# Turning Pipes to Blocks: Perspectives on the Costs of Capital Markets Infrastructure vs. Blockchain Alternatives

F. Adrian Adduci
Department of Computer Science
*Columbia University*
faa2160@columbia.edu

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*Abstract — The current system of moving and trading assets such as currency, stocks, and bonds has historical roots in a period where individuals had to meet physically to swap goods, as they lacked a discernible way to trust each other. While we have moved beyond selling stocks under a Buttonwood Tree, a system based on intermediaries that facilitates trading still exists. For example, third parties are responsible for confirming asset ownership, determining its price, transferring payments, and paying taxes. All of these duties are carried out at arm's length and at an added expense for the key parties involved, namely the buyers and sellers. Over time, this system has obscured the number of parties involved and the additional expense introduced by these layers. Replacing the existing system with an open-ledger blockchain could unlock significant cost savings for stakeholders across the financial industry by reducing unnecessary transaction costs and enhancing transparency across the value chain.*

## I. Introduction

As any person who deals with a bank regularly recognizes, there is a litany of fees and expenses that accumulate while doing business. For individuals or companies, these fees are incurred almost exclusively for the movement of assets within, into, or out of a financial institution.

Depending on the context, many of these expenses improve a financial institution's bottom line; that is, they do not enhance the quality of service a customer receives. However, given the history of financial market development, there are discernible layers of cost in business transactions today, resulting from the economic system that has been built.

Putting aside the vast range of services and assets that the financial services industry touches daily, it still has its roots in a fundamental concept: trust—the earliest forms of what we recognize as banks developed as a means of securely storing money. Beyond the basic needs of saving money, as new financial products were designed, such as loans and then later equities, a greater need emerged to engage trusted parties to do business on behalf of individuals. As the global economy expanded, these trusted parties soon developed a network to move financial products across the globe, marking the beginnings of the modern financial system. That said, this system still rests on the premise that one cannot always directly interface with a specific counterparty with whom one wants to do business, and, as such, one must rely on a network of trusted counterparties to move payments or financial assets.

Today, the global financial system is so intertwined with the global economy that it is difficult to differentiate where financial markets end and traditional businesses begin. With a global gross domestic product estimated at $88 trillion in 2019 alone [1], this sector is arguably among the most important to modern civilization. With all the advances we've made through the internet age, the pipes and plumbing of the financial markets still reflect more humble beginnings. Not only is the current system a patchwork of antiquated layers, but each additional layer also cascades the expenses incurred by transacting parties through either real cash outlays or a lack of transparency in asset prices.

This paper examines the cost of maintaining the existing infrastructure supporting selected components of the global financial system. Subsequently, the paper will also look to evaluate the relative cost of alternative infrastructure, which could support the capital markets, namely an open ledger system, commonly referred to as the blockchain.

Given the scale of the global financial system and how it is difficult to isolate one financial ecosystem without overlapping with another, the exact edges of the infrastructure that supports this system are quite nebulous. This factor makes quantifying the totality of infrastructure costs, in some ways, a matter of judgment more so than specific definitions. For this analysis, the infrastructure utilized in three vital financial products within the United States will act as a proxy for the system as a whole. Specifically, payment transfers, the U.S. stock market, and the U.S. bond market. As the United States is a large single market for each of these financial products and the regulatory system provides some of the highest degrees of disclosure in the underlying participant's cost-structure, this approach should approximate the scale of cost savings that might be recaptured.

Section II of this paper will briefly summarize the purpose, size, and components of the three financial markets that have been identified to give context to not only how large each of the respective financial ecosystems currently is, but also to help understand the cost structure that is attributable to the existing infrastructure that supports them.

Section III of this paper will then identify the individual components of the Capital Markets Infrastructure Providers (CMIPs) [2] which provide the logistic 'plumbing' to support these markets.

With the overall scale of each financial market and the critical infrastructure identified, Section IV will look to approximate the cost of that support. As mentioned, there is a large amount of overlap in the infrastructure that currently exists (for example, all stock trading systems work alongside payment systems). This section will also define the methodology used to approximate costs as it relates to transaction volumes.

