1965).
[47]E. J. Mishan, *Growth: The Price We Pay* (London, 1969), 52.

Note that the limits of alternatives (or the practical possibility space) discussed by E.J. Mishan in the quotation above does not depend on exogenous science and technology as when discussed by Rosenberg and Mumford, but instead are accounted for (implicitly) by institutional factors surrounding technology. In this sense, science and technology may act as suppliers of (an expanding?) possibility space and institutional factors as a restrain on it.

Another type of environment that has generated ideas of driving forces behind inventions is the external world. Best known among these is perhaps historian Arnold Toynbee who has assumed that inventions, or at least cultural change, was furthered by migrating humans of came into contact with new physical and ecological environments.[48] Rather than migration and encounters with unaccustomed physical and ecological environments, other broader theories of inventive activity on a cultural level stress the contact between different civilizations.[49] This idea, however, is not altogether different from the notion of technological frames discussed in connection to theories of individual invention above. The concept of frames stressed the inventive advantage for individuals combining knowledge in one specific field that proves to hold some interesting clues to the solution of an important problem in another field. It is perhaps these types of processes that become more frequent on a micro-level when by migrating humans come in contact with new physical and ecological environments.

But there are more elaborate ideas of how and why existing technologies generate inventions. Within the framework of the so called Actor-Network Theory, it is stressed how inventions need engagement from different actors such as individuals and organizations and even artifacts named actants, that can't speak for themselves and therefore need spokespersons in order to be realized.[50] The actors and actants are engaged in networks that can be either global or local. For the realization of an invention, however, it is crucial that there exists an obligatory point of passage between the networks, a point through which the resources that are obtained in the global network can be put to use by the local network. These resources can be anything from a market demand to scientific or engineering theories supporting the function of a specific device. The more resources that can be mobilized, the better are the possibilities to go from idea to invention. In the end, success is depending on the engagement that can be mobilized.[51]

On the other end of the spectrum are theories and models not taking technologies or externalities into account at all. The notion of collective invention for instance departs from the observation that invention takes place in non-profit institutions such as universities, profit-seeking firms and the mind of individual inventors. But, the proponents of the model hypothesize, a collection of agents may produce collective inventions characterized by exchange and free circulation of knowledge and information among themselves creating positive feedback allowing for high innovation rates and fast knowledge accumulation.[52]

Apart from the importance of the social and technological environments for the invention of new technologies, the Danish economist Ester Boserup has stressed the demographic environment when analyzing new technologies of agriculture. She claims that new methods and technologies for growing provisions are invented only under pressure of lacking resources which occur when the population grows to such an extent that existing methods and technologies does not suffice to supply the food needed using the land at hand. New and more efficient methods and technologies are developed, i.e. invented, in order to balance food supply with the rising need on a limited area of land. The novelties occurs at the cost of

[48] Arnold J. Toynbee, *A Study of History* (1934-61).
[49] William H. McNeill, *The Rise of the West: A History of the Human Community* (Chicago, 1963).
[50] Bruno Latour, *Science in Action* (1987).
[51] Bruno Latour, *Aramis or the Love of Technology* (1996).
[52] R. Cowan & N. Jonard, "The dynamics of collective invention", *Journal of Economic Behavior & Organization* 52 (2003), 513-532.

intensified farming in terms of higher productivity per land unit, which also implies lower productivity per labour hour. Therefore, knowledge of how to increase production is a necessary, but not sufficient condition for the introduction of new farming technologies. In addition to knowledge, demographic pressure leading to lack of food is also necessary for the introduction of new inventions.[53]

Boserup is unique in the sense that she does not view the possibility to invent as a sufficient condition for presenting new technologies. In addition, she claims the need of an imperative force in order to have changes in agricultural methods, namely demographic pressure. This is very different from the ideas of Rosenberg, Hughes and others who claim that the (economic) incentives for invention created by for instance reverse salients in a sociotechnical system are so overwhelming—although not sufficient—that no extra imperative force is necessary in order to explain invention. With one exception, all theories handled in the paragraphs above view inventions primarily as solutions to problems whether they are of technical, social, demographical or any other type. The exception is Actor-Network Theory where it is more often claimed that the problem is created as a resource after there is an idea of an invention. Finding a problem which the invention may solve creates another argument and engages more resources for its realization.

