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Can Blockchain Solve the Hold-Up Problem for Shared Databases?

White Paper

Economics of Emerging Technologies

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PRYSM GROUP

Prysm Group is an economic consulting and corporate learning firm focused on emerging technologies. Founded by Harvard PhD economists, the firm assists corporate clients, governments, and startups in the adoption and implementation of blockchain, digital asset, and metaverse technologies through its advisory and educational services. Prysm Group's areas of expertise include incentive design, monetization strategy, and governance for both open and closed blockchain and metaverse platforms. The firm delivers its executive education programs in partnership with the Wharton School.

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Introduction

In December 2018, major news outlets reported a feud between the Democratic National Committee (DNC), the national arm of the United States's Democratic Party, and the various state-level Democratic party organizations.[1] Tom Perez, the chair of the DNC, had called for a change in how the party manages its voter data. This data had historically been collected and controlled by the various state parties, interest groups, and campaigns in independent databases, which did not allow for real-time sharing of data among these organizations. Perez believed that this data siloing contributed to the party's election losses in 2016. He felt strongly that a change in how this data was managed might give them an advantage against the Republicans in the upcoming elections.

Perez called for the creation of a data trust similar to the one used by the Republican National Committee. This new system would be a for-profit, independent organization that licensed and compiled voter data from the various organizations into one central database. Independent party leaders, such as former Vermont governor Howard Dean, would lead the new organization, and party donors such as LinkedIn founder Reid Hoffman had been in talks to contribute funds. The state parties, the national party, and party allies would all have real-time access to use the data for political activities.

While the existence of a wholly centralized database had tremendous potential to help the Democratic party at both a state and national level, the state parties were not keen on this plan. There were two primary issues that divided sentiments. The first concerned the ongoing control of data. State parties had invested significant resources to collect this data, and they did not trust the national party and outside groups to effectively manage this prized information. Trav Robertson, chairman of the South Carolina Democratic Party, said, "I'm not willing to give up one of our most important tools to a group of people who have never even worked on a campaign before."[2]

The second concern was financial. Some state parties earned revenues through selling their voter data directly to campaigns. If the database was centralized, it was not clear who would be the recipient of any profits that the new data trust generated. State-level parties suspected that the investors in this new master database could have financial motives unaligned with the best interests of the party. While there were discussions that the state parties could get a share of any profits, they could not be guaranteed them.

To date, the DNC and the state parties have engaged in over eighteen months of intense negotiations on this topic. Despite the obvious and publicly acknowledged benefits that a shared database would bring, only preliminary steps, including some signs of progress in early 2019, have been made towards establishing one and realizing the value from collaboration.[3]

While the benefits of launching a shared database are clear, successfully implementing one remains a challenge.

The Persistent Challenges of Shared Databases

This is one very public example of a problem that is pervasive across industries and organizations. As the importance of big data grows in business and government, and companies' tools for utilizing data improve, the benefits of sharing data across organizations will increase. Implementing a data sharing consortium or industry-wide database is a shared goal in a variety of sectors. By sharing a single database rather than storing data in silos, industry collaborators can more efficiently transact, reduce redundancies in recording and transmitting information, determine the provenance of goods, and spot patterns and trends. Industry-wide databases could help the pharmaceutical industry to combat the multi-billion dollar global market for counterfeit medicines[4] and the luxury goods industry to take on the $450 billion global market for counterfeit luxury goods.[5]

While the benefits of launching a shared database are clear, successfully implementing one remains a challenge. A critical barrier deterring these valuable systems from being created and used -- which was adequately illustrated by the Democratic party conundrum -- is an economic problem known as hold-up. This problem occurs when, in a partnership or consortium where multiple entities bring together valuable assets to do business, one or more firms must make relationship specific investments. These are investments that are worth more in the partnership than outside of it. The hold up problem states that a firm that makes relationship specific investments will be put in an unfavorable negotiating position later on, allowing the other partners to take advantage of, or hold-up, the firm making the investment. As a result of the hold-up problem, organizations and firms may choose not to invest in these potentially profitable relationships, rather than risk being held up.

Shared databases that rely on traditional technologies can be highly subject to the hold-up problem. Many require the adoption of software and hardware systems that cannot be used outside the partnership. Further, participants may be required to contribute data into a shared format allowing for cross integration with other partners, but that may make it more difficult to pull their contributed data back out of the system thereafter. Most importantly, legacy systems require an administrator who will own and control the shared database itself.[6] Consequently, these relationship specific investments are highly subject to hold-up by that administrator.

Blockchain Holds Tremendous Promise for Alleviating Hold-Up

Blockchain is a tool that holds tremendous promise for helping data consortia to overcome the hold-up problem. Blockchain and Distributed Ledger Technologies allow for unified shared databases to be maintained in a decentralized manner, with no principal administrator. The changes in property rights and control introduced by blockchain's distributed structure are critical ingredients to lessening the loss from hold-up. From supply chain management to the healthcare industry, data sharing consortia are forming to use blockchain to implement shared databases that have long been needed but were previously unattainable.

The format of this paper is as follows. Section 2 explains the economics of the hold-up problem, provides examples from the non-blockchain world, and outlines the three economic drivers of hold-up. Section 3 highlights how hold-up, with respect to shared databases, is a significant economic problem that blockchain can be used to alleviate, and identifies the challenges of addressing the three drivers in this context. Section 4 discusses the general economic benefits of blockchain and identifies the potential and the limits for blockchain to address the three drivers. Section 5 concludes with steps to aid corporate leaders looking to use blockchain to address hold-up in their industries.

The Hold-Up Problem

The **hold-up problem** is an important result in the field of economics called Contract Theory. Before delving into the details, consider a classic example.

Example: The Coal Mine and the Power Plant

A power company, PowerCo, is choosing a location to build its newest power plant. The power plant requires coal in order to make electricity. Wherever the plant is located, it will need to pay to have coal shipped from one or more coal mines to the plant. The executives of PowerCo want to determine the best location for their new plant.

At first, it seems obvious how the PowerCo executives should proceed: they should locate the power plant in immediate proximity to the coal mine that can most cost-effectively provide the quantity and quality of coal that the plant requires. Then, the plant will buy the coal it requires in bulk from that mine, effectively minimizing shipping costs.[7]

But, it turns out that this may not be the best choice for PowerCo. Why not?