Finally, Section V will explain how a blockchain-based solution can be used to replace the existing infrastructure, including a view on estimating the total cost to implement a system that contains the necessary infrastructure.

Lastly, it is worth mentioning that this analysis will not attempt to address the breadth of financial products or ecosystems beyond the scope of the three markets discussed. Given less visibility into the infrastructure requirements for markets domiciled outside the U.S. and esoteric pricing mechanics of some financial products (e.g., commodities, foreign exchange), finding a reasonable cost estimate is unlikely.

## II. Overview of Financial Markets

The United States financial system is massive. One would expect that to be the case for the largest economy in the world by GDP [3]. As with all economies, underlying financial transactions must be executed seamlessly and daily to operate. The infrastructure supporting these transactions can be thought of as two classes: the movement of cash and the movement of assets (e.g., stocks, bonds).

### A. *Payment Transfer Systems*

Of all the infrastructure that supports an economy, paying for goods and services is arguably the most important and most visible component of financial infrastructure. These systems, which we will refer to as Payment Transfer Systems (PTS), take many different forms that may be familiar. The Automated Clearing House (ACH) is a commonly known system for transferring money between checking accounts. Banknet and VisaNet are standard systems for processing credit and debit card transactions from Master Card and Visa, respectively [4]. All of these payment systems have been built to help facilitate the accounting of money as it moves from one entity to another in exchange for goods or services.

Each of these systems also has another standard feature, an additional expense for those doing business. A typical PTS is a layered system of entities, each with a specific role. None of these entities participates in the market for free, and each charges a percentage of the notional amount that moves as a fee for their services.

As you may note, the total fees incurred during the movement of funds increase as more parties are involved in a transaction. This linear relationship is, in effect, a result of needing two individual parties that 'trust' each other to move the funds bilaterally. The farther you need to move the money, the more bilateral bridges you must build, and the more costs are incurred by the end users.

This system extends well beyond the flow of cash for goods and services. A similar dynamic exists in the multi-trillion-dollar securities-trading market. There, beneficiaries such as individuals, pension funds, and municipalities lose an (almost) unquantifiable amount of value to fees and expenses. Fig. 1 shows a typical debit card PTS, illustrating how additional counterparties add a layer of expense to a transaction [5].

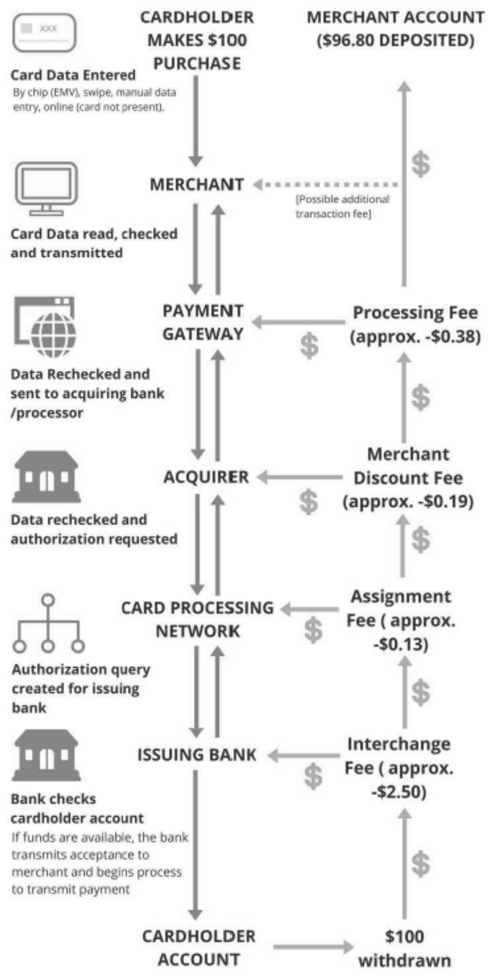


Fig. 1. Illustration of a PTS and associated fees

## B. *U.S. Public Equity Markets*

The equity markets in the United States comprise the markets in the U.S. where the public stock of both domestic and international corporations trades. While this includes the most visible component of the equity markets, like the exchanges such as the New York Stock Exchange or the NASDAQ, these are just central components of a much larger system that is at work.

