Bitcoin:
Co-Production of Software and Monetary Policy

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Review of STS Literature - Introduction to Co-Production

Science and Technology Studies (STS) is an interdisciplinary field that applies social scientific analysis to technology. The existence of a relationship between technology, society, and politics is clear and uncontroversial. STS scholars attempt to build theories and increase understanding of this relationship. The vast literature of STS consists of numerous case studies and an established vocabulary for classifying the analysis within. This essay talks about Co-Productive analysis as a bridge between the social constructivist and technological determinist extremes of the STS literature.

Formalized by Sheila Jassanof in "States of Knowledge: The Co-production of Science and Social Order", Co-Production of Science and Social Order is an STS framework that argues the co-dependence of science and society necessitate studying the development of society and the development of technology together. Social constructivists, such as Trevor J. Pinch and Wiebe E. Bijker argue that technology and scientific knowledge is a negotiation between various social groups. By contrast a natural or technological determinist like Thomas P. Hughes argues that technology is a metaphorical wrecking ball that changes society after introduction. By taking society and technology to be produced together, a Co-Productive narrative is entirely distinct and deserving of its place in the STS vocabulary.

It's important to understand that the aforementioned frameworks are terms used to describe narratives. Similar to how a choice that maximizes general good is called "utilitarian," a narrative ascribing a technological phenomena to inseparable social and technoscientific factors would be called "co-productionist." Jassanoff admits as much, stating that co-production *"should not be advanced as a fully fledged theory, claiming lawlike consistency and predictive power. It*

is far more an idiom" (Jassanoff, 2004, p. 3). It must be understood that arguments in favor of Co-Production argue not for its validity but instead for its utility.

Social construction asserts that scientific knowledge is socially constructed. Social groups are crucial in "deciding which problems are relevant" (Bijker & Pinch & Hughes, 2012, p. 22) and also when such problems are considered solved. After many cycles of negotiation between social groups the controversy reaches closure. Pinch and Bijker give a social constructivist analysis of the development of Bicycles. Their analysis talks about how many social groups, bicycle engineers, manufacturers, users, anti-cyclist groups, and women each had their own concerns. The STS term for a technology drawing differing concerns from separate groups is called interpretative flexibility. Each of these groups facilitated steps of variation and selection. The manufacturers vary their design in a negotiation between the social groups. This cycle repeats until closure. Once closure has been achieved, Bijker and Pinch discuss how the actual multi-directional model of bicycle development was morphed by social factors into a quasi-linear model (Bijker & Pinch, 2012).

This analysis is very enlightening, but is limited by the failure to acknowledge the clear influence of pure scientific innovation. What if no one had ever proposed the idea of a Bicycle? There would be no bicycles and thus one could make the argument that the entire movement was actually a technical innovation. In STS one has to be careful to avoid falling into such endless semantic arguments that could continue ad infinitum. The most salient point of the case study is the artificially linear history given by a history of bicycle manufacturing. We did not proceed from one model to another that was "objectively" better. The evolution consisted of negotiation

in which different groups fought from different positions. Clearly SCOT demonstrates a socially constructed knowledge of the history of technology.

Having fairly assessed SCOT, the technological determinists must have their space to show the merits of their analysis. Thomas Hughes is the foremost advocate of Technological Determinism. He asserts that a technology, after a certain time, becomes irreversibly embedded into society. Rather than being continuously molded by social groups, it is a metaphorical wrecking ball that leaves its own mark (Hughes, 2012). It overlaps with Social Constructivism to some extent in that it does afford society some short period of control over a technology. Reiterating a previous point, technological determinism and social constructivism are terms for categorizing analyses. Although the terms appear to overlap, a social constructivist narrative could not be mistaken for a technological determinist narrative.

We can use the case study of Bikes to elucidate this point. Rather than discussing the different social groups that influenced the development of the bike, one would focus on the technologies that influenced the development of the Bicycle. Bikes cannot be ridden easily on very uneven surfaces. Perhaps there was metallurgy that was necessary to manufacture the frames. Bikes are an echo of these past innovations. Next a determinist narrative of Bicycles would show how various anti-cycling groups were not able to overcome the utility of the bike. Despite the social factors pushing against the Bike, the Bike pushed itself forward.

Co-Productionist narratives show social factors influencing technology and technology influencing society. Jassanoff states that co-production includes both *"to avoid the strategic deletions and omissions of most other approaches in the social sciences"* (Jassanoff, 2004, p. 3). This is useful because Co-productive analyses can be more historical and include a complete

picture of events transpired. Revisiting the bikes example, a co-productive analysis would include women influencing the design and also how bikes' utility was able to overcome anti-bike advocacy groups.

