A General Definition of Technology and Quasi-Equilibrium Model of Technological Development

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Abstract: Living in a modern society dominated by technological progress, we still fail to precisely define the term "technology". This ambiguity in definition remains ostensibly irrelevant to the majority of both producers and consumers. But at its core, this situation is analogous to technology producers attempting to steer a boat in an accelerating current blindfolded with consumers as their passengers. As a result, many boats have perished, forcing passengers to abandon ship while causing immeasurable waste in time, money, and resources. This paper attempts to clearly define a universal concept of technology in both animals and humans. The critical characteristics of this definition are then discussed extensively. Based on this general definition, unique features of human technology use are coherently isolated and examined throughout the development of human civilization. In the context of modern society, a Quasi-Equilibrium Model of Technological Development (QEMTD) is derived on the basis of previous deductions and analyses. Finally, the qualitative and quantitative application of QEMTD is explained and explored via the example of cell phone technology.

1. The General Definition of Technology

It can be stated that the ultimate intention of an animal when using technology is to increase its adaptation to the environment and its reproductive advantage (Biro et al., 2013). In other words, it can be said that the general intention of an animal when using technology is to increase the user's survival experience. The term survival experience is used here is because a physical capability stays constant over time if neglecting possible physical decay over a short time period, while an experience that utilizes increased capabilities grows linearly over a certain amount of time. An increase in the user's capability and adaptation to the environment will not manifest its effectiveness until it has been used for a period of time. Combining this with the definition of tool use "as an extension of the body", we are able to formulate two necessary conditions for the general definition of technology. If both conditions are satisfied, then the conjunction of the two condition forms the sufficient ground for the general definition of technology. We can dissect the definition of technology by analyzing some of the most important characteristics of the two necessary conditions.

1) A physical object that extends the bodily capability of its user;

2) The intended usage of such an object is to directly increase the current survival experience of its user.

It can be further conjectured that from the analysis carried out above, all living creatures capable of actively interacting with the environment share the same goal of increasing subjective survival experience. Those that are capable of utilizing technology increase their bodily capabilities and subjective survival experience faster than those that are incapable. The incapable species remain passive during the process of natural selection and are subject to random environmental changes and genetic mutations and thus their subjective survival experience increases extremely slowly when compared to the technology-using species. This trait that differentiates the animals capable of utilizing the technology from those that are incapable could be the definition of general intelligence.

To further discuss the implication of this definition, we can generalize the relationship between the extension of capability and the increase of survival experience into a mathematical relationship. We can first denote $C(t)$ as a function of technology user capability that is only dependent on time t

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and is constant until the introduction of new technology. From our former definition, we can define a survival experience function $SE(t)$ that is a function of $C(t)$ and is also dependent on variable t. The relationship between $C(t)$ and $SE(t)$ can be expressed as:

$$SE(t) = \int_{t_0}^{t_f} C(t)dt \qquad (1)$$

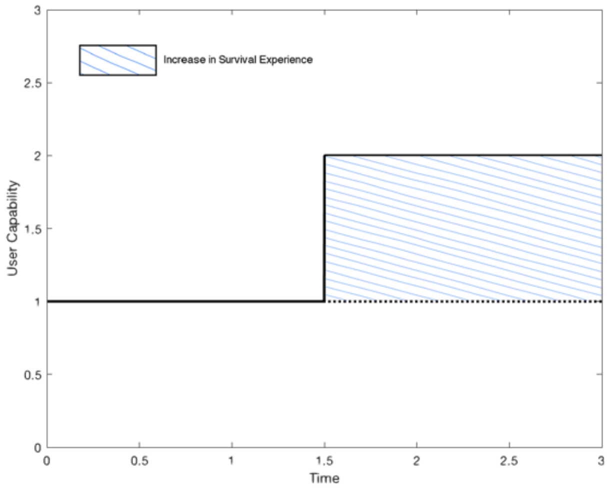

Fig. 1. User capability function with the addition of certain technology at t=1.

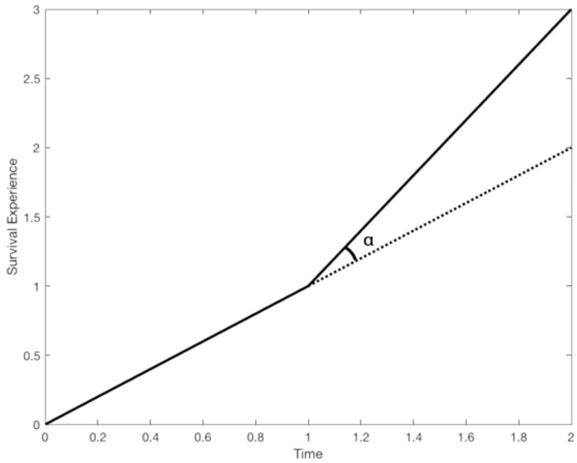

Fig. 2. Survival experience function with the addition of certain technology at t=1.

