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The Next Step After Three Decades: A Reply to Basu

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Sumitran Basu's "Three Decades of Social Construction of Technology: Dynamic Yet Fuzzy? The Methodological Conundrum" (2022) provides insightful comments and builds a solid cornerstone for us to review and reflect on the Social Construction of Technology (SCOT). It is an act of benevolence and generosity to write a review for future successors of Science, Technology, and Society (STS). With Basu's thorough and structured review of SCOT, we can learn from SCOT's past achievements and disagreements in Science and Technology Studies. Basu arranges this review of SCOT chronologically, from Trevor Pinch and Wiebe Bijker's first empirical case on bicycles to the evolution of SCOT after receiving criticism all around the field. In the section following the chronological review, Basu brings up his key insights on SCOT's methodological difficulties and dilemmas—the operational and the explanatory dilemmas (10-12).

1. Introduction

The operational difficulties occur when SCOT expands beyond the technological frame and introduce two other units of analysis: sociotechnical ensembles and technological cultures. Since SCOT has a robust methodology built from artifacts and relevant social groups to technological frames, it is challenging to incorporate sociotechnical ensembles or technological cultures. In other words, later-introduced concepts are only restrained to their own scale and challenging to build workable connections between artifacts, sociotechnical ensembles, and technological cultures. The explanatory dilemmas are rooted in SCOT's fundamental assumption that the change of an artifact can be explained from the bottom up.

Although Bijker later developed sociotechnical ensembles and technological cultures to meet the requirements of the macro-level analysis, he refuses to treat these macro-level concepts as *a priori* assumptions. Hence, sociotechnical ensembles and technological cultures are *explanandum* rather than *explanans* when investigating the causality of technology changes. The significant resources for explanation in SCOT are micro-level interactions amid artifacts, relevant social groups, and technological frames. After identifying these two dilemmas in methodological transition, Basu asserts that future attempts to make SCOT more universal and broaden its explanatory range will inevitably encounter operational difficulties and dilemmas (Basu 2022, 14).

Basu's review and penetrating diagnoses of SCOT's methodological dilemmas benefit future STS scholars and open a forum for revisiting the development of SCOT and STS. From the beginning, SCOT's pioneers—Bijker and Pinch—have been at the epicenter of scholarly debate. Criticism and comments from the history of technology, sociology of technology, and philosophy of technology are actively involved in the evolution of SCOT. Bijker and Pinch started their new academic journey after responding to the previous criticism and adjusting the analytical framework of SCOT. Their latest contributions can be shown in the recent progress of Responsible Research and Innovation (RRI), Public Engagement with Science, and Making and Doing in STS. Basu's solid review and comments allow us to look back and sort out the following steps for SCOT's future. Nevertheless, Bijker and his colleagues have already taken their next steps.

Based on the foundation built by Basu, I first revisit Bijker and Pinch's response to the criticism in SCOT's early years. SCOT received not only condemnation but constructive suggestions and revisions on easing the tension between micro- and macro-perspectives. I then illustrate how SCOT and other approaches in the campaign of social constructivism—Large Technological System (LTS) and Actor-network Theory (ANT)—answer the criticism and suggestions above. In a broad sense, SCOT, LTS, and ANT share common traits in their analysis of technology. However, their relationships are competitive and reciprocal simultaneously.

Reviewing these three approaches' trajectories reveals multiple paths and possibilities, which unfolded at SCOT's early stage. Like the interpretive flexibility may meet with some degrees of closure and stabilization, Bijker and Pinch epoché the ontological debate of SCOT, and they move forward with SCOT's methodology to achieve their ethical goals of technology—democratizing science and technology. Besides enriching Basu's fundamental work on reviewing SCOT, I pointed out that Bijker's latest focus on RRI and the democratization of technology can be our analysis object for thinking through SCOT.

2. Responses to the Early Criticism of SCOT

Bijker (1995, 122-126) proposed the "technological frame" as a response to the challenges of methodology and theory. The concept of technological frame particularly emphasizes the interaction and relationship between different actors and groups. That is, in addition to observing the characteristics of individuals, institutions, or systems, it is also necessary to pay attention to their goals, problem-solving strategies, practice, gain an even deeper understanding of their current theoretical knowledge, and explore how those knowledge and practice recognize relationship amid and within groups. In short, the technological frame focuses on how different social groups shape technology: the content of their social activities, communication patterns, and interactive forms. The technological frame further opens opportunities for involving non-technologist groups.