V. Economic and institutional environments

It is quite common to stress the institutional conditions for inventive activities. A generally accepted idea is that market conditions, in other words competition between inventions, with its inherent profit motives almost guarantees new inventions. In this system of thoughts, where demand generates powerful economic incentives for the development of new technologies, whether it is presented as a solution to a problem or not, are usually summed up under the concept of neo-classical economic theory. The basic notion is that if there is a strong demand for some useful still non-existing technology, a market situation is an efficient way to realize it. And if the technology fails to emerge, it can always be explained with too high costs of invention.

A time machine for instance, has a very high market potential on the demand-side. Still, the potential on the supply-side seems so low that few realistic risk capitalists are willing to invest even the smallest amount in such a project regardless of the enormous incomes it is likely to generate, should it be realized. Of course, the same type of considerations is valid for "space tourism", which over the past years, although expensive, has become a more realistic product than time machines. Thus, demand—whether it solves a problem of such a scale that the invention is likely to sell itself or put on the market padded with commercials—is a necessary but not sufficient condition for the realization of an invention in neo-classical economic theory.

An often used metaphor for the free-market economy stipulated by neo-classic theory is that of natural selection. Here, the inherent logic of technological change is illustrated by genetic variation whereas the mechanisms of decision made on a market as well as the institutions surrounding it corresponds to selection pressure exercised by the environment in natural selection.[54] Note that this notion of selection as a metaphor is somewhat different although not unrelated to the evolutionary economic theories described above. The most important difference is that the firm may adjust their fitness (profitability) consciously and according to carefully planned strategies and tactics in evolutionary economic theories while the selection pressure of market decisions acts blindly on genetic variation in the simpler version of the

[53] Ester Boserup, *The conditions of agricultural growth* (1965).
[54] Harvey Brooks, "Technology, Evolution and Pupose", *Dædalus* 109:1 (Winter 1980), 65-81.

metaphor described here. This simple version of the metaphor can be equaled to a situation where technologies are continuously tried in an existing environment and the one that on the whole is most efficient for the time being is adopted until the environment is changed to favour some other technology or new alternatives emerge that prove more efficient again.

This simple metaphor can of course be developed further and there numerous attempts to be sure. One of the more successful has been innovation researcher Maureen McKelvey's attempt to complicate matters by differentiating between science and technology as activities as well as government and market as institutional sources for seeking new knowledge.[55] In her co-evolutionary model, new knowledge drives the emergence of technological alternatives, while the selection among alternatives is a social process that does not necessarily lead to maximized profitability. Thus, scientific and economic environments have different criteria for what is to be considered incentives, success etc.

Another theory of invention stressing the demand rather than the supply is one presented by economist J.R. Hicks in the early 1930s to be further debated in the 40s and 50s.[56] To simplify more than perhaps is fair, the foundation of the theory is that labor saving inventions predominate because labor bulks so large a cost in business operation.[57] Thus, again demand has the strength to determine the general tendency in inventive activities.

In contrast to neo-classic theory, the American economist Jacob Schmookler has claimed that the relation between supply and demand in effect is opposite.[58] According to Schmookler, the primary driving force behind inventions is the use of accumulated knowledge, which he claims to be knowledge produced due to past demand, as well as present demand for additional knowledge.[59] A transformation, however, has occurred in that new scientific knowledge primarily is demanded in the form of capital goods rather than consumer goods. Schmookler's conclusion is that "the growth of modern science and engineering is still primarily a part of the economic process."[60] Thus demand drives technical change.

In more recently developed endogenous models, the claims has been somewhat weakened to statements about market incentives playing "an essential role in the process whereby new knowledge is translated into goods with practical value".[61] Here, it is also room for scientific research carried out without motives of rent seeking although the value of research always is created through endogenous processes. It seems that some inventions, those that come in the form of important scientific discoveries later to be exploited, aren't as endogenous as others. In fact, they seem to be altogether exogenous.