PowerCo will be investing a great deal of time and money in building the plant, and it will be counting on the coal mine to keep up its end of the bargain by providing the previously agreed upon amount and quality of coal. PowerCo will no doubt want to sign a long-term contract with the coal mine before building the power plant, stipulating the terms of the coal-purchasing relationship. PowerCo would hope that, as long as both participants abide by the terms of the contract, the relationship will run smoothly.

But, there may be circumstances that arise that are not accounted for in the contract. Maybe the coal mine finds that the coal depletes in quality sooner than anticipated. Or, the cost of mining the coal grows at a higher rate than expected, rendering the contract unsustainable for the coal mine. There are many reasons why PowerCo, or the coal mine, might want to revisit the contract they previously signed after the plant has been built.

This is when the choice of location for the plant becomes important. When PowerCo and the coal mine sit down to renegotiate, the coal mine knows that PowerCo has limited alternative options for sourcing coal. Shipping coal from an alternative, distant mine is expensive, and relocating the power plant to a new location is even more costly. As a result, the coal mine has significant leverage over PowerCo. It can use this advantageous bargaining position to extract profits and money from PowerCo. PowerCo is, quite literally, being **held up**.

More than being a threat to PowerCo's business viability, this imbalance of power leads to distrust in the business relationship. If the coal mine asks to renegotiate a previous contract, they could have genuine intentions, driven by needs to adjust the ongoing situation to increase profits. However, the reason for the negotiation could also be untrue, exaggerated, or even invented to capitalize on this imbalance of power. The mine may want to exploit the captive audience that the plant provides. It will be difficult for PowerCo to know which condition is occurring without significant effort and cost.

As a result of these risks, PowerCo's leadership may anticipate the downfalls of becoming so dependent on a single mine, leading them to locate the new plant equidistant -- but further away -- from several mines. While this new position is better for PowerCo, it results in higher shipping costs and a lower combined profit from the business relationship. The threat of the mine holding up the power plant results in a loss of profits from trade. This situation is unfavorable, yet, it's unfortunately not realistic for the power plant and a single mine to carry out a partnership reliant on unconditional trust.

Contracts and Contractual Incompleteness

Understanding the hold-up problem requires understanding several fundamental concepts in the economic study of contracts. Contracts are a staple in our daily lives. When we are negotiating terms of employment, a business partnership, or the purchasing of a piece of property, for example, we rely on contracts to specify what each person or organization participating is agreeing to, as well as the consequences of disobeying such agreements. For example, a contract between a business and an employee might include the scope of work that the employee is agreeing to complete, the compensation he or she will receive in exchange, and reasons that each side will be allowed to terminate the agreement.

Contracts are useful when economic transactions are complex and occur over extended periods of time. Some transactions -- called spot transactions -- do not require a contract. If a person is buying fruit at a farmer's market, they do not need a contract. The produce is concrete, they can see it, touch it and pick it out themselves. Once chosen, they pay immediately in cash, and the seller and buyer can mutually agree or disagree on the success of the transaction. But, if the buyer opts to pay for fruit upfront today that they will receive next month, they will most likely want an agreement - a contract - that stipulates what will happen for each of the different scenarios that may occur in the scheduled fruit delivery. In this situation, the future fruit quality is not presently tangible; it cannot be immediately evaluated by the buyer. Adding a future delivery element creates risks and uncertainties that a contract is designed to alleviate. The contract is a (hopefully) legally-enforceable agreement of a set of contingency plans that all participants agree to, intended to be mutually beneficial to everyone involved.

Within economics, contract theory focuses on the design of contracts and how contract design can impact the organization of markets and firms. This field originated in the 1930s, but accelerated in the 1970s. Nobel prizes have been awarded to five laureates for work related to contract theory, most recently in 2016.

Among the major concepts in the field of contract theory is contractual incompleteness. It is a fundamental tenet of contract theory that all contracts are inherently incomplete. When a contract is being drafted, it is impossible to list in advance every potential contingency. Further, it's difficult to predict what all the participants would like to see happen even in scenarios that can be anticipated. If the participants tried to think of every incidence that could occur and how to handle it, the contract would be long and unwieldy. Moreover, despite this effort, there would always be unknown circumstances beyond foresight that may need to be dealt with later on.

Even if the contract does stipulate what should happen in every particular circumstance that arises, it may not be fulfilled as originally anticipated. One possibility is that all participants may agree that they would prefer to do something else -- to renegotiate -- rather than abide by the terms of the contract. Another is that one or more of the participants may find it too difficult or costly to enforce the terms of the contract by appealing to a court or arbitration. For example, if a landlord fails to return a security deposit that he contractually agreed to refund, it may not be worth the legal fees for the tenant to hire a lawyer and take the landlord to court. Although in these situations a contract has technically been signed, it must be periodically revisited as the business relationship progresses. Contracts are living documents that cannot be subject to "set and forget."

A Framework for Hold-Up

Hold-up, a key implication of contractual incompleteness, was introduced to the economics literature by Sanford Grossman, Oliver Hart, and John Moore in the 1980s and developed over subsequent decades.[8] In 2016, Hart won the Nobel Prize for his work on incomplete contracts.

The hold-up problem arises when this concept of contractual incompleteness is combined with the need to invest significant resources in a business relationship, and in particular when those investments are uniquely valuable within that specific partnership. The example of the coal mine and PowerCo contains the three essential drivers of the hold-up problem:

Distributed Property Rights

Two or more individuals or organizations own assets (property) that they want to use together to produce something of value. Neither organization can produce the thing of value on their own.