Similar to the PTS that have developed to transfer money across the economy. A similar system has evolved to trade equities by 'bridging' the trust between transacting parties. This paper will refer to the movement of securities in all forms as a Security Transfer System (STS).

Setting an STS apart from a PTS is the ability to add valuation to the system. While transferring money domestically (that is, not exchanging it into a different currency), there is little argument over what the value of a dollar may be, as all products and services are (usually) quoted in the same domestic currency. The equity market, however, has developed to assist in answering the very question of what a particular stock may be worth to transacting counterparties. This factor adds the additional nuance of counterparties that can help bid and ask various prices for the assets that are sent around the system.

This system, as one would expect, is much more complex and adds more layers of cost to transacting in this market. The specific operational steps that occur when a stock transfer occurs within an STS are beyond the scope of our analysis. However, central to the cost analysis of CMIPs, it is worth noting that separate entities are responsible for a litany of different tasks. Examples include buying the stock on behalf of the owner, confirming and updating the ownership of existing stock, holding capital, and passing along legal or voting notifications to the owner, to name a few. Lastly, it is worth noting that many of these responsibilities might duplicate for both the buyer and the seller of the stock.

Fig. 2 illustrates an STS with the various intermediary parties between key stakeholders [6].

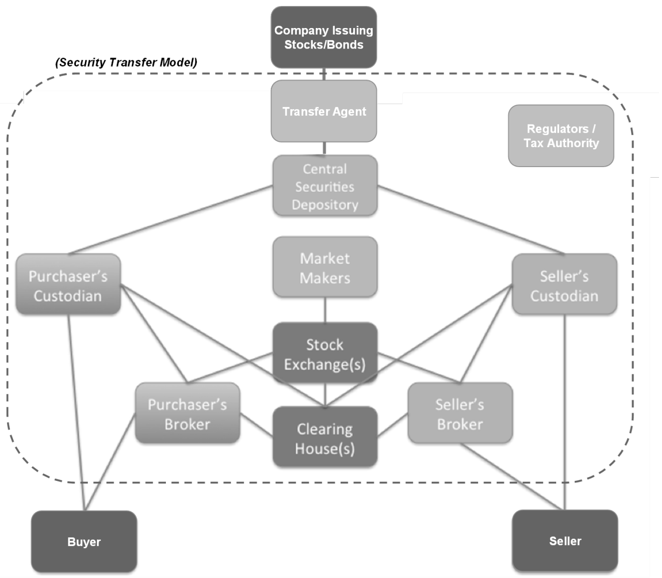


Fig. 2. Example of parties involved in the transfer of securities

## C. *U.S. Public Bond Markets*

The market for public bonds in the United States takes many cues from the equity markets, which developed much more quickly given the larger comparable size. While the total market value of the equities in the U.S. is approximately $30 trillion [7], the total public bond market in the United States is only approximately $7 trillion [8].

That said, the bond market in the U.S. remains an incredibly valuable source of capital for companies in the United States who wish to raise debt. This debt can then be used to fund a wide range of proceeds, such as capital expenditures, buying back their stock, or even buying other companies, to name a few examples.

The infrastructure that supports the bond market is, in fact, almost identical to that which supports the equity market. In fact, many of the counterparties that provide the infrastructure for supporting the trading of stocks also support the trading of bonds. They are so similar that a diagram of a bond market STS has been excluded, as it would look identical to the one provided for an equity STS.

As such, it is essential to note the total economic costs of replacing these providers, as there is significant carryover in cost savings to another major component of the capital markets that would be expected to use a similar replacement technology.

It is worth noting that the markets are not wholly identical, as individual counterparties in these different systems may have more or less responsibility depending on both regulatory issues and particular technical dynamics. For example, one new development highlighted with regularity in the bond market has been the development of electronic trading platforms. These companies have looked to fill the roles traditionally filled by market-makers such as large banks. As regulatory pressures on financial institutions increased following the financial crisis, specific roles in the financial system, such as buying and selling bonds, have become much more onerous for banks, and this dynamic has led to new market entrants trying to provide this service.

For our cost analysis, we will not distinguish between the actual entities providing the service and instead focus on the overall cost this existing system adds to the market.

