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Society, Technology, Product, and Responsibility: A Dynamic Feedback Systems Perspective

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Abstract: This paper briefly reviews prior research on the relationship between technology and society which has shown there are reciprocal influences between scientific and technological areas and political, economic, and cultural fields. This paper shows how the choice of different independent and dependent variables has influenced former scholarly works. The paper defines technique, technology, and technological capital, and argues that we should differentiate products from technological capital accumulated in a society. Products are made by mobilizing social resources and organizing the structure of social relations in a manner that is required for their production. Their production is also made possible by resource allocations for accumulation and utilization of certain technological capital. There can be specific intentions inscribed in products and technologies; however, they can have disruptive consequences. Technological capitals—and products made using them—are organic parts of the dynamic feedback structures of societies; therefore, they are among the state variables influencing the trajectory of same societies. Moreover, since societies are open systems, technological capitals and products can act as determinants for the trajectory of other societies and nature. This paper proposes a dynamic feedback model which examines the system of social processes that influence resource allocations, set priorities and constraints for universities and research institutes, and affect what we know and what we don't know. Social decisions on investments and resource mobilization for the production of a subset of possible products require certain social organizations and therefore, affect the society. The consequences of knowledge creation and production processes are new mixture of technological capital, organizations, and products. They simultaneously change the domain of possibilities for the decisions that are made in social processes. All of these variables—situated in a feedback system within a historical context—are influential on the social condition. The paper concludes that the inclusion of people and artifacts in our analysis should not distract us from noticing that non-human actors cannot be held morally responsible, and our decisions are the only variable that we may be able to change; therefore, for all the avoidable outcomes, the only factors that can be held accountable are humans.

Keywords: Technological Capital, Dynamic Feedback Social System, Responsibility

Introduction

Scholars have been intrigued by the dynamics of the interrelationship between our social situation and our technological progress. To understand the changing world we live in, to be active participants rather than passive subjects of these changes, and to comprehend the forces behind technological and social changes, we need to understand this reciprocal relationship. This paper is an attempt in the direction of developing models that can be used to predict how technological and social changes can lead to a better world.

Some researchers have emphasized technological change as the explanatory or determining variable for creation of new products; while others have emphasized the role of the society in shaping the technologies used in the production of artifacts. Some have tried to classify research projects with labels such as technological determinist and social constructivist, but this paper will show that these classifications are ambiguous and not productive. The feedback systemic approach which is suggested here renders such dichotomies unnecessary.

This paper briefly reviews some of the major prior research on the relationship between technology and society. Informed by these prior studies, it explains how scientific theories, technological capital, and products, change the domain of possibilities for the decisions that are made by social influences. The paper argues that all of them, situated in a dynamic feedback system within a historical context, are among the state variables[1] of the social outcomes.

[1] State variables are variables that are used to describe the situation, future behavior, and direction of a dynamical system. (Palm , 2010, 225)

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Exploring the Social Construction of Technology

Sociology has made important contributions to our understanding of technology. An interesting inference from sociological investigations is that products are created within societies, and technologies are socially constructed.

Brey (1997) has explained social constructivism as the belief that technological change cannot be analyzed following a fixed, uni-directional path; and cannot be explained by reference to economic laws or some inner technological logic. Social constructivism holds that technological change is best explained by reference to a number of technological controversies, disagreements, and difficulties that involve different actors or relevant social groups. There are several different streams of constructivist thought. The first stream that Brey identifies is strong social constructivism, which avoids all reference to the actual character of technology. This approach includes social construction of technology (SCOT). Another stream is mild social constructivism, or “Social Shaping" approach. This approach distinguishes between the social, the natural, and the technical parameters. It does not reject a role for non-social factors, and is willing to attribute properties and effects to technologies through social biases or politics, "built into" or "embodied by" them. The approach which employs a principle of generalized symmetry is Actor Network Theory (ANT), according to which any element (social, natural, or technical), in a diverse network of entities participating in the stabilization of a technology, has a similar explanatory role (98-111). In ANT terminology these human and non-human entities are called actors.

The roots of social constructivism, in the study of technology, are in the sociology of scientific knowledge (SSK). Woolgar (1991) has explained that the goal of the SSK project was to increase the susceptibility of scientific knowledge to relativism. The aim of SSK was to bring science as one form of knowledge in line with others (43, 44). Although Woolgar was not an enthusiast of extending SSK to the study of technology, he believed that technology is far more easily susceptible to relativism than scientific knowledge (36). Inspired by SSK, social shaping of technology includes a group of studies that includes different streams such as economic shaping of technology, path dependence, SCOT, and ANT (MacKenzie & Wajcman, 1999).

According to Bijker (1995) while social constructivists promote symmetrical analysis of successes and failures (9), internalists argue that we can understand the development of a technology only if we start with an understanding of the technological details, while contextualists claim that the economic, social, political, and scientific context of a technology is as important to its development as are its technical design characteristics (9). Bijker has identified three lines of research; the first one, focuses on inventors as system builders, thus combines analysis of individual creative actors with descriptions of their systemic constructs and contexts. The second combines the history of technology with the insights of psychology to explore acts of individual creativity, and the third describes "individual genius" as the result of a series of attribution processes by which one person eventually wins all (10). Scientific and technological developments are subject to contingencies. This suggests that trial-and-error models have advantage over goal-oriented models of technological development; although, technological developments are structurally constrained (11-15). A successful engineer is not purely a technical wizard, but is an economic, political, and social one as well (15). Bijker has elaborated on "interpretative flexibility" (76), and has identified a closure process by which interpretative flexibility decreases (86) and the artifact reaches higher levels of stabilization (252). Bijker argues that machines "work" because they have been accepted by relevant social groups (270). Then asks a question: “Can relevant social groups fantasize whatever they want without constraints?” His answer is: “No, their fantasies are constrained to previous meaning attributions”(282). According to Bijker “Consumer behavior and product image may, under certain circumstances, turn out to be more important elements in the micro politics of power than patent agreements, smoothly running production plants, or economic ownership relations” (286).