Further than discussing both social and technical together, a Co-Productive analysis treats the technical and social as influencing each other. Jassanoff explains that "Science, in the co-productionist framework, is understood as neither a simple reflection of the truth about nature nor an epiphenomenon of social and political interests" (Jassanoff, 2004, p. 3). Science cannot be completely understood without also acknowledging the social impacts and vice versa. Co-Production combats the mono-causality of purely social constructivist or determinist explanations of socio-technical events.

This is illustrated most lucidly and practically by the tendency of different nations to define the "same" phenomena differently. This was explored in great depth by John Carson who examined the differing definitions of intelligence between the U.S. and France. The test for intelligence, called IQ, was predated by the "Binet-Simon test" invented in France. This knowledge traveled across the Atlantic to the U.S. Americans used these tests of intelligence as a proxy for assessing merit. In France it was always expected that merit based judgements would be the result of a holistic process of which a test for intelligence was a minor piece. This difference is clearly socially constructed. France is a more culturally homogeneous country which trusts its government to make choices about who will be given merit based opportunities. America could not be more different. There is a deep distrust of the state and desire to create "technocratic solutions for social problems" (Carson, 2004, p. 203). The American system is less trusting of the actors running it and thus an objective test is seen as a way to combat any bias.

Carson ends with a literary flare: “The merit of science, in the American case, did not fit the same needs in France; correspondingly, the science of merit flourished in one context, and withered in the other” (Carson, 2004, p. 203). This Co-Productive analysis of intelligence assessments and merit based acceptance offers a much more comprehensive picture than a purely social or technical analysis could offer. The two are too closely dependent.

Co-Production of Science and Social Order is a relatively new addition to the STS toolkit. A Co-Productive analysis, as presented by Sheila Jasanoff in “States of Knowledge: The Co-Production of Science and the Social Order,” treats knowledge making and social development as inseparable. Through 13 case studies it’s shown that Co-Productive analysis can offer significant insights into the ways science influences society and vice versa. In my view, the best example of Co-Productive analysis is the study of the differing views on merit and intelligence between the U.S. and France. One can clearly see that the knowledge of intelligence comes from both science and culture. On the other hand, a focused analysis on social construction or technological construction can ensure that those factors specifically are not inadvertently left out of a piece trying to highlight both. The development of Bicycles was a social phenomenon due to it being a mass market product. Pinch and Bijker highlight this effectively. At the same time, certain larger developments like roads can be described effectively as metaphorical wrecking balls leaving a mark outside of clear social input.

Bitcoin

Now that we are up to speed on the STS literature, this paper will show how Bitcoin stretches Social Construction and Technological Determinism, forcing a Co-Productionist view.

Bitcoin is an overlay network protocol that coordinates updates to a transaction ledger. Its design is a marvel of decentralized systems engineering and has grown despite the derision of many governments. One could write a narrative that emphasizes the frustrations of the Bitcoin community and make a case for social construction. Different groups are negotiating what money is and who gets to make the final choice. On the other hand, Bitcoin's purposefully decentralized nature has resisted, without breaking a sweat, every attempt to limit its use. One could focus on how Bitcoin's use of cryptographic identity, proof of work consensus, and decentralized architecture make it a quasi-living force of nature that humans have to contend with. Bitcoin is a conduit for social and political change, designed to be a wrecking ball to affect the change the community wanted to see. It's a technology that demonstrates how science and society influence each other.

Economics Background: Money

Money is a good that is agreed to be a medium of exchange in the marketplace. Most clear is money's utility in facilitating trade. Bartering is massively inefficient because a specialized economy will rarely have two actors wanting to exchange their specific products. Otherwise small and simple transactions become large trying to organize a fair trade. Less obvious is money's role in providing price information. When an entrepreneur thinks about producing a good, he will have to enter the market for inputs. The price of these inputs compared with the price of the completed good are crucial for determining if the good is actually desired by the market, or if it takes more labor than buyers are willing to give up. The complicated companies that bring together industrial labor, raw materials, engineering intellect, marketing,

and distribution could not exist without money because they would not be able to tell if their production is net producing or net consuming. Lastly, the amount of money belonging to each actor in an economy serves as proof of the labor they have contributed.

Given these uses, the ideal money has a fixed number of currency units and is transferable in arbitrarily large quantities without friction or surveillance. The latter point is for convenience and reducing friction in trade. The former is the most important. A currency with a fixed number of units is crucial to preserving price information and preserving the value of one's currency units. If an actor produces some number of products for x currency units and then another conjures x units for himself at no cost, the social contract is violated. From the perspective of the market, the actor who did no work and the actor that did work are the same. They are entitled to the same goods and services, despite one having contributed nothing. The result is that each currency unit buys less and the working actor is deprived of their purchasing power. The inherent unfairness of currency supply expansion is the key motivation for the creation of Bitcoin that, after the distribution phase, adds no new Bitcoins.