# III. CURRENT FINANCIAL MARKET INFRASTRUCTURE

## A. *Custodians, Technology, and Regulators*

As you can observe in Fig. 2, there are various constituents involved in this process, and each charges for the services that they render. Beyond the significant financial institutions such as banks, the majority of capital markets infrastructure providers in our analysis fall under the category of an exchange (where trading partners meet), a custodian (one who physically holds a security asset for an owner), a technology provider (such as Bloomberg) or a regulatory agency (such as the Securities and Exchange Commission). Each market we will discuss has a slightly different structure, terminology, and critical CMIPs, but all are roughly equivalent in form, and all contribute an added expense to transacting parties.

For example, for the market makers alone, which traditionally are the investment banks that help initially issue securities for a company, fees for helping issue corporate bonds in the U.S. were as high as $11.2 billion in 2018, a nearly 68 basis point increase in the cost of debt for an operational function critical to doing business [9].

### B. *Banks and Payment Processors*

In many ways, banks and payment processors are both the same and very different. For any transaction that is carried out under an STS, there must be an identical, reciprocal transaction through a PTS. That is, to say a movement of a stock or bond has occurred also necessitates saying a flow of cash also happened.

Large financial institutions take on many roles that could be considered part of the group of CMIP that make the financial system operate. For example, a bank may actively buy and sell a stock on behalf of a customer, and then also move money into or out of that customer's account. Another example may be to act as a credit card processor, allowing point-of-sale for a merchant that accepts credit cards, crediting that merchant's account with cash when that sale occurs, and then debiting that customer accordingly. If neither the merchant nor the customer is a customer of the bank, the bank will engage with banking systems like the ACH or VisaNet to find the ultimate holder of each account and produce the correct changes to each respective party.

Therefore, banks have many overlapping responsibilities as CMIP, and depending on the specific and interacting counterparties, they may be either central to enacting a transaction or gatekeepers to accessing a more relevant portion of financial infrastructure.

### C. *Counterparties*

Counterparties represent the entities that wish to transact with each other using financial infrastructure. For example, this includes businesses that need to pay their employees each week or individuals who buy and sell equities in the stock market or companies, such as pension fund managers who may regularly invest in different markets, such as bonds. Counterparties are, in effect, the end users we believe will ultimately benefit the most by upgrading existing CMIP with blockchain technology.

Counterparties do not just include buyers and sellers of assets, but issuers of assets as well. When a counterparty is an issuer, they represent the source or origination of the stocks and or bonds that are exchanged in the market. The most well-known example of a company being an issuer is an Initial Public Offering (IPO), where a company issues the stock for the first time to the market. However, many companies continually access the market as issuers either in the form of follow-on offerings for equities, or bond issuances for debt raises. The types of issuers can vary dramatically depending on the market. For purposes of our analysis, we are focused on U.S. corporate issuers (e.g., Google or McDonald's) and excluding entities like municipalities or local governments from our study.

Additionally, there may be the added benefit of additional transparency in the market. Often, the true price of a security is hard to judge, given all the different layers of parties involved in a transaction. A simplified system may mean a more transparent view of valuation, which also helps counterparties in the long run, away from the visible overhead.

## IV. Evaluating Current Infrastructure Costs

The goal of this analysis is to identify the additional overhead that is passed through to the end users of a financial transaction by current CMIPs and to highlight the relative cost basis that would be achieved by moving to a technology-based system such as blockchain.

As such, the methodology that will be applied to identify the overhead incurred by counterparties using existing infrastructure will be to first look at the total revenue captured by existing CMIPs. It is our view that a blockchain-based solution would effectively replace all intermediaries if implemented correctly, which means all CMIP revenues could be recaptured by counterparties, who currently see these revenues as transaction expenses.

While this methodology implies CMIPs operate in a perfectly competitive market, given a large number of competitors, we take the view that operating expenses and profit margins are significantly compressed. Therefore, revenues for the overall industry will work as a proxy for total pass-through cost to market participants.

Lastly, the method for identifying revenues will vary between the payment and security markets we have identified. Payment systems are reasonably fractured. Therefore, industry data provided by large financial institutions will act as a proxy for the entire market. The stock and bond markets have more transparency on issuance fees, which will help shape our views on revenues generated by CMIP overall in these markets.