In addition, Bijker also proposed the concepts of inclusion and power (Bijker 1995) to explain that different social groups will participate in producing technical objects to varying degrees, and some scientists or engineers may use marginal titles. While some are highly substantive, different groups have varying capacities to exert control or influence over other groups. Bijker supplements SCOT with the technological frame, inclusion, and power, thereby anticipating that the interpretation of SCOT can reveal the following two possibilities: the social structural environment will shape technological objects and vice versa. Ronald Kline and Pinch (1996) also agreed with Bijker's proposal and explored how the social structure of gender affects the design of rural cars. Their research pointed out that the car design process is without women's participation because American men are traditionally regarded as technical experts.

However, the expansion of the relevant social groups to the social structure seems to be questioned not deep enough and broad enough to resolve many criticisms of SCOT's structural nature (Klein and Kleinman, 2002: 31). Bijker's response to social structure seems to be limited to the level of social groups. Some scholars also claim the structure of a technical object inherits the historical and cultural identity of the past. Therefore, constructivists such as Bijker's structural strengthening to SCOT are still considered myopic (Edwards, 2003).

3. Constructive Comments after Criticism of SCOT

Criticism of SCOT provides constructive and specific suggestions to strengthen SCOT, especially on the social structure (Klein and Kleinman, 2002; Edwards, 2003; Feenberg, 2003). Moreover, Hans Klein and Daniel Kleinman had more in-depth consideration of the missing structure in SCOT, which may also cause SCOT to ignore power inequality. Klein and Kleinman pointed out that state and resource accessibility are the key elements for effectively constructing the social structure of technology. They urged SCOT should present the state's influence on technology in its analysis. The state can exert high control or dominance over the social structure, especially when technologies are monopolized, whether naturally or not. Moreover, the country's industrial and industrial policies are critical structures that influence technology. Finally, the state is often involved in formulating technical standards, which can implicitly shape technological development (Klein and Kleinman 2002, 41-43).

Similar to Klein and Kleinman, Paul Edwards appreciated SCOT's contribution to dismantling technology determinism. Yet, he also agrees that SCOT needs to build linkages to social structure. Edwards (2003) conceptualized three levels of social structure: micro, meso, and macro. By pointing out that force, time, and social organization are the basic principles shared by the levels of social structure, he elaborates that the three basic principles form different functions and phenomena at different levels to varying degrees. For him, the technological infrastructure can effectively involve technology and society at micro and macro levels—local artifacts and technical knowledge for the micro level and ideology and modernity for the macro level. Therefore, studying technological infrastructure can contribute to the micro-level SCOT and reach the complex relationship between modern technologies and societies. According to Edwards, SCOT and even STS community should pay more attention to infrastructure and large-scale technological systems, such as transportation, energy, and information. Furthermore, he encourages researchers to study interactions between each level rather than only investigating technology and society at the individual level.

SCOT successfully built a stronghold for repelling technological determinism. However, this social constructivist stance faces criticism about missing structure consideration in a broader sense. Klein, Kleinman, and Edwards' critical yet constructive comments on SCOT bring new directions to the development of SCOT. Structuralizing the social or building interconnections between micro- and macro-level in SCOT enhances its ability to reconcile the gap between micro and macro or technology and society. The two methodological dilemmas brought up by Basu may be mitigated through Klein, Kleinman, and Edwards' constructive suggestions.

4. Structural Considerations of the Social Construction of Technological Systems

Yasushi Sato recognized the need to structuralize SCOT and tried bridging the gap between micro-technical practices and macro-societal values (Sato 2007). He explores the impact of social structural factors in the United States and Japan on the systems required for space engineering. This structural-focused analysis further pointed out the practice and cultural differences in space engineering between the United States and Japan.