Contractual Incompleteness

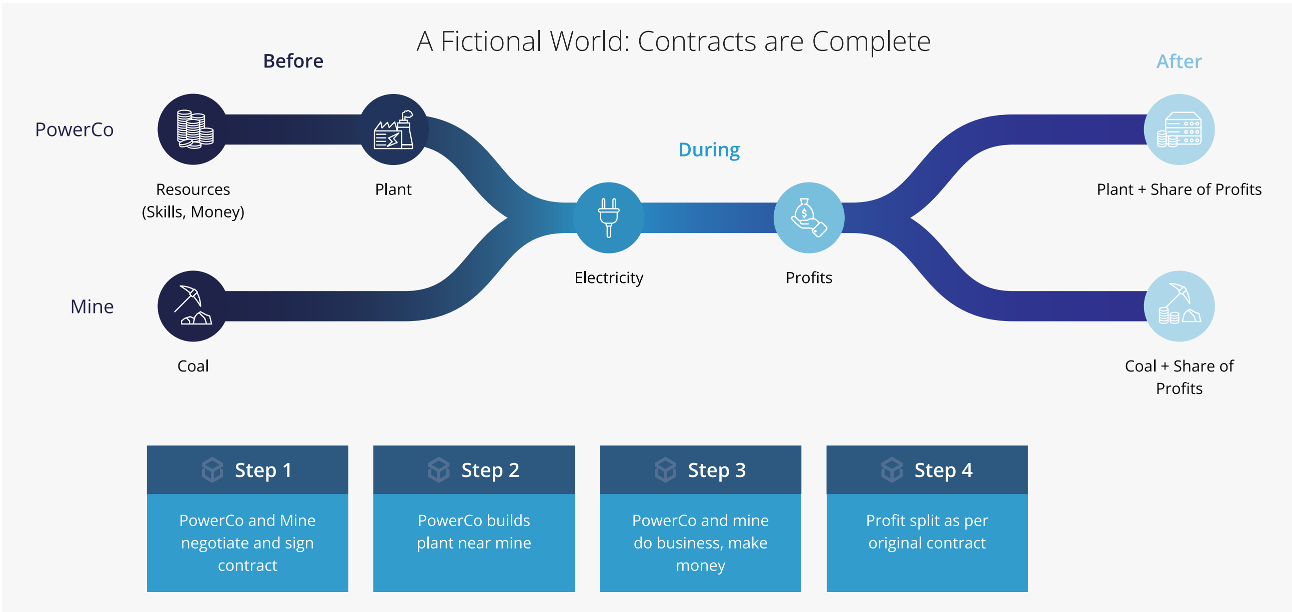
The participants cannot write a contract that stipulates what will occur in every possible future contingency once they choose to do business together.

Relationship-Specific Investment

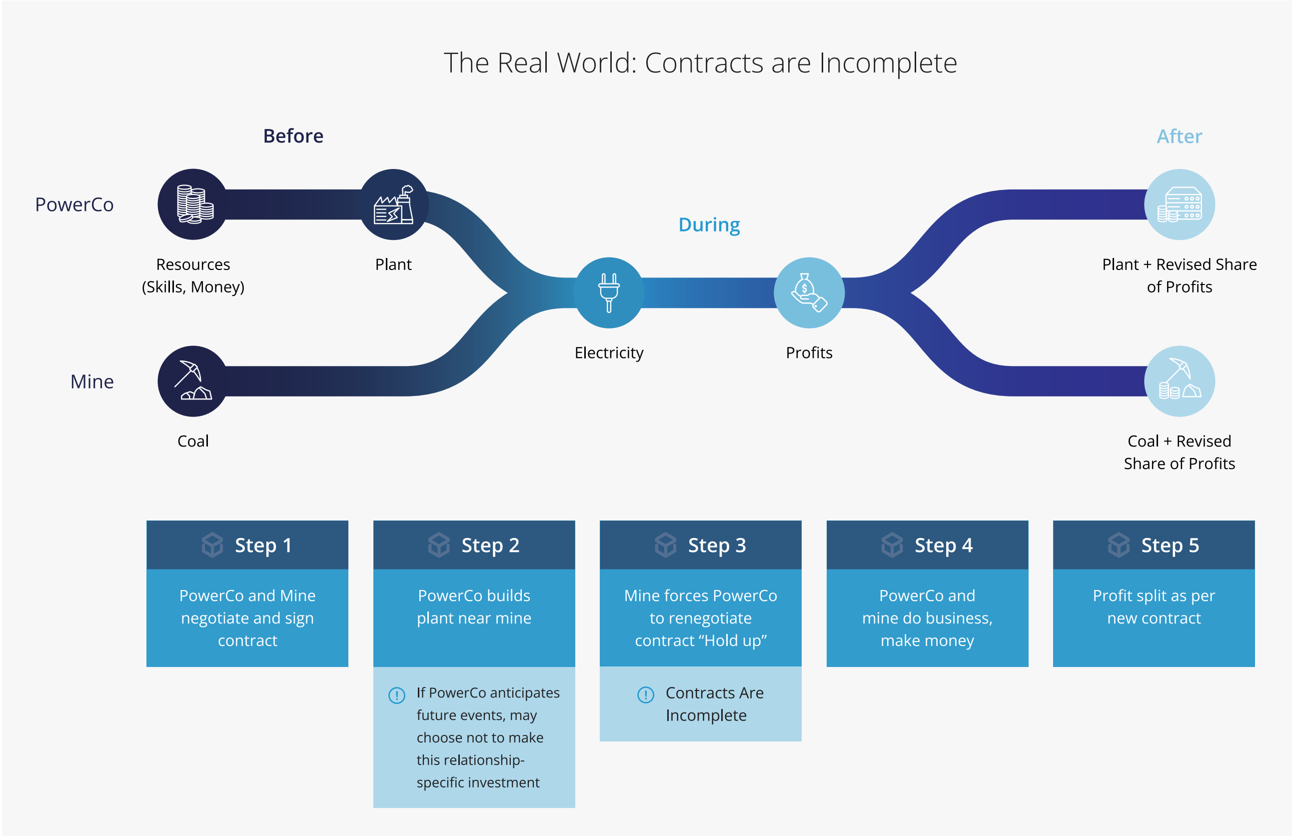
Before the participants conduct business, one of the parties must invest a significant amount of money in tangible or intangible assets, such as manufacturing facilities or human capital, that provide limited value outside of this particular relationship.

A critical element for understanding hold-up is grasping the concept of the **outside option**. In any negotiation, the bargaining position of each participant is determined in part by what happens if a participant walks away from the negotiation altogether. The better this outside option, the more they can demand within the ongoing negotiation process. In the case of a salary negotiation, for example, an employee's outside option is the best job offer they can receive outside of the current position on the table. Likewise, in the case of PowerCo and the coal mine, PowerCo's outside option is to source their coal from a different mine.

Consider how these three essential drivers combine to generate the hold-up problem, using coal mine and PowerCo as an example.



Suppose that the coal mine and PowerCo lived in a fictional world in which contracts are complete. PowerCo and the mine can write a contract that covers every possible future event and circumstance. In this world, the business arrangement would be straightforward (see Figure 1). PowerCo insists that it and the coal mine sign a contract stipulating how they will split profits before the plant is ever built. At the time this negotiation takes place, PowerCo has a very strong negotiating position because it has a great outside option; it can choose almost any mine to partner with. If PowerCo does not like the offer on hand, it can take its money and resources and invest them elsewhere. Therefore, it has the leverage to negotiate an attractive split of the future business proceeds with the mine. Once this agreement is reached and the contract is written, PowerCo can construct the plant very close to the mine, confident that its investment will be recouped via the contract that has been signed.