### A. *U.S. Payment Transfers*

The Federal Reserve publishes a periodic report that identifies the total payment volumes in the U.S. The total value of all non-cash payments in the U.S. in 2015 was estimated to be $177.85 trillion [10]. The value of payments is more than double the value of all public companies in the world combined [11]. Additionally, McKinsey & Company publishes a bi-annual review of industry performance within the payments industry. Cross-referencing the two publications allows for an estimation of the total cost basis of the payment-focused CMIPs. Tab. 1 highlights the transaction volumes of core payment systems, as well as estimated margins and CMIP revenue.

TABLE I.
NON-CASH PAYMENTS AND CMIP REVENUES

| **Non-Cash Payments Made in The United States (2015)** | | | |
|---|---|---|---|
| ***Type*** | ***Amount (Billions) [12]*** | ***Operating Margin (Basis Points) [13]*** | ***Revenue (Billions)*** |
| ACH | $145,300 | 13 bps | $182.75 |
| Credit Cards | $3,160 | 189 bps | $108.0 |
| Debit Cards | $2,560 | 153 bps | $87.5 |
| Checks | $26,830 | 17 bps | $46.75 |
| **Total** | **$177,850** | | **$425.0** |

As discussed, our methodology operates under the view that the entirety of these revenues could be recaptured by a blockchain solution if appropriately implemented. We will discuss the nature of an open-ledger system in more detail in Section V; however, for our analysis, we will use $425 billion of per annum revenue as identified cost savings.

## B. *U.S. Public Equity Markets*

The equity markets in the United States have a much more definable cost structure than payment systems. There exist primarily two areas where overhead occurs as a result of the existing financial infrastructure.

First, primary markets, which are the issuance of new stock to investors, have a publicized and visible fee wallet associated with them. For this analysis, one would assume that the existing system of utilizing financial institutions, such as investment banks, would be circumvented in the same fashion as how banks are not a functional part of the system that operates other open ledger systems, like new cryptocurrencies, such as Bitcoin. Therefore, our analysis will assume all primary market fees are recapturable overhead. Additionally, fees for this service are correlated directly to volumes of equities that are issued to the market.

Next are the secondary markets that incorporate a much broader swath of the capital markets value chain and, as such, leverage a much more extensive range of parties. Not only are many of the counterparties involved that handle certain primary market activities like executing and clearing trades, but there is also a separate set of operational responsibilities which are covered as well, managing collateral (e.g., for short sellers) and the custodial management of holding the securities, which was previously mentioned. While large financial services organizations also play in these areas, other counterparties, such as exchanges, central security depositories (CSDs), custodians, and analytic companies, all come into play.

To note, when working with financial information, we are limited to only publicly reported data. There are many situations where a fee may be incurred by transacting parties, but not be visible beyond the transacting parties and the intermediaries they utilize to undertake that trade. While the class of trades where this occurs is easy to identify (e.g., a private placement of stock to a single owner), it is challenging to quantify the costs associated with these exercises, and therefore any transaction that does not have publicly available information related to it has been excluded.

Bloomberg, the data service provider, publishes an aggregated annual league table data that summarizes the total primary market activity in the equity markets, as well as publicly available fee data. This league table will inform our calculation of fees earned by CMIPs in both primary and secondary markets, which we will identify as the costs that can be recaptured by a blockchain solution.

Tab. 2 shows the ten-year historical trend for primary market equity issuance and associated revenues [14].

TABLE II.
LEAGUE TABLE ELIGIBLE EQUITY ISSUED IN THE U.S.

| **Annual Equity Issuance in The United States** | | | |
|---|---|---|---|
| ***Year*** | ***Issuance (Billions)*** | ***Fees (Basis Points)*** | ***Total Fees (Billions)*** |
| 2018 | $181.9 | 386.4 | $7.0 |
| 2017 | $184.4 | 380.8 | $7.0 |
| 2016 | $160.5 | 333.3 | $5.3 |
| 2015 | $204.1 | 359.0 | $7.3 |
| 2014 | $218.3 | 398.7 | $8.7 |
| 2013 | $242.2 | 381.5 | $9.2 |
| 2012 | $223.7 | 276.9 | $6.2 |
| 2011 | $164.9 | 359.7 | $5.9 |
| 2010 | $172.7 | 342.6 | $5.9 |
| 2009 | $218.9 | 395.2 | $8.7 |
| **Average** | **$197.2** | **361.4** | **$7.1** |

Since capital markets activity is tied to overall economic activity in a market in a particular year, for this analysis, we will look at a ten-year average to determine our revenue base. On average, the primary markets in the United States see approximately $197 billion of new stock issued each year, with roughly $7.1 billion of fees going directly to the financial institutions that help instigate that primary market's activity.