Williams (2000) has proposed an interpretation that integrates intention in the process of research and development. He has reviewed the history of press, radio, cinema and television and explains how social conditions and the intentions to satisfy needs have been the driving force of the technological development (39).

According to Feenberg (2004) constructivism rejects the assumption that technologies succeed on purely functional grounds, and argues that theories and technologies are underdetermined by scientific and technical criteria; and therefore, there is a surplus of workable solutions to any given problem, and social actors make the final choice among a batch of technically viable options (212).

Winner (1993) has argued that social constructionist writing had an almost total disregard for the social consequences of technical choice based on the false assumption that the impacts of technology have already been studied (368). Brey (1997) has noted that some social constructivists took Winner's comments to heart; and consequently, ANT scholars paid more attention to the social results of technical choice in their studies of the inscription process. He has maintained that Winners' critique caused a change of momentum in strong social constructivism towards a more balanced direction. Subsequently, Latour (1994) proposed the actor network approach as one of the most powerful ways of resolving the technological determinism and social constructivism dichotomy in technology studies (151).

Informed by above-mentioned studies, this paper acknowledges that for a comprehensive understanding of the process of product development, considering the dynamic feedback between science and technology is essential. To understand the product development process the intentions of developers and investors cannot be neglected. To comprehend the product acceptance by the customers, it is important to note that using any technology, there are many products that can be made, and the role of relevant social groups in the closure process is crucial. This process, in fact occurs for a specific implementation of a technology, when it becomes a successful product. This product which is mass produced is later interpreted as the first in a category.

Factors Describing Observed Relationships between Technology and Society

There have been attempts to provide descriptions of the relationship between information and communication technologies (ICTs) and observations in contemporary society. For example, Bell (1976) has studied the shifts in the fabric of contemporary societies as a result of technological change. He has emphasized the determining role of technology. He has defined pre-industrial societies as those where the labor force is engaged in extractive industries like mining and fishing and forestry and agriculture, and the individuals are often seeking only enough to feed themselves. He sees industrial societies as goods-producing societies and post-industrial societies as those where the economy is based on services (126-128).

Beniger (1986) has claimed that the information society was created around the end of the 19th century as a result of needs in a social control system that had been moved from its equilibrium by industrialization. He has proposed looking at society as a processor with material and energy as its input, and goods and services as its output (32-33). Beniger has described how technology has enabled the society to move from a situation where more than 80% of people were involved in agriculture to a society where less than 10% are involved in it (23). He has identified cycles of technological progress, crises of social control, changes in social structures, needs of the new society, leading to another technological progress.

Leiss (1990) has identified three possible positions regarding the overall impact of modern technology on social change. One position emphasizes the beneficent aspects, another sees modern technology as a coercive force that penetrates and undermines social institutions, and the third position assumes that technology invokes only possibility but has no determinate ends or consequences (27-29).

Castells, Fernandez-Ardevol, Qiu, and Sey (2006) have described how mobile technology has been used as a tool to organize large demonstrations (193). Studying the text messages transmitted on mobile networks in a diverse set of countries, they have concluded that different context in which the messages circulate and their resonance with each person, the origin, and the political power embedded in wireless technology can describe the differences in mobilizing impact of mobile messages (211).

Some scholars emphasize that the positive outcomes from technological progress are not historical necessities. They also draw our attention to the fact that we have a choice of directing our technological progress and social organization in different directions. Feenberg (2002) has argued: "To the extent that we are able to plan and control technical development through various public processes and private choices, we have some control over our humanity" (18). His main argument is that an alternative system based on public participation in technological decisions, workers' control, and requalification of labor force is possible (12). He has proposed that we can open technological development to the influence of a wider range of values, which requires "broad democratic participation" (34).

Based on the work of the scholars discussed above we can conclude that, although the interpretations of researchers about development and consequences of technologies are different, we have many observations and evidences that indicate the impact of socially constructed technologies on society. In the next section we look at the theories proposed to explain this reciprocal relationship.

Explanations for the Impact of Technological Change in Society

According to Winner (1978), Karl Marx's conception of technical and social change was an aspect of his general theory of historical materialism. Marx's theory argued that people do not establish their conditions of life or their identities; their status depends on the material condition necessary for the mode of production extant in their times. Marx argued that the multitude of productive forces accessible to men determines the nature of their society, hence that the 'history of humanity' must be studied in relation to the history of industry and exchange (77-79). Since Marx, the works of a number of other scholars have been influenced by the belief that technological transformation has been and will probably continue to be a cause of change in our institutions, practices, and ideas. These scholars include Herman Kahn, Olaf Helmer, Raymond Bauer, Daniel Bell (Winner, 1978, 74-75), R.J. Forbes, Emmanuel G. Mesthene, John Kenneth Galbraith, Jacques Ellul (Leiss, 1990, 24), Innis, and McLuhan.

Winner (1978) has claimed that determining things is what technology is all about. If it were not determining, it would be of no use and of little interest. The first function of any technology is to give a definite, artificial form to a set of materials or to a specific activity (75). According to Winner another aspect of technological progress is the technological imperative. Technologies have conditions of operation, which demand the restructuring of their environments. There are certain things that need to take place before an instrument is in working order (100). Thus, according to him the idea of determinism is not one that ought to be rejected right away. The tendency to dismiss the entire issue places a taboo on important questions (77). Winner (1986) has argued that a certain set of consequences could be explained by the political attributes that are inscribed in the products when they are designed and built. He has maintained that technologies can have political attributes in the sense that they are invented, designed, or arranged to have a particular social effect. A given device can be designed and built in such a way that it produces a certain set of consequences. He also argues that certain technologies are inherently political technologies because their adoption requires the creation and maintenance of particular social conditions.