Now consider the case of the real world, in which contracts are incomplete (see Figure 2). PowerCo would like to reach an agreement with the mine about how proceeds will be split before ever building the plant. This gives PowerCo a strong bargaining position to make a good deal because, as discussed above, it has many other options to put its resources to good use. But, no matter how detailed or well-thought-out the original pre-investment contract, there will always be some circumstances in which the contract will need to be revisited after the plant is built because contracts are incomplete. At that point, the relationship-specific investment of building the plant near the mine implies that PowerCo's outside option in negotiation is even worse than before. Rather than owning highly-mobile resources like money and time, PowerCo now owns a plant near one mine and far away from others. This plant is very valuable when working with the neighboring mine, and much less valuable when working with mines further afield. This worse outside option means PowerCo can be held up by the mine, which has the leverage to demand a higher fraction of the business proceeds than was originally agreed upon.

As mentioned, in the absence of solutions to hold-up, a company in PowerCo's position will choose not to make the relationship specific investment of locating next to the mine. Instead, the plant is likely to choose a central location between multiple mines with whom PowerCo can negotiate on an on-going basis. While this reduces the impact of hold-up on PowerCo, it also results in higher costs for the plant and a less-profitable partnership than if PowerCo could have partnered with a single mine.

Levers for Reducing the Impact of Hold-Up

Solving the hold-up problem means empowering firms to make investments that will increase value creation and joint benefits from partnerships. In the case of PowerCo, this would mean finding a way for the plant to be located next to a mine without sacrificing negotiating power. There are three potential avenues for reducing hold-up, corresponding to the three components of the hold-up problem:[9]

Vertical Integration

A frequently-proposed solution to the hold-up problem is (vertical) integration, whereby the mine buys the plant (or vice versa). Under common ownership, there is no longer any incentive for one party to be adversarial to the other.

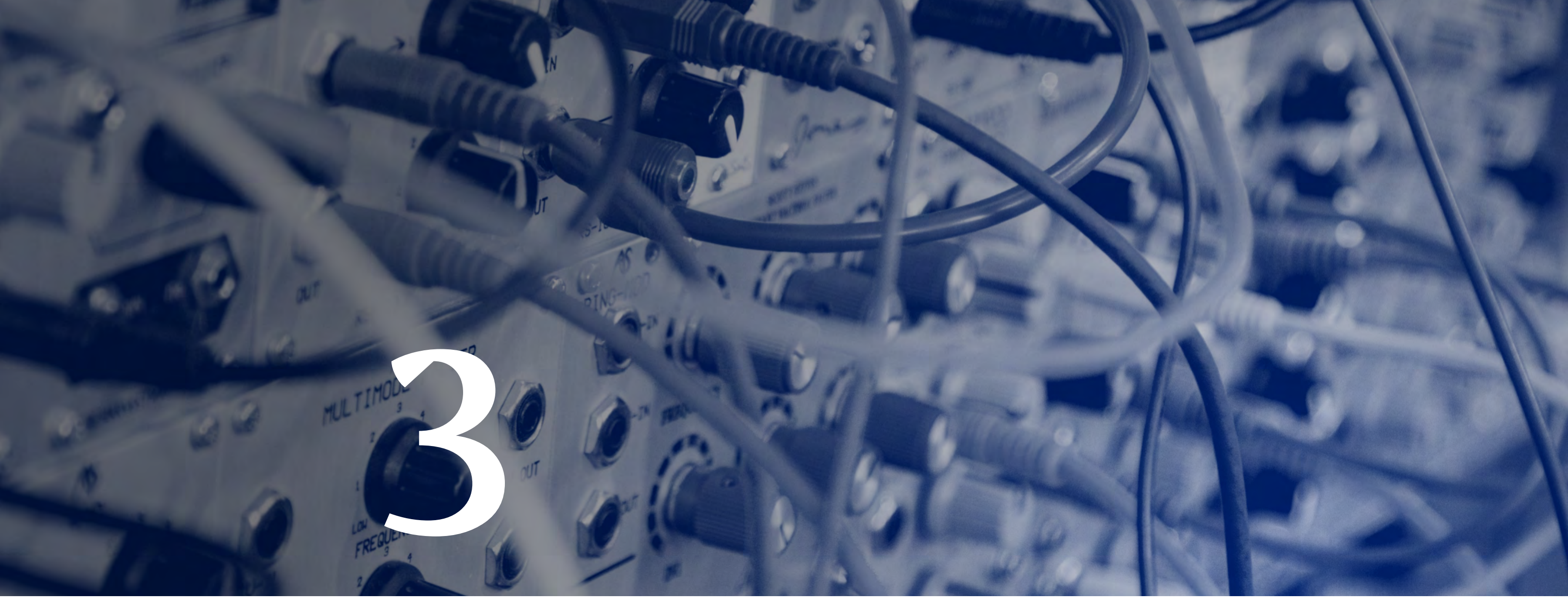
Redesigned Renegotation

Some solutions to the hold up problem revolve around the way the contract is written, with a particular focus on how they deal with renegotiation processes.

Improved Outside Option

The last potential solution is to improve the outside option of the firm making the investment by increasing the value of that investment when put to other uses.

The possibility of leveraging one or more of these avenues in order to overcome the hold-up problem is very context specific. In many cases some channels will be completely closed. For example, integration would be unlikely to work in the context of shared databases. Similarly, reducing the specificity of investments isn't likely to happen for power plants.