Sato first discusses the factors that led to the success of America's Apollo program in the 1960s. During that time, a system engineering method was derived from coping with design, manufacturing, and testing amid the US military-industrial complex's rapid development. High degrees of mobilities and interchangeabilities of systemically designed parts, trained personnel, and engineering knowledge from the US system engineering benefit the program. Sato found that the US systematic engineering model fully reflects the culture of contractual individualism—meritocratic and contractual ideals. This culture not only helps system engineering to be accepted by US officials and workers but further expands the scale and diversity of system engineering.

Compared to the US, the practice model of Japanese space engineering, specifically engineering institution, inherit and share their general social and cultural structure so that their practice emphasizes people rather than systems. Japanese engineering stresses the leadership of senior engineers and informal communication. While there is a stable and human-ruled hierarchical order for engineering design and manufacturing, it is not easy to implement an individualistic contractual system. In regard to global scale competition, the social and cultural structure has made Japanese space engineering less able to compete with the United States. Although the Japanese authority recognized this gap and established another research institution to adopt the American system engineering model, Japan's dominant social norms have strong cultural power. Hence, the new institution faced many struggles and conflicts. In short, it is challenging to transplant the United States' experience directly to Japan. The process and direction of space technology development in the United States and Japan are deeply influenced by deep structural factors such as their countries, societies, and cultures.

For Thomas Hughes, the social factor of SCOT is not the only explanation for the development of technology, and it does not fully explain the development of large technological systems. He focuses on the long-term evolution of technological systems and social, political, and economic environments. The directions of LTS' evolution are multiple, and the original purpose may change or become more complex. The local context may also vary the evolution. The evolution of LTS also embodies the network concept, focusing on the interaction of people and things. The LTS is continuously and closely embedded in long-term development with society, institutions, organizations, behaviors, and culture. Moreover, it will gradually become obdurate and affect society and other technologies (Hughes 1987).

Frank Geels builds his approach on Hughes' technological momentum and challenges the stability of the technological system. By exploring under what circumstances a system may

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face turbulence, he argued that technological development should be understood through multi-level approaches, and the transformation of large-scale technological systems is mainly related to the formation of governance systems (Geels 2007). The governance system is not limited to influencing technical rules but also comprises social functions and values. Geels' analytical frameworks, multi-level perspective (MLP), contain three levels: niche innovations (niches), sociotechnical regimes (regimes), and exogenous sociotechnical landscapes (landscapes) (Geels 2002; Geels 2012). These three levels show structural differences from low to high, and the development of the three is influenced by each other.

Bruno Latour took another approach—ANT—differing from SCOT and LTS, to symmetrically approach people and things regarding social construction to resolve the society-technology dichotomy (Latour 1992). He pleads for a symmetrical method to people and things without explaining technological change with social factors or inquiring how society is affected by obdurate technology. He advocated that humans and non-humans should have the power to set norms or impose obligations on each other. Things affect social behavior: statutes, restrictions, and requirements. This new way of understanding the world refuses to explain with social or natural entities. Therefore, ANT provides a unique approach to technology and a new worldview.

The philosophical ambition of ANT can be concentrated on irreduction (Latour 1988). Latour proposed a new philosophy against the traditional assumption that reduces our world to human awareness and things outside it. Non-humans are neither inherently reducible nor non-reducible to others. Latour's standpoint of irreductionism indicates his incompetence with the social. From his point of view, "like the ether of physicists, the social of sociologists is an artifact caused by the same lack of relativity in the description (Latour 2005, 102)." Therefore, Latour criticizes the explanatory power of the social and treats it as an *explanandum* instead of an *explanans*. Since the social is kept stable and used to explain the technological change in Bijker's work, Latour disagrees that SCOT is part of the corpus of ANT (Latour 2005, 10-11).