Williams (2000) has identified two classes of cause and effect theories in technology and society studies. One in which technology and its effects are accidental, which he has called technological determinism. The other in which technology is accidental but its uses are symptoms of other changes in society, which he called symptomatic technology (37, 38). Feenberg (2004) contends that technological determinism rests on the assumption that technologies have an autonomous functional logic that can be explained without reference to society. Technology is presumably social only through the purpose it serves. Technology would thus resemble science and mathematics by its intrinsic independence of the social world. Yet unlike science and mathematics, technology has immediate and powerful social impact. What technological determinism seems to mean is that: society's fate is at least partially dependent on a non-social factor without suffering a reciprocal influence (211).

Scholars have used different dependent and explanatory variables in their research on technology-society relationship. There are scholars who have looked at technology as a dependent variable in some of their research endeavors, and as an independent variable at other times. One example is Bell (1976) who has claimed that technology has shaped transformations in society by increasing production, reducing costs, revolutionizing transportation, and creating new social classes (189). Bell also believes that the post-industrial society is based on the centrality and primacy of theoretical knowledge as the source of innovation, policy formulation, planning and control of technology and technological assessment (14-29). It seems that Bell does not consider technology as being autonomous; he does not believe technological development is accidental, and he does not assume that its effects are unpredictable either.

"Technological determinist" may be a useful construct to classify a piece of scholarly work, it is not suitable for labeling scholars, since as we noticed above a scholar may identify different determinants in their different studies. Unfortunately, sometimes, as Winner (1993) has stated, technological determinism has become a conceptual straw man leading to neglecting the effects of one of the determinants (371).

The decisions made regarding the allocation of capital for technology development, and the process in which a particular product is selected by market mechanisms, such as investment, marketing and demand; lead to technologies which embody values. It is important to note that many of these decisions are not technological or scientific decisions. They are not all made based on scientific method. Consider the example of Pasteur whom Latour (1983) has studied. He was a creative scientist who had a theory about anthrax. In his labs in Paris and in a farm, he tested his theory up to a level that gave other scientists enough evidence to consider his theory a probable description about effects they had observed. Moreover, he was an innovator who developed not only the technologies to test his theory but also technologies that enabled the mass production of a product useful for his society and the world. He marketed his innovation to gain the support of all of the stakeholder forces and like a franchisor created a methodology and procedure to be used in a chain of laboratories. Pasteur has played many roles. Sometimes he was a scientist, sometimes an engineer and sometimes a businessman. Some of his decisions were made at his discretion, some were dictated by the society, and some were limited by the nature of anthrax. Scientists these days do not do all of the above tasks themselves, and therefore it should be even easier now to see the influence of different forces on different stages of a development.

As was noted above, scholars in science and technology studies have found that there are reciprocal influences between sciences and technologies on the one hand, and political, economic and cultural fields on the other hand. The difference between technological determinism and strong social constructivism seems to be their choice of independent and dependent variables in their studies. While technological determinism tends to consider technology as an independent variable shaping the social outcomes, social constructivism usually includes social factors as at least one of the determinants in a study. The social factor as an independent variable can be treated as the only explanatory variable as is in SSK and SCOT, or can be used with other explanatory variables like non-human actors in ANT. Scholars have used different approaches in their different writings during their life.

Some scholars, searching for sufficient causes, trace the observations in their causal chain to a scientific, technological, or social event. To claim temporal-linear sufficient causality, one of the requirements is that one should demonstrate that the cause happened before the effect. The introduction of any product and every technological progress can be traced back to a social change or societal decision. Every social transformation can be identified as appearing after the introduction of a product, or coinciding with a different set of technologies. Some scholars tend to stop their historical investigation at a technological change, and have emphasized the importance of such changes, while others tend to stop at a social transformation, and emphasize that. This decision, about when to stop, hints people to categorize particular research as being in the camp of technological determinism, or the stream of strong social constructivism.

On the one hand, the limitations of technological determinism – which could not adequately explain the stabilization, the closure, and the choice between possible outcomes – have led to a general tendency toward social constructivism. On the other hand, the inadequacies of the strong social constructivist approach, prohibiting natural or technical elements to be explanatory variables, have led to inclusive frameworks like ANT. The lack of precision, lack of novel predictions, utility, and testability will be the driving force behind the next shift where these approaches are reconciled in a more powerful methodology. Beniger (1986) attempted to look at the society from a different perspective when he has considered the social system as an organization that is bound together by a system of communication (38). He has proposed that society should be seen as a feedback control system defying the laws of entropy (8-10). This is the direction in which we will proceed. In the next section this paper will attempt to construct a model of the system that includes science, technology, products, people, public institutions and social structures.

A Model for Dynamic Feedback System of Societies and Technologies

According to Åström, K. J., & Murray, R. M. (2008) a dynamic system is a system whose behavior changes over time, and the term feedback refers to a situation in which dynamic systems are connected together such that each system influences the other and their dynamics are thus strongly coupled (1).

In the following sections we define a number of constructs, and identify the system elements. Then we propose process modeling as a suitable approach to understand technologies in societies. We introduce an open dynamic system composed of multiple feedback loops as model for the technology as an organic element in the society. At the end, we discuss some advantages and moral consequences of using the proposed model.