This sharply contrasts with the conventional view of monetary economics pronounced in J.M. Keynes' General Theory of Employment, Interest, and Money. Keynes argued that economists have a role in directing aggregate behavior through interest rates. Keynes' "Monetary Authority" would balance employment and inflation which he thought to be inversely correlated (Keynes, 177). The classical Laissez Faire approach, in his view, leads to hoarding that could provide massive growth if spent or invested. By inflating the currency, savers are forced to invest and spend thus creating growth that wouldn't have otherwise happened.

Keynes' approach and posture is antithetical to human freedom. He and his contemporaries in government show an unabashed entitlement to control financial decisions of citizens. Examine the sheer effrontery of a passage from page 161 of the General Theory.

> "The only radical cure for the crises of confidence … would be to allow the individual no choice between consuming his income and ordering the production of the specific capital-asset which … impresses him as the most promising investment available to him. It might be that, at times when he was more than usually assailed by doubts concerning the future, he would turn in his perplexity towards more consumption and less new investment. But that would avoid the disastrous, cumulative and far-reaching repercussions of its being open to him, when thus assailed by doubts, to spend his income neither on the one nor on the other."

The policy prescriptions offered are clearly self-serving. Bitcoin's view of economics, also referred to as the "Austrian School", leaves no room for the government or economists to decide how citizens financially act. The Keynesian view of economics portrays economists and the government as the bad tasting medicine we don't want but desperately need to save us from ourselves. The cost of non compliance with the solution is total expropriation of the value of savings through inflation.

Bitcoin is a reaction to Keynesianism and the industrialized inflation theft for which it provides intellectual and moral cover. The radical posture of the community can be understood

through the infuriating trope that those fleecing the masses are actually the most moral. Reading between the lines of the previous passage, Keynes acts as if he's giving a gracious gift by allowing the inept citizens to choose which investment they'll be forced to buy. By contrast, the exercising of one's right to save the money they earn is characterized as selfish gluttony.

The pseudonymous Bitcoin creator and the community that formed around him were unhappy, to put it mildly, with their labor being stolen by their respective governments. Their concerns and arguments were not new. Ludwig von Mises had already published *The Theory of Money and Credit* in 1912, one of the foundational texts of the Austrian School of Economics (Mises, 2013). This was almost 100 years before the Bitcoin white paper was published in 2008. Just shy of three decades before the Bitcoin whitepaper in 1984, F.A. Hayek stated in an interview "I don't believe we shall ever have a good money again before we take the thing out of the hands of government, that is, we can't take it violently out of the hands of government, all we can do is by some sly roundabout way introduce something that they can't stop" (Hayek, 1984, 00:19:23). Bitcoin is that "sly roundabout way … they can't stop."

Technical Background: Bitcoin

The Bitcoin developers sought to create money from first principles. It needs to have accounts and the ability to move funds between accounts. The design constraints, given their social and political motivations, demanded that no one entity would have any control over the transfers. So long as there is sufficient funds in the account, the transfer should be completed. This is achieved by comprising Bitcoin of many equally privileged nodes, each of which contain a copy of the same transaction ledger. Any single node dropping off does not affect the

operations of the remaining nodes. No one node can force any other to accept a transaction. The transactions fit into blocks are ordered with interlocking hashes and the accounts are protected with permissionless digital signatures.

When complying with the protocol, a node accepts a transaction block if the block hash meets a difficulty requirement. The process of adding transactions is intentionally difficult to impose massive energy costs on any attacker. Given that the process of properly formatting a block to meet the difficulty requirement requires a brute force approach, those who can produce the most guesses per second will control block production. The assumption is that most of the Bitcoin participants will want the network to continue operating as intended and their collective hash power cannot be overpowered by any malicious organization. Ironically, in the event of a serious attempt to overpower Bitcoin, the attacker would leave on their mining equipment to pay off the cost, further strengthening the network against attacks.

Nodes communicate transactions to each other using a network flooding technique. Each node has at least two peers. Nodes are allowed to change peers if a current peer is being uncooperative, unreliable, or exhibiting signs of malevolent behavior. When a transaction is introduced to one node, it sends this unconfirmed transaction to other nodes to be mined into a block. The peers of the original sender then relay the transaction to their peers, and so on. This pool of unconfirmed transactions is called the “mempool" since it is usually kept in computer memory. Transactions are able to enter the global “mempool” through the introduction to any node which makes censorship of Bitcoin impossible. It’s not just extremely difficult, but completely impossible. A nation would have to prevent any access to the internet.