5. Reciprocity and Rivalry between SCOT, LTS, and ANT

The constructive comments on SCOT's early achievements include social structure, technological system, and people things association. For Sato, Klein, and Kleinman, structuralized the social can enhance SCOT's ability to reveal the institutional, political, and cultural factors that contribute to the construction of technology. Furthermore, the values and ethics of technology, neglected in the previous SCOT analysis, can be restored to this structuralized version. Hughes, Edward, and Geels focus on the technological end. Technology in their studies is not a single artifact, like a bicycle, synthetic resin, or light bulb, but a set of machinery, industries, entrepreneurs, investments, and institutions. The growth, decay, and evolution of technologies and societies are disclosed by studying the fabric of LTS. Moreover, interactions amid micro-, meso-, and macro-level of the large infrastructure, such as electricity, water, or transportation systems, can be included in LTS. ANT or Latour's sociology of association provides another approach to investigating the relationship between technology and society. Latour advocates for following people and things without treating technology or society as a priori assumptions. Hence, researchers can symmetrically assess technology and society in a flattened world of humans and non-humans. Compared to SCOT and LTS, ANT is a different method for technology studies and a new way to think about the composition of the world.

For Bijker and Pinch, SCOT, LTS, and ANT all belong to the social studies of technology and share similar methods for studying technology even though there are cross-wired between each approach. These three approaches have common traits in three folds: research agenda, seamless web, and integration of empirics and theory (Bijker and Pinch 2012). However, Bijker and Pinch hold their stand in methodological relativism and further delineate boundaries between SCOT and other approaches. Bijker agrees with ANT's general principle of symmetry. Like archaeology, SCOT's analysis can be applied to a social group and investigate all the artifacts related to this group (Bijker 1993, 134). Yet, Bijker refuses to accept Latour's plea for irreductionism and argues it is inevitable to reduce a certain amount of the sociotechnical web to tell a lucid story (Bijker 1993, 127). In other words, SCOT still aims to explain technological changes, although resources for explanation are interactions between the relevant social groups.

Bijker recognizes that the LTS approach can incorporate meso and macro issues related to economic and industrial development or regulatory regimes for the technological system. He then includes the technological system as one of the units of analysis for studying technology. However, Bijker argues that the sociotechnical ensemble may be better when inquiring about boarder range relations between technology and society. Based on his argument, there are two differences between a technological system and a sociotechnical ensemble—a theoretical and an ontological edge (Bijker 2010, 66-67). While the technological system can be directed toward the technical side and use non-technical resources for understanding, the sociotechnical ensemble denotes an unsettled context of whether it should be treated as technical or social.

Circle back to SCOT itself, Bijker explicitly claims his attitude to previous criticisms and comments on SCOT. He is "less interested in the philosophical question 'What is technology?' than in the technical question 'How to make technology?', the political question 'How to use technology?' and the scholarly question 'How to study technology?' (Bijker 2010, 63)." Bijker turns to the early descriptive model on artifacts after his effort in developing analytical frameworks and concepts. In his recent studies about second-generation biofuels, Bijker and his colleagues analyzed the interpretive flexibility of biofuel in India through relevant social groups in the socio-economic-political landscape (Pandey et al. 2021). They identify discourses from various relevant social groups in different locations to inquire how the second-generation biofuel has been framed. The research can contribute to the policymaking process to facilitate inclusive and effective discourses coalition in multiple directions. In other words, Bijker and his colleagues' focus shifted from the scholarly question to the technical and then political one—from "how to study our technological cultures to the question of how to construct them (Bijker 2017, 315)."

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Therefore, as Basu pointed out in his review, operational difficulties still exist between Bijker's units of analysis: singular artifact, technological system, sociotechnical ensembles, and technological culture. The following SCOT practitioners may find it challenging to build linkages among each unit of analysis. Consequently, SCOT's research can only focus on a single unit of analysis with a vague technological culture in the backdrop. Moreover, it falls short of Edward's suggestion of studying technology, society, and their interaction within different scale levels. The explanatory dilemma comes along with the operational difficulties in SCOT. Bijker refuses to treat the social or the technical as a priori assumptions, let alone use them as *explanans*. Hence, power, which links to the closure and stabilization process, is not given as an intrinsic property. Rather, power is an *explanandum*.

6. SCOT's Next Step toward Constructing Technology

Despite his effort to build theoretical frameworks for SCOT, Bijker engages with the tasks of STS's practice and politics. He first affirmed that the STS under the Dutch tradition was indeed derived from a more political orientation in the first stage. The Dutch STS scholars in the second stage began to be dissatisfied with action-oriented research, only criticizing various ills or symptoms of technology but lacking a fundamental understanding of modern technology. So, Kuhn's The Structure of Scientific Revolutions and the German Starnberg group began to influence STS research in the Netherlands. Dutch STS scholars are concerned about how these theoretical studies can finally be fed back to social practice. In the third stage, empirical research on science and technology also began to develop, and technical research mainly focused on engineering and technology, as well as issues such as technology and society (Bijker 1988).