Necessary Constructs

While investigating the extent to which technologies are influenced by, or influence society, some researchers tend to use loosely defined words, when referring to broad areas of knowledge and to practitioners in those fields. As a result, the differences between areas of science and technology on the one hand, and products on the other hand are sometimes neglected and sweeping generalizations are made. We should note that "pure basic science", "use inspired basic science", applied science, natural science, social science, technology, technique, engineering, products and artifacts are all different constructs. Also we must not ignore the fact that scientists, engineers and technicians are humans who know sciences and technologies, and use them to produce products and artifacts. All of the above-mentioned areas of knowledge, fields of society, types of products, and groups of people, influence the condition of the society in different ways; and each is affected by society in a certain way and to a certain degree.

Inspired by McLuhan (1967), it would be sound to say that "products" (like hammers, cars, cell phones, digital cameras, laptops, databases, search engines, and websites) are artifacts that we use to extend our abilities, to affect the natural world, to improve our senses, and to increase our processing and memorizing capabilities. We make some artifacts using developments in science, and produce others by simply applying certain techniques, and mobilizing resources.

According to Leiss (1990), "techniques are solutions to practical or theoretical problems arising out of the environmental forces" that impact us (29). Harold Lasswell has defined technique as "the ensemble of practices by which one uses available resources in order to achieve certain valued ends" (cited in Leiss 1990, 26). According to Agazzi (1998), since we can refer to technical skill in different professions like a craftsman, a professionally able lawyer, a pianist; "technique is essentially the able application of a certain know-how, which has been constituted through the accumulation and transmission of concrete experiences that in particular also entails a careful exercise" (2). There are "large sectors of technical progress that are quite independent of the advancements of science; they follow the traditional path of the accumulation of empirically discovered useful devices or procedures without any need for a scientific understanding of their efficiency" (6).

This paper considers "technique" as a practical ability, or successfully used procedure, that allows one to perform given activities or to obtain certain results efficiently and effectively. A technique is not necessarily accompanied or supported by knowing why such concrete procedures are especially efficacious.

Sometimes in addition to using techniques, artifacts are made by the application of theories that have predictive validity. We gradually develop knowledge about designing novel products. Webster's Third New International Dictionary defines technology as "the science of the application of knowledge to practical purposes".

Mesthene regards technology as "the organization of knowledge for the achievement of practical purposes". For Galbraith "technology means the systematic application of scientific or other organized knowledge to practical tasks", and for Forbes "technology, is the result of interaction between man and environment, based on the wide range of real or imagined needs and desires which guided man in his conquest of Nature." (cited in Leiss 1990, 25-26)

In order to achieve practical results, technological development may draw benefits from diverse fields such as science, engineering, mathematics, linguistics, and history. Agazzi (1998) has argued that technology is a branch of technique that has a closer links with science. The application of scientific knowledge to find the solution for concrete problems typically needs planning and may require the construction of a machine. The how and why of such machine's functioning is known in advance to the extent that it is designed through the use of the available theoretical and practical knowledge (5). "Technology cannot exist without science, and science cannot exist without sophisticated technology" (8). At the same time, however, it should be noted that although they are related, they are different. Science seeks to obtain objective knowledge while technology aims at producing concrete results in the form of objects, commodities, tools, or procedures (1).

This paper defines the construct "technology" as the knowledge about an intelligent envisioned composition of artifacts, techniques, procedures, or methods of doing things in a system that is designed with utilization of science to produce certain goods, to make specific tools, to provide certain services, or to accomplish certain tasks.

Technologies are different than products that embody technologies. One technology can be used to produce many products and one product can embody many technologies. The cell phones and washing machines we buy and take home are not technologies. They are products that are produced by using many technologies. Technologies don't do anything by themselves. They don't change or grow by themselves. Technologies are envisioned and are applied by humans to produce products. The way products embody technologies is through purposeful design and clever production utilizing the technological capital.

"Technological capital" is the accumulated knowledge that empowers people, firms or societies who own it to intelligently envision a composition of artifacts, techniques, procedures, or methods of doing things in a system that is designed to utilize science to produce certain goods, to make specific tools, to provide certain services, or to accomplish certain tasks. A person or a society may have many forms of this capital. The fabric of our technological capital will depend on the decisions made for its development.

With the use of technological capital as a construct representing a form of accumulated knowledge, we can better understand that technologies are forms of wealth that are not flatly distributed between the individuals within a society. They are forms of wealth that are not available to all societies either. Fernandez et al (2000) have assumed that technological capital includes knowledge related to the access, use, and innovation of production techniques. Nordhaus (2000) has used the concept of technological capital at a national level, and García-Muiña and Pelechano-Barahona (2008) have explained an effort to measure technological capital of a firm using a multi-dimensional concept. Using this construct, we would be able to properly analyze the impact of development of, and changes in technologies, on society. One advantage is that technological capital is clearly positioned within the social system. We are able to theorize about the relationship between this capital, and the creation of products, then analyze their impact, and understand the mechanism through which each influence the social system.

However, the development of technologies, and the production of resulting artifacts, is influenced by social processes that mobilize resources toward their development. Once they are developed, these technologies determine the boundary conditions of what can be produced, and the resulting products determine what we can do. Recursively they also influence the possibility and probability of the next technologies and products we may develop.

We may theorize that technology and society are in a feedback system. However, since technologies only exist in societies, we are led to a model of society that considers the technologies as one of the internal attributes of the society, an explanatory variable that is internal to the system.