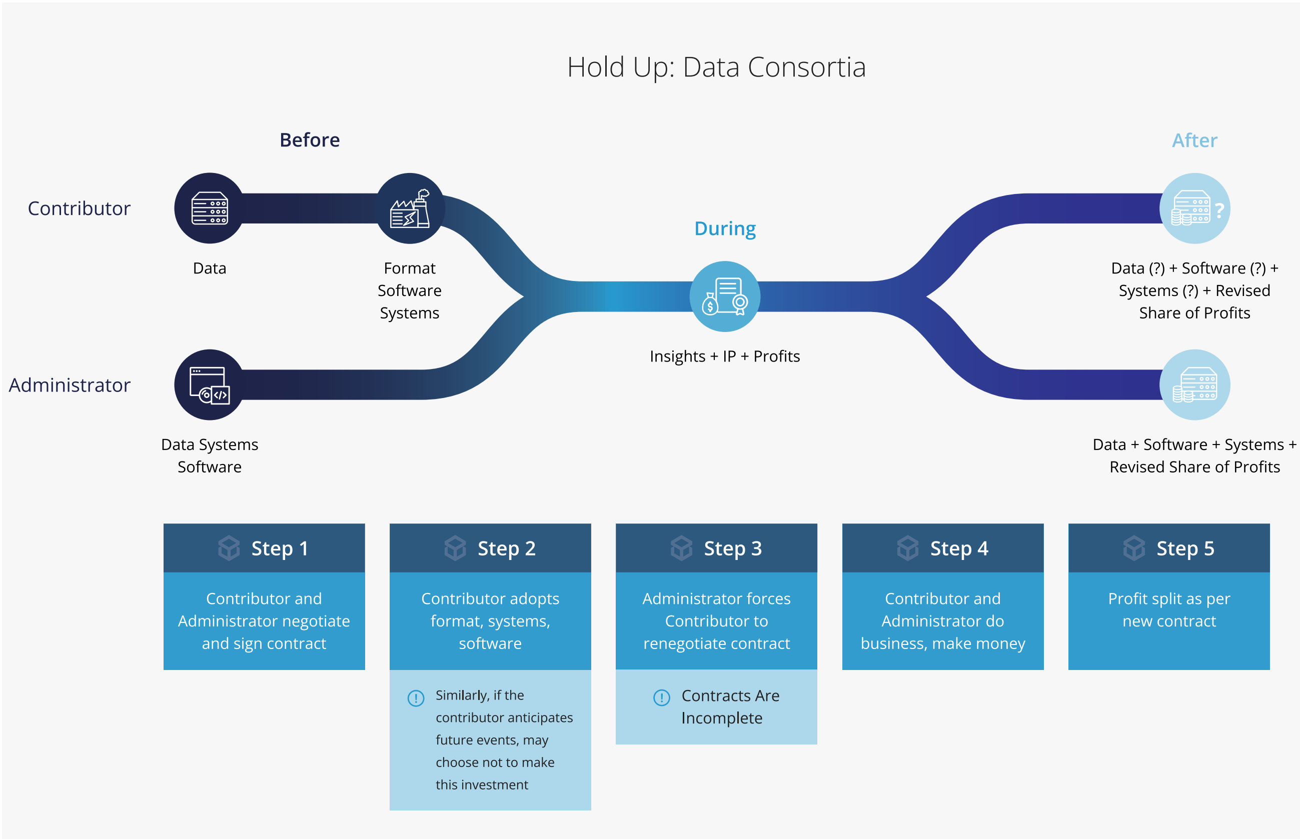
Shared Databases and the Hold-Up Problem

As organizations explore how data can add value to their activities, they frequently find -- as did the state Democratic parties and the DNC -- that data holds more value if combined with data from other organizations. Thus, they face the challenging question of how to share data and enter into collaborative environments while effectively maintaining full control and ownership of their information. When the issue of data control is combined with the extensive investments in hardware, software, and business processes required to organize, analyze, and utilize data effectively, the hold-up problem becomes a constant concern.

In the past, organizations seeking to combine and share data with others were frequently required to enter into a collaboration in which multiple organizations contributed data to a database that was controlled by a single entity. This entity could be one of the organizations contributing, or it could be an additional party. Entering such a collaboration required relationship-specific investments that might include buying software or hardware, adopting new systems and processes, and even converting data into a new, common format. These shared data projects suffered from all of the drivers of the hold-up problem.

Shared Databased: Hold-Up, Compounded

Data is a different type of resource than most others used in economic relationships. First, data has almost no cost to replicate: once a single copy of a data set exists, additional copies can be made at virtually zero marginal cost. Second, data has value only if it can be read and interpreted. A data file alone is of little use if those holding it cannot see the values contained in the data and interpret those values in a meaningful way. Both software and context are required to make data meaningful. These distinct characteristics complicate the many ways in which hold-up can occur.



The property rights for data are much more convoluted than they are for physical assets, complicating the issue of **distributed property rights**. In a traditional hold-up problem, such as the coal mine and PowerCo, property rights are relatively straightforward. PowerCo owns the plant, the coal mine owns the mine (and coal), and if the business relationship dissolves, each organization retains the property it entered with. Data is an entirely different beast. Once a firm's data is added to a shared database, the database administrator may become the owner of a copy of that data. Imagine if, once PowerCo built a plant next to the mine, a copy of the plant would remain there (and available to the mine owner) forever, even if PowerCo left. This dramatically reduces the negotiating leverage of the contributor when threatening to leave the collaboration. Further, although a contributor to a data collaboration may be able to leave the collaboration with all the data they contributed, the data may have been converted into a format that is no longer readable without proprietary software, rendering it much less valuable (or even useless). The contributor may be able to maintain a separate "clean" copy of the data, but this requires significant additional effort and investment.

Second, the possibilities for incomplete contracts expand when discussing data. Because one central party hosts and administers the database, all other organizations in the collaboration may have to share (copies of) their data with this central administrator. It is nearly impossible, once the data has been shared, for its owner to write a complete contract stipulating every condition for how the data will be used, who it will be shared with, and how the profits from the collaboration will be split. Even if agreements like these are reached in advance, they might be costly or impossible to enforce, rendering them functionally useless. The fact that data can be copied so easily compounds this problem. As anyone who has tried to get material removed from the internet knows, controlling the usage rights of freely available electronic material is next to impossible.

Finally, data collaborations require significant relationship-specific investment. As mentioned above, each organization has to procure and adopt the hardware and software that the collaboration agrees upon in order to ensure that separate teams can contribute to a fully compatible and integrated system. These tools have both high monetary and implementation costs and may take years to incorporate into an already complex business practice (see the EMR example discussed below). They may even be proprietary assets of the database administrator. Each time a contributor adds a piece of data to the collaboration, they are making another relationship-specific investment in the format, software, and structures being used.

Together, these forces render hold-up problems in data collaborations that are quite complex. Not only are contracts more difficult than usual to enforce, but contributors in a collaboration may not even be able to guarantee that they can leave the collaboration with the property that they entered the business transaction with. An organization unable to retain and leave with their data contribution will be in an especially disadvantageous bargaining position in any contract renegotiations they may face.

Prior to blockchain, the options for forming a data collaboration were far more restricted. An organization could maintain its own database, thereby foregoing the benefits from collaboration.