Survival experience $SE(t)$ is the result of the technology user experiencing its capabilities from time t_0 to t_f because the passage of time is a necessary condition to define an experience. With the introduction of technology at $t = 1$, the user's capabilities and thus the slope of its survival experience is augmented, which can be represented qualitatively by the Fig. 1 and 2. It is also worth noting that the intentional increase in survival experience has to be consistent with the augmentation in capabilities, meaning that only intention of using enhanced capabilities can count as increased survival experience. For instance, when someone uses a commemorative coin as money, the coin can be considered as technology since it satisfies both of the necessary conditions, especially in enhancing the user's ability to trade, which is composed of many bodily capabilities. When one uses the same coin as a decoration, on the other hand, it should not be considered as technology because of the inconsistency in capability increase and intention. Even though the coin enhances the user's bodily capability when used as money, it no longer enhances bodily capabilities when used as a form of art. Spatial variation, however, is not a necessary condition for survival experience and thus any spatial variable is ignored in the general definition of technology.

By the general definition of technology, technology must increase the user's capability, as a result, its survival experience must also increase, as illustrated in Fig. 2., denoted by α and has the characteristic of $\alpha > 0$. There are a few assumptions required for the graphical relationship to hold true.

1) The implementation of a certain technology is sudden: straight jump from the old capability to new capability.

2) User capability starts with a nonzero value and stays constant over time without the introduction of technology.

3) The survival experience of the technology user is continuous between implementations of technology.

2. Limits in Modern Human Technological Development

When the quantity of producers outnumbers the quantity of the consumers, because the intention of producer exceeds the intention of consumers, the producer's intention of using technology will become dominant. In this case, most advanced technology created by producers is self-consumed because consumers are incapable of conceiving a practical user scenario and thus are unlikely to adopt. Such a hypothetical economy, in general, will enjoy faster technological progress due to the producer's limitation of intention is greater than the consumer's. On the other hand, in a consumer based economy, the intention limit of consumers drags down the higher limit of producers, resulting in slower overall technological growth when compared to the former scenario. In this situation, even when producers consume their own product, the effect on the overall technological progress is negligible due to their small population. In the context of modern society, a producer-dominant economy that displays large scale self-consumption behavior does not exist. In the case of the U.S. economy, the Personal Consumption Expenditures (PCE) / Gross Domestic Product (GDP) factor never fell below 0.5 since record, indicating the characteristic of a consumer-based economy (U.S. Bureau of Economic Analysis). This indicates that for the U.S. economy, the limitation of intention will predominantly come from consumers. But due to the nature of consumer intention, producers are able to influence consumer intention by manipulating the past experience of consumers, which can be done in ways such as advertisement or marketing in general. Because the producer intention limit is higher than that of consumers, in a consumer-based economy, producers are often capable of increasing consumer intention. Further categorization of consumer intention can be generally achieved by Everett Roger's diffusion of innovations model, which characterizes consumers as innovators, early adopters, early majority, late majority, and laggards. The criterion for differentiating different types of adopters is innovativeness, the ability to adopt new ideas, which is analogous to our definition of intention limit (Rogers, 2003). In the context of our analysis, innovators correspond to those who are most likely to derive intentions from past experience (knowledge) to utilize the newest technologies while laggards are the opposite of innovators.

In order to better understand the influence of cost and the willingness of technology users to gain an increase in its capability, several modifications are required to elaborate Eq. 1. Firstly, in the context of modern economics, the name survival experience function can be modified to the technological utility function, denoted $\mathrm{TU(t)}$, to better adapt to the contemporary environment. $\mathrm{TU(t)}$ also represents the collective utility function, meaning minor variations within the economy are ignored. Secondly, subjective cost term $\mathrm{c(t)}$ is added, assuming a step-wise characteristic that resembles user capability function $\mathrm{C(t)}$ over time, with each step corresponding to each increase in capability increase. The complete technological utility function can then be derived.

$$\mathrm{TU(t)} = \int_{\mathrm{t_0}}^{\mathrm{t_f}} (\mathrm{C(t)} - \mathrm{c(t)})\mathrm{dt} \qquad (2)$$