A further development of these ideas is presented by economist William J. Baumol, who correctly differs between invention and innovation and claims that innovation, rather than invention, creates economic growth.[62] He further observes that economic growth of the present capitalist economic system lacks historical parallels, which to large extent depends on its mechanisms for furthering both revolutionary new ideas that tend to appear among independent innovators and routinized innovation in large oligopolistic firms where entrepreneurial activities have been exhanged for managerial ones. This shift is due to the

[55]Maureen McKelvey, *Evolutionary innovations: The Business of Biotechnology* (Oxford, 1996), 26-36.
[56]J.R. Hicks, *The Theory of Wages* (London, 1932).
[57]Gordon F. Bloom, "A Note on Hick's Theory of Invention", *The American Economic Review* 36:1 (March, 1946), 83-96.
[58]Jacob Schmookler, *Invention and Economic Growth* (Cambridge, Mass., 1966).
[59]Ibid., 175-177.
[60]Ibid., 177.
[61]Paul M. Romer, "Endogenous Technological Change", *The Journal of Political Economy* 98:5 (October 1990), S71-S102.
[62]William J. Baumol, *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism*, (Princeton, 2002).

insight that innovation costs are principally an investment no different from investments in productions sites. The only difference is the higher risks involved in innovation investments.

One other important feature developed by Baumol is how innovations create new innovations in a feedback process to a large extent built upon the notion of innovations enlarging a possibility space recounted above. Most importantly, capitalism, according to Baumol, rely on legal institutions securing private ownership and the responsibilities implicated be signing contracts. Together, they constitute a foundation for oligopolistic competition with innovation rather than price as the primary weapon. This situation is explained by the high entry and exit costs for firms wishing to compete on these markets. In this way, the mechanisms behind dynamics of industrial sectors producing consumer goods are becoming similar to those of industrial sectors producing capital goods, especially the military. Here, for a long time, the efficiency of products have been more important than costs. In extension, the result has been a routinization of innovation.

Regardless of the economic factors analyzed are viewed as forces generating problems and thus demand, as Hicks does, or generating resources and thus supply in specific strategic fields of knowledge, as Schmookler does, the above theories view economic factors as central in a theory of invention. But there are also a number of theories where are institutional factors very different from economic profit are seen as essential. More specifically, there are a number of theories regarding the institutional environments of technological change.

The perhaps most straightforward and general in its approach is denoted “the social construction of technology” (SCOT) in order to stress the importance of relevant social groups over science and technology in the production of inventions and innovations. The theory does not stress supply, nor demand. Both sides are viewed as made up of relevant social groups with different abilities to influence technological change including the production and diffusion of inventions and innovations. An invention with support in relevant social groups powerful enough will be recognized and spread.[63]

Such a model of technological change is rather simplistic, perhaps even banal. In a straightforward sense, technology is obviously socially constructed. What else could it be? But with some more controversial addendums, these ideas can very easily be transformed into much hotter material. The most debated such addition is the assumption that scientific results as well as the world external to humanity are endogenous to social forces and relevant social groups which are able to employ these just as any other resource in their strive to promote certain designs over others. With this assumption, we are back to the often used metaphor of science and technology as a putty clay that can be modeled at will and without constraints, a notion that was born in the debate over science and technology as endogenous to economic factors.

Another concept mirroring institutional forces behind invention and innovation different from economic factors are technopolitical regimes.[64] Under technopolitical regimes, inventions may be driven by a strive for satisfying some culturally defined demand valued in the regime, for example an internationally unique solution to how nuclear power can be exploited in order to produce both electricity and plutonium for weapons. The main point is that concepts such as efficiency and functionality are extremely context-dependent. Time after time, it becomes clear how socially and culturally conditioned demand decides which inventions and innovations are created and realized although calculated and economically motivated demand

[63]Wiebe E. Bijker, Thomas P. Hughes & Trevor Pinch, eds., *The Social Construction of Technological Systems* (Cambridge, Mass., 1989); Wiebe E. Bijker & John Law, eds., *Shaping Technology/ Building Society: Studies in Sociotechnical Change* (Cambridge, Mass., 1992).
[64]Gabrielle Hecht, *The Radiance of France* (1998).

points in other directions. Functionality of an invention does not necessarily have anything to do with consumer demand or market decisions. Instead, group identity or trust may be just as important.