Alternately, some type of federated database system could be used, in which a central entity developed an interface by which multiple fragmented databases could be accessed through a single portal that would need to be developed and administered by a central entity. Which option was chosen depended on the relative benefits provided by each. Given the option of contributing to a shared data infrastructure administered by another organization, firms frequently chose to forego group collaboration. Unfortunately, this meant abstaining from the benefits of combining data with others.

Shared Databased: Hold-Up, Compounded

The Democratic party example in Section 1 illustrated how hold-up can impede economic value creation in the context of shared databases. All three of the drivers of hold-up contributed to the DNC and the state parties' impasse in data collaboration.

Central to the dispute between the DNC and the state level parties was contractual incompleteness. The state-level organizations wanted two things: control over who could access the new database, and a guaranteed share of the profits that were generated. But, given the technology at that time, it was impossible for the state parties to write an enforceable contract with the DNC to guarantee these terms in advance. If they gave up their hard-earned data without such a contract in place, they would no longer be able to negotiate for the pecuniary and non-pecuniary benefits they wanted from their contribution.

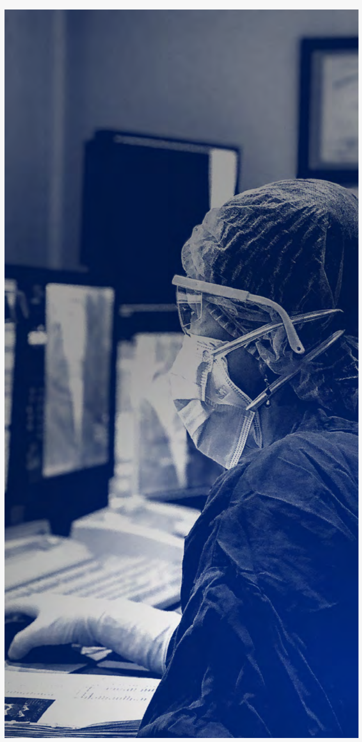
Adopting the DNC's central software and data structures would be a significant relationship-specific investment that could threaten the data sovereignty of the state parties. This investment threatened their property rights: they might not be able to regain ownership of their data in order to leave the collaboration, or their data might be in a format that was no longer useful on its own. Further, maintaining a separate database with the shared information would be a significant additional cost.

Given the inability to contract in advance, participating in the DNC's central database continues to be a significant risk for the state parties. Instead of working together to generate a sorely-needed party resource, the state parties and the DNC have instead engaged in years of unproductive haggling.

Shared Databased: Hold-Up, Compounded

Another, more complex example of the costs of hold-up comes from the world of medicine. In 2009, through the HITECH Act, the United States government instituted incentives for healthcare practitioners and hospitals to adopt Electronic Medical Records in place of legacy paper filing systems.[10] Proponents of Electronic Medical Records (EMR) systems claimed that they would provide a unified data infrastructure, allowing the seamless electronic transmission of medical data and histories across providers that save time and money. At the same time, patient data could be aggregated and mined for valuable medical insights, and fraud and HIPAA violations would be reduced. The adoption incentives, distributed by the Centers for Medicare and Medicaid Services, reward levels of meaningful use.[11] The requirements for meeting meaningful use were designed to escalate over time, beginning with keeping record of certain types of information in 2010 and expanding to include the ability to transmit categories of information to certain stakeholders, such as patients and pharmacies.

Ten years after the HITECH Act, the state of EMR in the US healthcare industry is still far from reaching its goal of seamless data transmission.[12] The independently maintained EMR systems of approximately 4,500 hospitals[13] and over 350,000 provider offices[14] in the United States continue to have limited interoperability. In 2017, the 4,520 hospitals alone reported using EMR software from 186 different developers.[15] It wasn't until 2018, nine years after the HITECH Act, that the Veterans administration adopted an EMR system[16] that was compatible with the Department of Defense's EMR system. Moreover, individual hospitals often invest significant resources in customizing their EMR implementations, resulting in systems that may not be compatible with others provided by the same supplier.[17]



EMR Basics

EMR systems are implemented by medical practitioners at the office or hospital level to record patient records and information in digital files. An EMR system for a medical practice has two components: software and storage. The software allows doctors, nurses, and administrators to enter data into a patient's record using digital document forms. These digital forms can then be accessed by professionals and patients alike to view the information within. The patient records are kept as digital files that can be stored on computer servers, whether in the cloud or within on-site servers. These systems are typically provided to practitioners by specialized information technology companies who develop and maintain the digital patient record software, and who may also provide cloud storage services for the records.

The costs of this fragmentation are steep. While many factors have been highlighted for contributing to the disappointing state of the EMR ecosystem, including poor user-friendliness, system shut-downs, software bugs, and the unwieldy amount of data that the regulations require from practitioners, interoperability and the proliferation of data silos are constantly at the top of the list. Providers and patients attempting to interact with multiple EMR systems face challenges as varied as transferring the physical custody of the data, converting the data from one software system to another, and translating the broader meaning of the data to a new context. Dealing with multiple EMR systems as a patient or provider is costly, frustrating, and time-consuming.

EMRs and Hold-Up

Given these costs, why would providers voluntarily choose to build silos? Why not coordinate on a single EMR system that can be used across providers? Hold-up can help explain this. We explore the three drivers of hold-up in turn, and their consequences for patients and providers.

Property Rights

The medical industry continues to debate who owns a patient's medical data. Much to the surprise of many patients, in 49 of the 50 states, patients do not explicitly own their own medical data.[17] Therefore, any EMR system that would allow for data to be transmitted easily from one practitioner to another would be subject to a host of complex property rights issues. For example, do both the sender and the receiver own a copy of the transmitted data after the transfer is complete?

In practice, even a relatively simple relationship between a practitioner or hospital and an EMR provider presents property rights challenges. While - nominally - most EMR providers allow that the stored data belongs to the practice and/or patient, it may be difficult to actually obtain and use the data outside of the relationship with the EMR. The EMR's cooperation may be needed in order to retrieve data files that are hosted by the EMR, or to obtain the software that allows the data files to be read. Moreover, many EMR providers stipulate as part of their terms of use that they automatically receive the ownership rights to de-identified data for research and commercialization purposes, even if the complete data remains the patient's property.[18] This leads to questions about what constitutes de-identified, vs. complete, data.

For these reasons, the specifics of the contract between an EMR and a practitioner are critical, and any contractual incompleteness can lead to major problems.