In the perspective of the user, when subjective cost $\mathrm{c(t)}$ of a new technology exceeds its increase in capabilities $\mathrm{C(t)}$, the integrand drops below 0, resulting in $\alpha < 0$. By condition two of the general definition of technology, the user will choose not to adopt such technology. When $\mathrm{C(t)} = \mathrm{c(t)}$, old user capability stays constant and is equivalent to no new technology adopted. Only when $\mathrm{C(t)}$ outweighs $\mathrm{c(t)}$, the integrand remains above 0 and the acceptance of new technology becomes definite ($\alpha > 0$). This concept is similar to the tradeoff between marginal cost and marginal utility in medium-term diminishing utility return but different in the way that there is no long-term diminishing marginal technological utility by the condition two of the definition, the exact reasoning will be presented in the implication section. By Eq. 2, the adoption of new technology is further restricted by subjective cost $c(t)$. The subjective cost can be broken down into the concepts of objective cost and user intention. User intention has been clearly defined while the objective cost is the minimum cost of for a producer to manufacture the technology. This cost is minimally governed by the combined cost of its precedent technologies. All precedent technologies can be further categorized into sustaining and disruptive precedent technologies (Christensen, 1997). Sustaining precedent technologies are mature technologies that are low cost to implement but are close to reaching their performance limit. Disruptive precedent technologies, on the other hand, are technologies that fail to exceed the performance and cost benefit of sustaining technologies in the beginning, but has the potential of decommissioning sustaining technologies in the long run. The dilemma of minimizing objective cost and maximizing demand for performance can be reconciled by utilizing the combination of disruptive and sustaining precedent technologies under various market situations (Christensen, 1997). The above analysis concludes the investigation of new technological utility limits, and we can now start the examination of possible contemporary scenarios where α drops below 0 due to an objective reduction in utility.

Sources of decrease in objective utility in modern society can still be divided into two categories: environmental and anthropic reduction. Environmental reduction accounts for all natural disasters such as hurricanes and floods or accidental interaction with the environment such as accidentally losing one's phone at sea. This reduction can be alleviated by the implementation of technologies such as weather forecasting or waterproofing technologies that directly aim to counter the effects of the environment. Anthropic reduction, however, is harder to control since it involves other humans. When utilizing technology, the intention of the user can be divided into intentions that involve in other humans or intention that does not. For intention that involves in other humans, this intention could become the anthropic reduction in the recipient's perspective. When one intends to use technology that would result in a reduction in other people's technological utility, such use of technology should be regulated and documented. This principle urges technology producers to thoroughly inspect such possibility of misuse and should impose regulations when this possibility becomes reality. It could also be the case that by manipulating consumer intention through the dissemination of false information, producer coaxes consumers into the decision of adopting new technology when in fact new technology decreases user's previous abilities and resulting in $\alpha < 0$. Cases like this can be regarded as ethical concerns when utilizing technology in general.

In summary, a new technological utility must be accompanied by its necessary precedent technologies and has an upper bound, producer intention β, which is constrained by two major factors, consumer intention, and above zero growth of user capability ($\alpha > 0$). Due to malleable consumer intention, producer intention β is capable of affecting consumer intention limit. Allowed new utility α and consumer intention are capable of influencing the magnitude of each other with a situational direction of effect. Consumer intention remains above allowed new utility because consumers may not afford the cost of an intended technology. Objective reduction of α may still occur through environmental or anthropic influences, but can be mitigated through the implementation of targeted technology and appropriate prevention and regulation. Combining these limitations, a consolidated model named the Quasi-Equilibrium Model of Technological Development (QEMTD) can be formulated to explain the limitations when implementing new technological innovations in the context of modern society. The term quasi-equilibrium process is originally used to describe a slow enough thermodynamic process for a system that allows the system to remain in internal equilibrium. But due to the apparent similarity between this thermodynamic process and technological progress, the term quasi-equilibrium is adopted for an analogous description. From Fig. 3., the maximum increase in technological utility is imposed by producer intention β, while α is limited by Eq. 2.

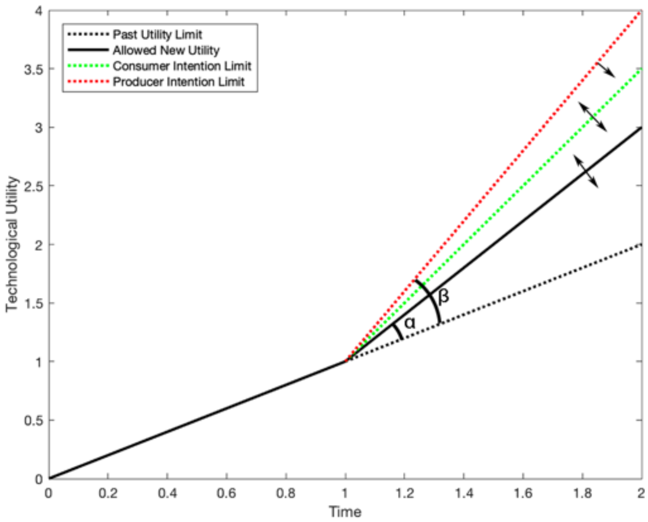

Fig. 3. Limitations when increasing subjective technological utility, imposed by the Quasi-Equilibrium Model of Technological Development.

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