Bitcoin accounts are not usernames and passwords in a database as is the case with most websites. Instead, Bitcoin protects its accounts with digital signatures. Each unspent transaction output (UTXO) can be opened if a very large number, referred to as the signature, is provided that satisfies a mathematical invariant. Without the private key, it would require infinite resources to provide a solution and steal someone's UTXO. Rather than having a centralized database check that a password value is correct, permissionless math is able to achieve the same effect.

Bitcoin, being a software technology, has a clear technical dimension. It uses novel proof of work consensus, network flood communication, and digital signatures to replace the more common centralized solutions that would have been shut down. Facebook, now Meta, attempted to launch a private currency called Libra. The French finance minister wrote that Libra was "a threat to national sovereignty" (Le Maire, 2019). Other world leaders piled on and the project was eventually suspended. If Bitcoin had not been designed to withstand extraordinary pressure, it would not exist today.

Software as a Conduit for Political Change

The decentralized architecture of Bitcoin allows for a deterministic interpretation. The delicately designed incentive structure moves participants in the network to defend it. These technical defenses have withstood extraordinary pressure from governments. These pressures quickly killed centralized alternative currencies like Libra. There is little anyone could do, barring an extinction level event, to stop Bitcoin from marching onward.

Satoshi Nakamato, the likely British but still unknown creator of Bitcoin, and the community that formed around him, took issue with the systematic expropriation of their wealth. They saw that this was misdiagnosed as an issue of policy and that the fiat system of money is architected to enable civilization scale expropriation of wealth. The approach of using a decentralized protocol to peacefully assert their rights has been vindicated. Bitcoin unequivocally shows that software is an incredible tool for asserting natural rights. It improves on revolution and protest by simply delivering the desired benefits peacefully.

There are other notable projects like PGP, TOR, and Nostr that are focused on separate problems but all take the same software based approach to solving them. PGP and TOR are tools that allow users to communicate securely and privately. Nostr is protocol inspired by Bitcoin that uses digital signatures, rather than account credentials, for online identity. The servers that offer content publicly are only providing bandwidth. If a server bans a creator, the creator maintains his audience, since they are looking for a public key, and just need to find some other server on the planet that will serve his content.

Software is ultimately a liberating technology. This pattern of software being used to assert natural rights illustrates the coproduction of society and technology. Bitcoin and none of the technologies briefly discussed above can be described as simply a social phenomenon. Nor can they be described as simply a technological innovation like graphics processing units. They are both social and technological phenomena. Bitcoin and these aforementioned projects give us reason to be optimistic about the future of liberty.

Conclusion

Bitcoin is a novel technology that has spawned an entirely new class of software: Blockchains. The way that it's been able to achieve such dramatic political change without force or asking permission is even more groundbreaking. Sociological analysis of this phenomena requires an appreciation for the social motivations for creating technology and the ways in which this technology can be unleashed in a manner that is difficult to regulate. Hopefully STS scholars will recognize Co-Production as a valuable tool for conducting sociological analysis of technology and is particularly required in cases where software is being used as a conduit for political change. Further, hopefully engineers realize certain problems that might appear out of reach may just require some carefully written C++.

References

Bijker, W. E., Hughes, T. P., Pinch, T. (2012). *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology (Anniversary ed.).* MIT Press.

Bijker, W.E., Pinch, T. (2012). The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. In Bijker, W. E., Hughes, T. P., Pinch, T. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology (Anniversary ed.).* MIT Press.

Carson, J. (2004). The Science of Merit and the Merit of Science. In Jasanoff, S.. *States of knowledge: The co-production of Science and Social Order*. Routledge.

Hayek F.A. (1984). *F. A. Hayek on Monetary Policy, the Gold Standard, Deficits, Inflation, and John Maynard Keynes* [Interview]. Cato Institute. https://www.youtube.com/watch?v=EYhEDxFwFRU

Hughes T.P.. (2012). The Evolution of Large Technological Systems. In Bijker, W. E., Hughes, T. P., Pinch, T. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology (Anniversary ed.).* MIT Press.

Jasanoff, S. (2004). *States of knowledge: The co-production of Science and Social Order*. Routledge.

Keynes, J. M. (2012). *The General Theory of Employment, Interest, and Money.* Cambridge University Press

Le Maire, B. (2019). Facebook's Libra is a threat to National Sovereignty. https://www.ft.com/content/bf2f588e-ef63-11e9-a55a-30afa498db1b

Mises, V. L. (2013). *The Theory of Money and Credit.* Skyhorse Pub.

Nakamoto, Satoshi (2008). *Bitcoin: A Peer to Peer Electronic Cash System.*

https://bitcoin.org/bitcoin.pdf