Another theoretical approach to inventions and innovations is the notion of systems of innovation. Systems of innovation come in different shapes and are most commonly defined by geographical scope or industrial branch. Thus are usually national, regional or sectorial. But no matter of attribute, this is in essence an institutional perspective on innovations stressing both the interdependence between different actors involved in innovation activities such as firms, individuals, public authorities, special interest groups etc. and the fact that inventions and perhaps also innovations more often than not emerge in the intersection between different organizations and fields of knowledge.[65] In order to understand why some inventions become innovations, it is necessary to map and analyze the relations between different organizations as well as the legal, social and economic institutions that guide their exchanges and actions such as cooperation or competition. It should perhaps be added that these ideas most effectively describe invention and innovation of capital goods, where it is often essential for a producer to cooperate closely with a customer, often a state agency.

Another concept used in order to illustrate the importance of institutional and networks as conditions for invention and innovation is development blocks. A development block is the factors linked to a specific industrial activity. The growth of a development block depends on the complementary investments made in other fields related to it. As a result, imbalances and structural tensions may appear within the development block, which may cause further changes and invention activities. Imbalances may arise for different reasons, either by market signals through a drive for efficiency or by changes in network relations between firms and other organizations. They may be the result of activities within a single firm or of cooperation between a number of actors.[66] The key point is that imbalances may cause both depression and expansion depending on their type.

VI. Historical trends

So far, different explanations of innovations and inventions have been reviewed. In order to bring the different pieces together, it is necessary to also shortly account for the different ideas of dynamics of inventions and innovations. Firstly, it is clear that most theories assume the process from invention over innovation to implementation as gradually involving more and more people. Inventions tend to be the result of creative acts of individuals while innovation is a co-operative group action and market implementation something that includes even more people.[67] On another time-scale, it has been suggested that the emergence of new technology on new markets follow another pattern starting with disruptive (or radical) innovations that make existing competence obsolete and disruptive market relations creating new links between producers and buyers. In this early phase, innovation is dominated by push on the supply-side, whether based on scientific knowledge or other forms of skills that still is out of demand. After the establishment of innovation and market, new products can either be developed using existing technologies in order to establish new market relations or using disruptive technologies for already enrolled buyers. In the last phase, regular innovations are introduced

[65] Bengt-Åke Lundvall, ed., *National Systems of Innovation: Towards a theory of innovation and interactive learning* (London, 1992); Charles Edquist, ed., *Systems of Innovation: Technologies, institutions and organizations* (London, 1997).
[66] Håkan Lindgren, ed., *Economic Dynamism*, Stockholm Businees School, Institutet för ekonomiskhistorisk forskning, Research Report No 6 (Stockholm, 1996).
[67] S.W. Becker & T.L. Whistler, "The Innovative Organization: A selective view of current theory and research"; *Journal of Business* 40 (1967), 462-469.

on established markets.[68] Here, the demand-side has become more important than the know-how developed on the supply-side.

On a much larger time-scale, it is often assumed that inventions and innovations have gradually become more and more dependent on empirically based and systematically produced knowledge as well as confirmed theories. Simultaneously, it is often assumed that both inventions and innovations tend to involve more and more resources, both material and personal, in order to be successful. In the graph presented in the introduction above, this reasoning would implicate a trend from the above left corner towards the lower right corner.

This reasoning can be combined with the discussion of technical change as an endogenous or exogenous process. In this context, many scholars have pointed out that due to its cumulative nature, new scientific knowledge tends to be generated more adequately with regard to inventions and innovations, an indication, it seems, that scientific knowledge is endogenous. Simultaneously though, arguments based on the cumulative character of science and technology usually supports the linear model where research is viewed as the primary engine behind technical change. Such reasoning also implies that important parts of knowledge production indeed is exogenous. Often, the escape route out of this conundrum is a co-evolutionary conclusion regarding the relation between knowledge production and invention.