Therefore, in "Do Not Despair: There Is Life after Constructivism", Bijker believes that the research on STS still contributes to political practice (Bijker 1993). SCOT deconstructs the determinism of science and technology, reveals the construction process of technological systems, and interprets its elasticity and plasticity. At the same time, SCOT can provide a niche for STS to intervene in technological disputes and promote change. If we trace back to the research on the Sociology of Scientific Knowledge (SSK) orientation, through the principles of symmetry and impartiality, it is intentional or unintentional to support the inferior side in science and technology disputes (Scott et al. 1990). In the early 21st century, new emphasis was observed in STS that assessing technologies are socially constructed to asking more normative questions—like how technologies should be constructed (Hamlett 2003). Edward Woodhouse and his colleagues detailed this normative tendency in STS: scholar-oriented, policymaker-oriented, and activist-oriented (Woodhouse et al. 2002). Based on their analysis and advocation, scholar-oriented STS research results can either be used to fuel the science and technology social movement or policymaking.

Bijker's recent plea for bold modesty to construct the world and his engagements with the scientific advisory council in the Netherlands demonstrates his inclination toward the normative approach in STS. Like other activist STS scholars, he claims that researchers are intervening in the social construction process while studying the social construction of technology (Bijker 2017). This intervention is inevitable but also can be deliberate and planned. Bijker draws insight from Responsible Research and Innovation (RRI) to facilitate the rethinking exercise of SCOT. On the one hand, the deliberated interventionist approach in SCOT aims for a more responsible, sustainable, and justice development and use of science and technology in society. On the other hand, RRI-incorporated SCOT requires anticipation of desired future societies, reflexivity of researchers, innovators, and policymakers on their works, the inclusion of relevant groups, responsiveness to the need of society at large (Stilgoe, Owen, and Macnaghten 2013).

For Bijker and his plea for bold modesty in STS, science, technology, and knowledge are produced and interact with society through multiple social processes and institutional machinery. These processes and machinery shape democracy and translate values into governance. By strengthening the machinery of democratic deliberation and knowledge production, like advisory councils, peer review, journalism, public dialogues, and civil society, we can ensure our democracy functions inclusively and effectively. Furthermore, researchers, activists, or citizens, whether their positions or beliefs, need to seek a balance between confidence in their expertise and modesty when engaging with others (Bijker 2017).

7. Conclusion

"One can either debate the possibility of the sociology of scientific knowledge or do it (Shapin 1982, 157)." Steven Shapin made this provocative claim before he and Simon Schaffer published their Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life. This claim is still worth contemplating when we review the last thirty decades of SCOT and consider its possible future. Basu's review paper provides access to the past of SCOT and reminds us of the unsettled debates within SCOT's methodology. In a succinct manner, he points out the operational difficulties and explanatory dilemmas that inhibit SCOT from broadening its explanatory range and possess its foundation in social constructivism. To overcome these inevitable difficulties, Basu suggests that SCOT can do better for engaging with extant social theories, such as critical theories of technology or evolutionary economics.

Basu's review marks the previous paths and the unsettled debates in thirty years of SCOT's development. However, Bijker steps into the campaign of doing more SCOT rather than debating the possibility of it. His latest effort indicates SCOT is shifted from scholar-oriented to policy-maker-oriented and further activist-oriented STS. This move facilitates collaborations between SCOT and RRI and correlates with the Making and Doing projects (Downey and Zuiderent-Jerak 2021) in the last decades. Compared to Basu's emphasis on the unsolved difficulties and dilemmas in the past, Bijker moves forward to constructing sociotechnical worlds with bold modesty. It is also worth reviewing and evaluating this recent focus on reconstructing science and technology within SCOT and wilder STS. Meanwhile, we can inquire about this new development with Basu's contributions to observe how the operational difficulties and explanatory dilemmas have been bearing and transformed.

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