Contractual Incompleteness

As with any data that is relinquished to another party, maintaining control over how it is used and by whom it is accessed is next to impossible. This is vividly illustrated by the prevalence of data breaches in the EMR space. While the 1996 HIPAA Security Rule lays out strict standards for the storage of sensitive health information that providers must abide by, the industry has still been plagued by data breaches that allow unknown third parties to access medical data. In 2015, these breaches totaled hundreds of millions of records.[19]

Enforcement of existing contracts is a significant and visible problem for EMR customers.

Further, enforcement of existing contracts is a significant and visible problem for EMR customers. To date, several EMR providers have refused to give users physical custody of their health data when switching systems, requiring intervention from the Department of Justice. For example, eHealthWorks, an EMR provider, was fined $155M by the DOJ for, among many violations of federal law, not making data available to customers who wanted to switch providers.[20] When EMR systems refuse to abide by previously-signed data agreements, the only recourse for providers and patients is to engage the legal system, which may be prohibitively costly.

Relationship-Specific Investment

Choosing an EMR system is a significant relationship-specific investment. An EMR system can cost anywhere from $160,000 for set-up and $85,000 per year in ongoing maintenance for a five-person medical practice, reaching up to billions of dollars for an individual hospital.[21] Partners HealthCare paid Epic $1.6 billion for an EMR implementation starting in 2015.[22] Not only is the financial investment substantial, it requires a considerable investment of resources and time to fully integrate the EMR into the provider's workflow. The Cincinnati Children's Hospital Medical Center Emergency Department, a Level 1 Trauma Center, took over 3 months to adjust their medical care provision to their new EMR, during which time patient Length of Stay increased by up to 20% due to challenges in delivering high-quality care.[23]

If a practice wants to then switch systems, these large investments of money, time and training need to be made again. Further, because the systems are not interoperable, the data needs to be translated in its entirety from one format to another, adding more money and time to an already enormous investment. While major providers, including Cerner and Epic, are starting to provide conversion services for individual patient-level records,[24] transferring numerous, whole records between EMR systems can become cumbersome and expensive for both patients and providers.[25] In all, once the data is obtained, it can take several years and hundreds of millions of dollars to migrate it to a new EMR.[26] Even then, there may be issues with understanding the context in which the data was entered, and the broader meaning of the various values in a new health practice.[27]

As a result of these hold-up drivers, the fragmentation of the industry continues. Providers are reluctant to enter into collaborations or data sharing consortia that could improve communication of records across providers, leaving the EMR space highly siloed and dysfunctional.

4

Blockchain & Hold-Up

How can blockchain help to address the hold up problem for shared databases? Before delving into that specific question, consider the general economic benefits that blockchain provides.

The word “blockchain” gets used as a catch-all for a suite of technologies that work together to provide economic benefits. These technologies include distributed ledgers, smart contracts, zero-knowledge proofs, encryption, etc. Many of the benefits discussed here, and in subsequent sections, rely both on the distributed ledgers and one or more of the partner technologies.

Economic Benefits of Blockchain

One of the most effective ways to deliver value to participants in a market or economy is to reduce inefficiencies. Inefficiencies arise when parties engaging in trade are prevented from reaching the best possible collective outcome, either due to frictions such as search costs, or due to incentive problems such as the hold-up problem. Blockchain’s shared ownership structure can reduce inefficiencies in a wide variety of settings through three channels:

Coordination

Blockchain allows a group of stakeholders to coordinate on a shared database for their common use. It creates a source of instantly verifiable information among this group, reducing the frequently substantial costs of communicating and reconciling data across different sources.

Commitment

Blockchain, together with smart contracts, allows participants to commit to future actions and outcomes using code to enforce them. This reduces the risk of one of the parties reneging on a previous agreement, and also reduces the cost of enforcing these agreements. While smart contracts do not solve contractual incompleteness (or the hold-up problem) in its entirety, they do provide valuable tools to lessen hold-up in certain circumstances.

Control

Blockchain enables stakeholders to retain local control of their data, thereby balancing bargaining power among participants. It better allows these stakeholders to capture the value they create.

The specific benefits of employing blockchain in a given setting depend on the context at hand, and the relative costs and benefits of addressing various inefficiencies. For shared databases, all three of these channels can be used to improve outcomes for participants.

Reducing Hold-Up with Blockchain

Through the levers of coordination, commitment, and control discussed in the previous section, blockchain provides a powerful set of tools to help combat the hold-up problem.

As a result of increasing individual control over data, blockchain reduces many of the issues around data custody and property rights. The distributed nature of the ledger implies that organizations can contribute data to the collaboration without the concern that they will lose custody altogether. (Whether they can read the data is a separate question, which we discuss below.) Similarly, if a contributor wishes to leave a collaboration, they can do so at any time. In many cases, blockchain can allow a data owner to cut off collaborators' access to their data if they choose to leave a collaboration, providing a valuable layer of security to the partnership.

Because data remains in the custody of its owner, many of the challenges of contractual incompleteness are also reduced. Data owners can enforce their own data use and access requirements, without needing to rely on behavior modifications and/or monitoring of others. While the full scope of legal contracts cannot yet be captured in smart contracts, (and smart contracts cannot solve contractual incompleteness or hold-up in their entirety), smart contracts offer credible commitments that previously made agreements will be enforced once investments in the relationship are made.[28] Smart contracts can employ oracles and other verifiable information sources to automate common inter-party database maintenance activities.

These two benefits of blockchain together could have provided an elegant solution to the DNC and state parties' hold-up problem, which stemmed primarily from these two forces. The distributed control of blockchain would allow the state parties to regulate who would be granted access to their data, and in what form. Smart contracts could also automatically deliver payment to state parties whenever the DNC received payments for data. By using blockchain, the DNC could have built their own for-profit database, without requiring the state parties to relinquish control of the invaluable assets they had invested ample time and effort to develop. They could have captured the gains from trade, without worrying about the potential for hold-up.

As we saw in the EMR example, the relationship-specific investment in shared software, data formats, and systems can be an overwhelming contributor to the hold-up problem. Even if a contributor can maintain custody of data when leaving a collaboration thanks to blockchain, the cost of switching systems to join another collaboration could be prohibitively costly. Solving this lock-in problem requires more than blockchain, which we discuss in the next section.