The distribution and transfer of technological capital can be studied as a variable in a feedback system with natural, social, economic, and political factors to analyze the trajectory of the society. In this model of society, different methodological differences can be reconciled. The search for cause and effect between members of feedback loops is neither meaningful nor productive. This theoretical framework has proper space for human agency, science, and technology. It can lead to novel and testable predictions. It will have explanatory power. This paper argues that using feedback process methodology, the relation between technology and society will not appear as a paradoxical relation, it turns out to be a complex feedback relation.

Identifying the System Elements

As we noted in our review, some scholarly work, in which technology has been considered as a variable, have advocated symmetry between humans and technological actors. Latour (1988a) has emphasized that machines are human lieutenants, to show that studying social relations without the non-humans is impossible. He has argued that socio-economic, topological, geometrical and technical variables influence the non-human actors, such as machines, and they in turn, influence the social network. Our understanding of social relations without considering the impact of non-human actors is incomplete (Latour, 1992). Some advocate even a generalized symmetry. Law (1978) has suggested that the same type of analysis should be used for all components of a system whether these components are human or not (132); therefore, social elements in a system should not be given special explanatory status (130). The model presented in this paper includes human and non-humans; but the asymmetry in responsibility will be emphasized in next sections.

Figure 1 displays a simplified diagram showing that our societies are parts of nature; some societies accumulate technological capital, and mobilize their resources to produce goods or services based on this knowledge. Products and artifacts are designed in those societies where the technological capital exists, or is accumulated by allocation of social resources; but products can also be produced in societies that do not have the technological capital but acquire means of their production. The impact of the products will be observed in the societies where they are used and consumed, in societies where they are produced, and in societies where the people have neither theoretical and technological knowledge, nor the means of their production.

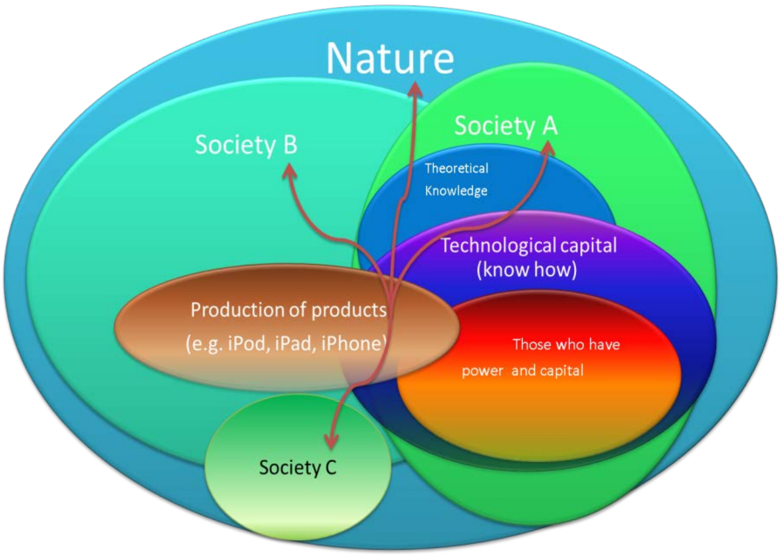

Figure 1: Social Mobilization of Resources to Create Products Influences Societies and Nature

Therefore, not only should we study the technology as an attribute of some societies but also, there should be four further branches of studies. The first branch is the study of the impact of technological capital on the faith of the same society which accumulates it. The second is the investigation of the effect of mobilization for production on societies where the products are designed and made. The third is the analysis of the impact of products on all consuming societies; and the fourth is the understanding of the impact of the production process and products on the nature. In the next section we will explain, in more detail, how these interrelated influences are realized.

Modeling Technology in Society

In this section we construct a dynamic feedback model of the social system in which technologies and products are created. Figure 2 is a visual illustration of the reinforcing feedback loop between technological research, technological capital, and domain of possibilities. Theories, technological capital, and products change the domain of possibilities for the society of their origin, and other societies. And the new domain of possibility will in turn change the dynamics of technological research.

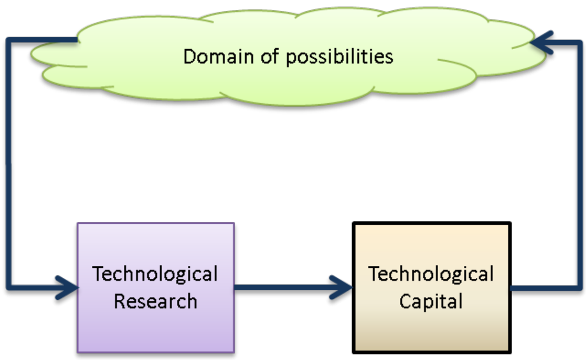

Figure 2: Technological Research, Technological Capital, and Domain of Possibilities

Moreover, as presented in figure 3, accumulated technological capital enables societies to successfully mobilize their resources for the production of a set of goods and services which are instrumental in changing the domain of possibilities. Technology is created by the utilization of applied sciences and the employment of existing techniques and available tools. However, as Agazzi (1998) has argued, certain scientific research cognitive problems can be solved by projecting and constructing appropriate apparatuses or instruments. Between the scientific knowledge and instruments, a system of reinforcing feedback is established, a reciprocal stimulation to ever more rapid and expansive growth (5).