But since scientific knowledge also can be viewed as non-cumulative, an alternative interpretation could be that knowledge seem to be more closely related to invention and innovation processes for other reasons than functional, for instance ideological. If an invention, for instance, can be supported by scientific findings, it seems to constitute a stronger argument for its furthering over time than if it can't regardless of if that knowledge has any practical use in the process or not. Such reasoning, on the other hand, can easily be viewed as arguments for knowledge production as endogenous, at least in those cases where the invention is assigned economic value. The closer the relations, causal or other, are between knowledge production and inventive activities and the more often these inventions with close relations to knowledge production have economic value, the more reasonable endogenous models appear. But the issue cannot be finally resolved as long as the relation between scientific knowledge and inventions as well as their economic value remain unspecified.

What complicates the issue considerably is that it seems as if radical inventions with high economic potential tend to be produced in closer relation to scientific knowledge that only to a smaller degree relies on the cumulative character of science and thus tend to be of a more exogenous kind (not emerging in relation to economic activities), while scientific knowledge underpinning conservative inventions with lower (incremental) economic potential seems to be cumulative to a larger degree and thus less exogenous. This is the reason the debate over technical change as endogenous or exogenous cannot be resolved. In addition, if we assume, as for instance Hughes and Baumol do, that radical inventions tend to be produced by individuals or small groups outside of larger organizations, the trend towards inventions and innovations more commonly produced within larger oligopolistic firms or other resourceful organizations would also imply that radical innovations are becoming scarcer relative to conservative ones while at the same time retaining their importance for economic growth. Hence, each and every radical (exogenous) invention becomes more economically important over time.

Another distinction that is fruitful in this context is that between capital goods and consumer goods defined in the introduction according to the level of expertise needed to use the product in question. With this definition in mind, the markets for capital goods and consumer goods

[68]Vivien Walsh, “Invention and innovation in the chemical industry: Demand-pull or discovery-push?”, *Research Policy* 13 (1984), 211-234; William J. Abernathy & Kim B. Clark, “Innovation: Mapping the winds of creative destruction”, *Research Policy* 14 (1985), 3-22.

are likely to be very different. The market for consumer goods, assuming regular capitalistic institutions, would tend to be best characterized by competition between suppliers, whether with innovation or price, while the market for capitalist goods would tend to be best characterized by cooperation between suppliers and end-users and perhaps even with some cooperation between suppliers.[69]

It is clear that exogenous factors such as ideological preferences or beliefs play a more important role in the latter types of markets than in the former, not least since some of the markets, for instance the one for military capital goods, are rather price insensitive. In addition, capital goods have historically been more science-dense than consumer goods although the gap is closing to such an extent that the concept of consumer capital goods has been introduced. Still, if science has closer relations to the invention and innovation of capital goods, new knowledge is to a lesser degree endogenous. From this perspective, a research intensified development process of consumer goods would imply an endogenous trend for the production of new knowledge. Again, however, the trends are far from clear. For instance, the observation of an intensification of research in the development processes of consumer goods may well follow from more efficient channels for applying knowledge and technology developed in capital goods sectors such as the market for military equipment.[70] If so, the research intensification of consumer goods sectors is more characterized by fitting existing knowledge for slightly different purposes rather than producing new knowledge. In fact, Baumol’s observation that innovation rather than price has become the primary weapon on some consumer goods markets may well be an indication of such a process. If so, production of new knowledge as well as exploitable inventions are to a larger degree exogenously produced by suppliers cooperating with end-users on capitalist goods markets with access to rather large resources. Hence, on a structural level, social environments as well as resources no doubt are the most important factors behind new stuff. That is how it comes about according to existing theories of invention and innovation.

[69]To characterize the relations between suppliers and users on capitalist goods markets, the concept of development pairs has been introduced, see: Mats Fridlund, *Den gemensamma utvecklingen: Staten, storföretagen och samarbetet kring den svenska elkrafttekniken* (Stockholm, 1999).
[70]William J. Baumol, *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism,* (Princeton, 2002).