Blockchain's Limits: The Need for Software, Standards, and Governance

While blockchain offers a compelling lever to reduce the property rights and contractual problems involved in data-related hold-up, the relationship-specific investments are less clear. There are several critical issues that must be addressed in tandem for blockchain to fully realize its potential as a force to reduce hold-up.

The first issue is that of technological standards. Many of the data infrastructures that we rely on every day -- such as the Internet, email, and word processing -- use common standards allowing data to be imported and exported throughout various proprietary programs, effectively minimizing lock-in. Microsoft, for example, was cajoled into adopting the Open XML standard in 2006, which allowed users to access Microsoft Office documents using non-Microsoft software. Relationship-specific investments are dramatically decreased if an industry employs common standards that allows data to be easily ported, read, and processed using a variety of software tools. The economics of standards is a wonderfully complex topic that has been fruitfully explored over the last two decades.[29] Both industry governing bodies and government can play a powerful role in designing and advancing the adoption of standards, whether through choices in research investment, subsidies, or their own procurement decisions.

The second issue is that of software property rights. In a truly open blockchain, such as Bitcoin or Ethereum, nodes keep the data stored within the blockchain, as well as employ important open-source software required to read and write to the blockchain. When Bitcoin forked into Bitcoin and Bitcoin Cash, for example, both chains of the fork retained their entire data histories as well as the software required to continue as a viable, independent blockchain. When software is proprietary, such as in many EMR systems, one cannot immediately assume that the software cooperates with the data. Does a node in a blockchain-based data sharing consortium automatically retain the rights to software that allows them to read their data? Do they automatically retain copies of software that allows them to operate as an independent entity? In order to prevent data owners from being restricted access to their data, we may need a new legal framework for describing and guaranteeing property rights to software.

Third, funding models may need to change to support these new collaborations. Hold-up can work to the advantage of the creators of proprietary technologies: data and software lock-in can help for-profit companies increase their revenues by increasing switching costs for customers. A highly interoperable ecosystem may no longer prove to be a fruitful investment for third parties. Instead, the consortia and collaborations themselves may need to fund these projects, so that they can reap the full benefits.

Finally, there will always be a need for governance. Governance is the set of decision-making procedures that allows a group of consortium members or collaborators to make decisions about plans of action to take. Even with the most robust smart contract infrastructure, there will invariably be unanticipated events that need to be adapted to, resulting in fundamental changes to the system. Specifying robust governance is essential if a collaboration craves longevity.

Five Steps for Corporate Leaders

Whether blockchain can reduce the impact of hold-up, and what other changes will be required in tandem for a collaboration to occur, is highly context dependent. However, there are five takeaways we can offer for corporate leaders as they consider a blockchain-based solution to database collaboration problems.

1

Identify Past Impediments

Which of the three drivers of hold-up - distributed property rights, contractual incompleteness, and relationship-specific investment -- drove previous consortium failures? What concerns did participants express?

2

Apply Blockchain Through an Economic Lens

Blockchain brings three fundamental economic benefits: coordination, commitment, and control. How can each be applied to address the drivers of hold-up?

3

Address Context, Not Only Data

Data requires software and context to be meaningful. Issues such as software custody may be just as essential a component of reducing hold-up as data ownership.

4

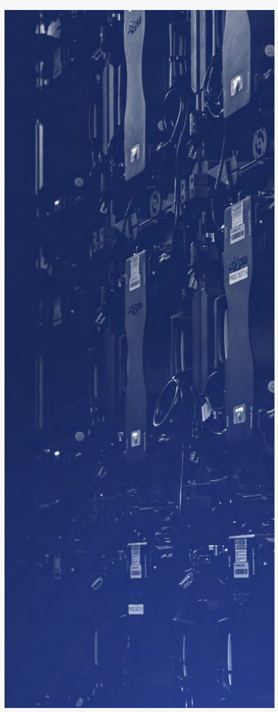
Consider Aligning on Standards

Many industries have benefited from voluntarily adopting standards. Consider whether collective coordination on a single standard could lead to better outcomes for all participants.

5

Governance is Essential

No matter the complexity of the smart contracts and code, situations that require group decision-making will always arise. Well-defined governance ensures that the consortium can handle those unexpected events.



Interested in learning more about the impact of Hold-Up?

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Endnotes

[1] This vignette is compiled from the following sources: https://www.huffpost.com/en- try/heres-what-the-big-fight-over-the-dncs-data-is-really-about_n_5c184f03e4b0432554c36e42 https://www.usnews.com/news/politics/articles/2018-12-18/- democrats-fight-over-who-owns-data-ahead-of-2020 https://www.politico.com/story/2018/12/06/democratic-national-committee-voters-data-1045995 https://www.burlingtonfreepress.com/story/news/politics/elec- tions/2019/02/13/howard-dean-head-new-democratic-voter-data-exchange/2857951002/ https://www.wired.com/story/democrats-fix-crumbling-data-operation/
[2] https://www.politico.com/story/2018/12/06/democratic-national-committee-voters-data-1045995
[3] https://www.wired.com/story/democrats-fix-crumbling-data-operation/
[4] https://www.who.int/medicines/regulation/ssffc/publications/GSMS_Report_layout.pdf
[5] https://www.businessoffashion.com/articles/intelligence/fighting-the-450-billion-trade-in-fake-fashion
[6] In the case of semi-centralized databases, such as federated database systems, a central authority is required to develop and govern the interface between the various databases. This authority can also control access to the contributing databases.
[7] We assume, as a simplification, that one mine is capable of providing all the coal the power plant needs. If that's not true, the argument is similar.
[8] See e.g. Grossman, Sanford J.; Hart, Oliver D. (1986). "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration"(PDF). Journal of Political Economy. 94 (4): 691.
[9] For a further discussion of some of the proposed solutions to hold-up, see http://www.columbia.edu/~yc2271/files/papers/holdup.pdf
[10] https://www.healthit.gov/sites/default/files/hitech_act_excerpt_from_arra_with_index.pdf
[11] https://www.cdc.gov/ehrmeaningfuluse/introduction.html
[12] See e.g. https://khn.org/news/death-by-a-thousand-clicks/ and http://fortune.com/long- form/medical-records/
[13] https://dashboard.healthit.gov/quickstats/pages/FIG-Vendors-of-EHRs-to-Participating-Hospitals.php
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[27] https://www.medicaleconomics.com/article/interoperability-fhir-standard-not-panacea?utm_source=bibblio_recommendation
[28] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3093879
[29] See, among many others, https://faculty.haas.berkeley.edu/shapiro/standards2007.pdf

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