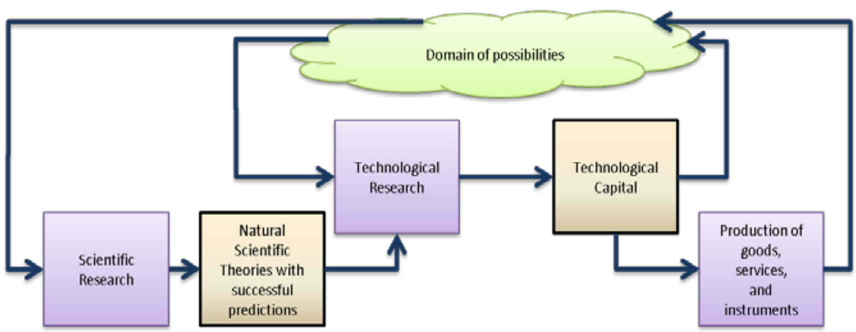

Figure 3: Nested Feedback Loops between Possibilities, Science, Technology, and Products

Each change in the domain of possibilities has another accelerating effect (through its enabling consequence on scientific research) which leads to more powerful scientific theories. Scientific theories with better predictions enable more successful technological research, and therefore, accelerate the inner loop in figure 3.

However, it is important to remember that the change in the domain of possibilities, and the usage of the products, is not limited to what is expected by the designers and investors; many times people identify possibilities that were not intended, and use products available to them in ways that are unexpected. Also, we have to notice that changes in the domain of possibilities don't give competing possibilities similar probabilities. What will actually happen is the outcome of the whole system.

Figure 4 shows a dynamic systems interpretation of the social construction processes we discussed in section II (Exploring the social construction of technology). Depicted in red, the society's attitudes, culture and the media system in relationship with processes of collective decision making, such as elections, and in tandem with power relations in the society influence the funding decisions by the government, market choices, investments and consumer's behavior, and overall, resource allocations in society. Culture and decisions, which are formed in historical trajectory of the society, are influenced by media, which traditionally has been controlled by the power elite, and is becoming more diverse. Simultaneously, people's decisions and culture influence media effectiveness, shape power relations, and regulate resource allocations. At the same time, this allocation influences the culture, media, democratic processes, and power relations in societies. This feedback process inscribes the stamp of social situation on technological development in different countries.

The feedback subsystem in figure 4 is part of the structuration of social organizations and formation of social processes. Through these processes, decisions about production of certain products are made. The production of products is what necessitates certain modes of production be established, and certain questions be answered. What these social processes necessitate not only affects the structure of social relations but also influences the priorities set for universities and research centers (shown in orange at the top of figure 4).

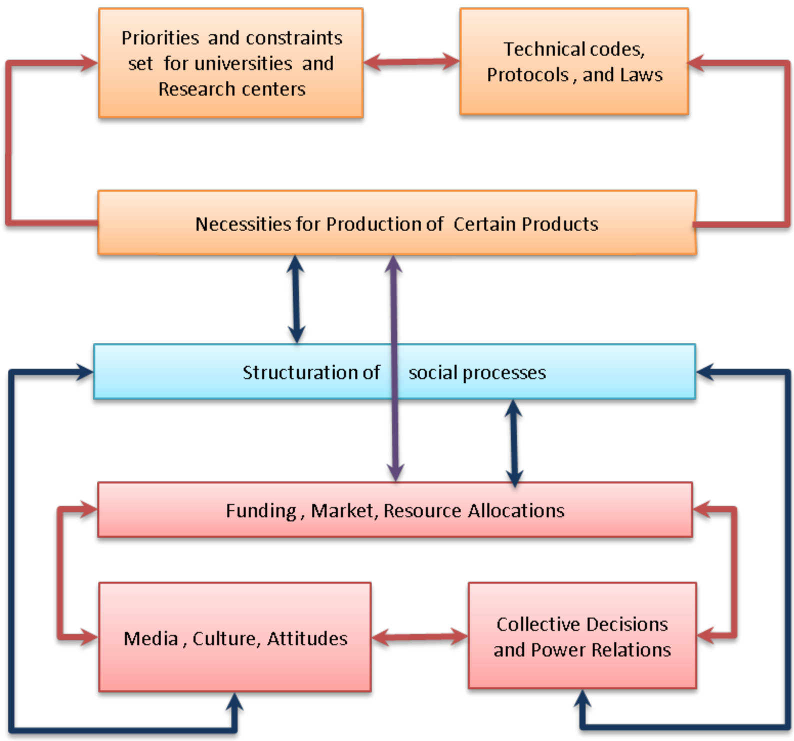

Figure 4: Dynamic Relationship between State Variables That Influence Research Priorities

Natural and social sciences endeavor to give us an understanding of nature and society; and technologies are developed to facilitate certain results. Their designed composition tends to limit the set of needs they may satisfy, or the services they can provide. Although technologies can be used by innovative users in circumstances other than those that have been considered in the design plan, technological outcomes, as Feenberg (2002) has suggested, depend on the principles considered in their design, purpose of their employment, and how they are employed (43-44).

Developers of technologies have their methods. They use science and mathematics and other known techniques, but as Feenberg (2002) has observed, the values of a particular civilization are embodied in technologies. This embodiment takes place by the way we choose among all possible technological solutions and the path we choose for their progress (V). The evolution of technologies is not an autonomous process and is rooted in interests and social forces (48). Interests are institutionalized at two levels, the levels of laws and of technical codes (20).

Technical codes influence rules of operations such as reliability, strength, human factors, and so on (76). Therefore, when a selection between many technological solutions to the same problem is necessary, technical codes become more important in decision making process. Once a method of doing things is widely used it becomes coded in protocols and standards, and becomes influential in the shaping of the future progress. There can be many solutions when dealing with a problem. But all possible solutions cannot be funded; for efficiency and compatibility a choice based on technical code is made.

It is important to note that technical codes are also determined by people who are not necessarily working in the capacity of scientist or engineer. The safety laws, emission laws, and budget allocation in government and corporations for research are examples of the influence of social institutions on the development of science and technology. Chomsky (2011) has argued that, in many industrial countries, extensive government interventions regulate disorderly markets; and major corporations have been subsidized by the flow of taxpayer money to research and development through military establishment (80). It is important to note that the processes depicted in orange in figure 4 are also situated in social structures they influence as well. The necessities of planned production, on the one hand, require certain modes of production and influence political and economic decisions on resource allocation; and on the other hand, influence the laws, technical codes and protocols used by researchers and producers.

Figure 5 shows a conceptual model of some of the major feedback processes between human and non-human elements, and environmental variables in the society explained above. This depiction is informed by what was discussed in section IV (Explanations for the impact of technological change in Society); but instead of identifying causes and effects, depicts a dynamic system with multiple feedback loops and many state variables.

Social actors interested in development of technologies establish certain social structures necessary for knowledge and artifacts production. Once theoretical knowledge and technological capital are formed and used, they change the domain of our possibilities, and have influence on our lives. As presented in Figure 5, power relations and collective decisions in the society directly and indirectly with media and culture, influence the resource allocation to most scientific endeavors. The resulting theories are used to develop technologies for producing certain results. Social actors influence the laws and technical codes governing the operation of technologies and the direction of investments in making of products. However, it is important to notice that not every product we imagine is producible; the possibilities are limited by natural limitations.

Since societies are open systems, the accumulated technological capital and products produced, both within and without every society, will produce intended or disruptive results. Therefore, some of their impacts, the change they cause in the domain of possibilities, are inscribed and some are unintended. The products are designed and produced to provide certain possibilities, but they also open unexpected possibilities for the users that use them in innovative ways.

Some needs, in any particular period, are beyond the scope of existing or foreseeable scientific and technical knowledge. Sometimes technologies and related products are invented, designed, or arranged to have a particular social effect. A given device can be designed and built in such a way that it produces a certain set of consequences. Even when certain technologies are not designed to have a certain social impact, their adoption requires the creation or maintenance of particular social conditions. They still may have unexpected social effects by changing the topology of actors, or creating novel opportunities for new science or new products that may be realized years later.

The possibilities of the disruptive use of technological capital arise because many of the possible uses of scientific theories and technologies cannot be envisioned at research time. People will eventually use these forms of knowledge (and products produced based on technological capital) in very innovative and novel ways, to solve their many problems. Once the resulting products are used in factories, offices, or other places, they in turn have expected and unexpected influences on possibility of new labor relations, human involvement, and feasibility of outcomes, procedures, and levels of bureaucratic control.

In a feedback system like this, every variable may be a contributory cause, which may be neither a necessary cause nor a sufficient cause. All the variables are responsible, to different degree and via different mechanisms for the current state of the system. In this feedback system, technologies, and technological capital are part of the system, their change and development influences the system analogous to neural development in body. They are not outside our body, and we can study them as systems with many feedback loops.

As signified by dashed lines in figure 5, the dynamic subsystem “S” of social processes which affects priorities and constraints in universities and research institutes, biases scientific and technological research toward funded research projects. The outcome of these social processes sometimes enables, and sometimes limits scientific and technological research on different subjects, and determines which products will be produced. Funding certain kind of research influences what natural and social scientific theories we have, and cutting the budget for certain kind of research influences what we don’t know about the nature or society, and both influence the kind of technologies we have. Situated in these processes, by decisions we make, we shape the domain of our possibilities and construct the future of humanity. Therefore, when making decisions, we have to pay careful attention to the changes in the domain of possibilities that will arise from our resource allocations.

As the green line on the left side of the figure 5 signifies, our past decisions about the direction of scientific and technological research, as well as what we have decided to produce influences the domain of possibilities; the new domain of possibilities will in turn change the dynamics of the power relations, media and culture, and eventually the resource allocations in the society. This feedback highlights the change in the domain of the possibilities as the state variable that explains what was described in section III (Factors describing observed relationships between technology and society).

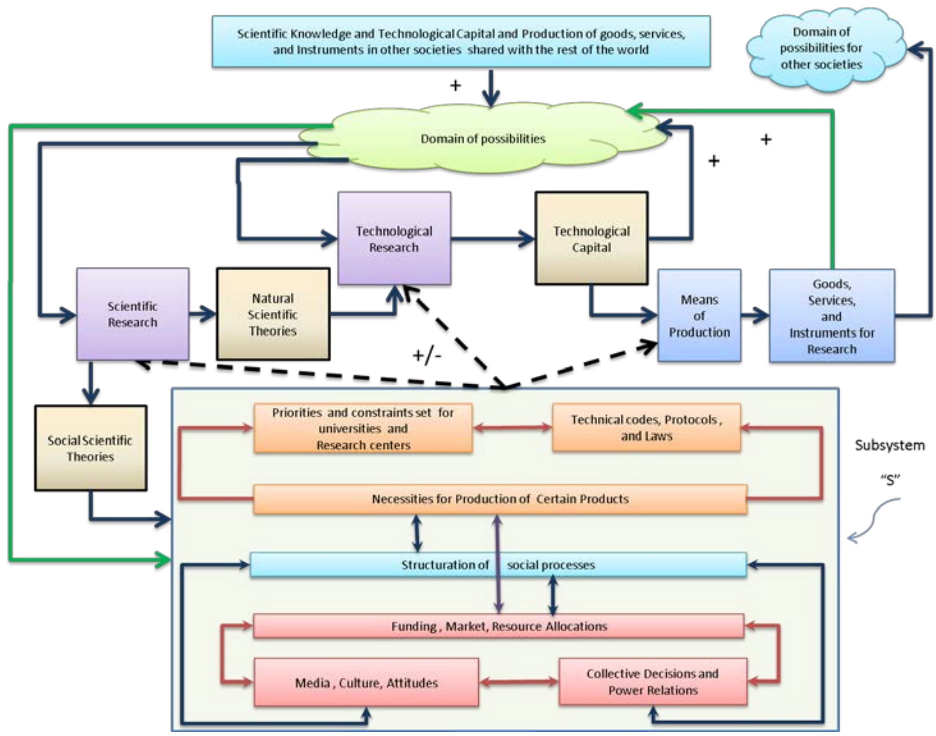

Figure 5: Dialectic of Sciences, Technologies, Production; and Political/Economic Decisions

In systems like this, there are many state variables; and several of the variables are in concurrent feedback loops. In a feedback loop, search for a sufficient cause, an independent variable, and a dependent effect is a fruitless endeavor. A change in every part of feedback loops in the system has understandable effects on other parts. Elements of this social dynamic system are not only human actors but also are non-human actors, and environmental variables.

Some branches of communication and media studies have been using methods such as multi-linear regression analysis and factor analysis to deal with a large number of variables, as complex as journalism and as abstract as memory, and persuasion. Unfortunately, feedback systems cannot be studied with time-invariant linear analysis. Luckily, we have the methods and means to analyze dynamic nonlinear systems. In this paper showed how technology and society studies can benefit from these methods.

Scientific and technological progresses widen the domain of possibilities; but the decision to produce any and every product remains a human decision. It is the power relations between humans within a feedback loop with technological capital, which influences the collective decisions about resource allocations. Based on this model the change in the domain of possibilities simultaneously affects the power relations, collective decisions, media effectiveness, and the culture. More research should be conducted, based on the proposed model, to theorize the extent and direction of these effects.

Responsibility

In studying science, technology and society, which are related in a complex open system of dynamic feedback loops, we should avoid extremism in parsimony, or attempts to reduce the system to linear sufficient cause and effect models, such efforts may lead to oversimplification. Moreover, we should resist personification of artifacts, loose definitions, and using the constructs without rigor. We must not ignore the importance of clarity, lucidity, and understandability, which in my view has severe consequences that are as bad as reductionism.

Increasingly, we use new products to collaborate, communicate, and make decisions. Information and communication technologies (ICTs), and products made using ICTs, are some of contributing variables of our domain of possibilities. Humans are living organisms; sciences and technologies are types of knowledge; and products are neither humans nor knowledge; products, technologies and sciences are created by humans, but all of them are explanatory variables for the world system we live in. This inclusive look at all the influential variables should not lead to the rhetorical practice of personification of the influence of non-humans. Although referring to different constructs as if they are similar entities may simplify the research hypothesis on the surface, when we refrain from referencing different subjects as if they are one and prevent construct validity problems we develop better understanding of social systems. The practice of personification sometimes happens while we elaborate on the opportunities or risks that are related to the development of some fields of science and technology, for example, when we criticize science or technology for the harm to humanity caused by using them in certain ways, or when we rhetorically refer to them as human saviors.

Jacques Ellul had expressed a nostalgic story of human’s historic inability to protect the values and qualities of life from technique (Rheingold, 2002, 199). Ellul also had claimed that: “Technique has become autonomous; it has fashioned an omnivorous world which obeys its own laws and which has renounced all tradition" (Winner, 1978, 75). Even Rheingold has warned us that “information and communication technologies are starting to invade the physical world” (Rheingold, 2002, 85). But, since artifacts and constructs such as science and technology cannot be held accountable, statements that position them as the subject of an effect may distract the attentions from those who can be held accountable for the outcomes. The social researchers, natural scientists, philosophers, artists, power elite and citizens are the only ones that can be held responsible.

Considering agency for non-human actors is plausible in the sense that they are influential variables of the trajectory and outcomes. However, when they are personified, what is sometimes neglected is that non-human actors cannot be held morally responsible. As a result, statements are made that do not clearly identify who should be held accountable for specific outcomes.

We have to avoid statements that may be confusing the agency of artifacts in its social scientific sense, with their accountability in moral sense. The practice of referring to science and technology as agents may be useful because it reminds us to include them in the network of the actors, but personification is a risky road, which may also lead to forgetting that any moral criticism of non-humans is not fruitful.

Conclusion

The dynamic feedback system of social processes including attitudes, culture, media, collective decisions, and power relations determine investments for the production of a subset of products conceivable within domain of possibilities. Through resource allocations by investment and funding decisions, which affect priorities and constraints set for universities and research institutes, and through laws, protocols, and technical codes, societies sometimes enable, and sometimes limit scientific and technological research on different subjects. This process influences what we know and what we don’t know about the nature; moreover, it affects what we know how to make and what we don’t.

Scientific theories and technological capitals are developed and used by people in different societies to produce different products; they, intentionally or not, change the domain of possibilities for the decisions that are made by political, economic, and cultural influences. All of which, situated in a dynamic feedback system within its historical context, are among the state variables of the social condition. Moreover, societies are open systems, and technological capitals, and products can influence the trajectory of other societies and the nature.

Since the unintended consequences of technological capital and products are uncertain, and because there are many feedback influences in the system, the state of the system is always tentative; and because of the role of our decisions in shaping the domain of possibilities, an impact from human agency is possible. The current order of resource allocation in societies is not the only possible order; and the probability of a different order partly depends on our decisions.

That we include people and artifacts in our analysis should not distract us from seeing their differences. Non-human actors cannot be held morally responsible; and our decisions are the only variable that we may be able to change; therefore, for all the avoidable outcomes, the only ones that can be held accountable are humans.

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The International Journal of Technology, Knowledge and Society explores innovative theories and practices relating technology to society. The journal is cross-disciplinary in its scope, offering a meeting point for technologists with a concern for the social and social scientists with a concern for the technological. The focus is primarily, but not exclusively, on information and communications technologies.

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