There is significant overlap in services that are provided by underlying CMIPs that are involved in both the primary and secondary market activities. This fact, as well as that many CMIPs transact across many different asset classes, means our methodology will need to address appropriating the correct cost base that can be recaptured.

In our view, the most straightforward method to delineate this revenue and identify the cost base is to evaluate total revenues across all asset classes for CMIPs in the secondary market and then attribute these revenues on a pro-rata basis as a proportion of primary market activity. That is, using the total fees that have been generated by the primary markets for equities as a starting point, we can then attribute an appropriate proportion of all the fees that are created across the value chain for all capital markets activity back to equities. While there can be a disconnect between primary and secondary market activity in a given economic cycle, this method provides, in broad strokes, how much CMIP revenue is generated by the equity asset class.

The consulting firm Oliver Wyman provided a 2013 estimate for the total revenues earned throughout the capital markets value chain. With total transaction volumes somewhat static since 2013, we will assume CMIP revenues are also steady since this report was issued. Additionally, the estimate reported on the global capital markets value chain, and as such, we have adjusted revenue estimates to just the United States. Tab. 3 below is a summary of the revenues earned in the capital markets value chain for equities [15].

TABLE III.
REVENUE ESTIMATE FOR U.S. EQUITY VALUE CHAIN

| ***Value Chain*** | **Per Annum Revenue (Billions)** [a] | | | |
|---|---|---|---|---|
| | ***Sell-Side*** | ***Venues*** [b] | ***CSDs*** | ***Other*** [c] |
| Primary | \$7.1 | \$0.4 | \$0.0 | \$0.0 |
| Execution | \$65.5 | \$4.6 | \$0.0 | \$2.5 |
| Clearing | | \$1.4 | \$0.0 | \$0.4 |
| Services [d] | | \$0.4 | \$1.1 | \$13.8 |
| Post-Trade | \$0.0 | \$0.0 | \$1.4 | \$7.1 |
| *Sub-Total* | *\$72.6* | *\$6.7* | *\$2.5* | *\$23.8* |
| ***Total*** | **\$105.6** | | | |

a. Adjusted for pro-rata share of U.S. primary market equity revenues

b. Includes exchanges, inter-broker dealers, and central counterparties

c. Includes custodians, data and technology service providers, and other third parties

d. Services includes custody, settlement, and collateral management

The revenues generated by the broader capital markets ecosystem are impressive. Relative to the \$7.1 billion of average revenues produced by the primary market each year, CMIPs see an estimated \$98.5 billion of additional revenue, bringing the total revenues generated in supporting the U.S. equity market from end to end to approximately \$105.6 billion each year. It is our view that this entire revenue base can be viewed as cost overhead by all transacting parties (i.e., buyers and sellers) in the market, which can be extinguished by replacing the current value chain with an open-ledger system.

C. *U.S. Public Bond Markets*

The bond markets in the United States, similar to the equity markets, also have a definable cost structure. Also similar to equities, there exists the same dynamic of primary and secondary markets, which are supported by overlapping CMIPs. Our analysis of the current cost basis of the U.S. bond market will apply a similar methodology to how we evaluated the U.S. equity market.

Primary markets also have a visible fee wallet, which we will also assume for this analysis, that can be circumvented and is re-capturable overhead. The secondary market activity incorporates a similar network of participants as the equity market value chain, including market-makers, exchanges, custodians, and post-trade analytic counterparties. This framework makes comparing the cost base between the two markets relatively straightforward, as it relates to the CMIPs that let the bond market function.

That said, it is worth noting that in practice, the secondary bond market in the U.S. is much less liquid than equity markets. As mentioned, there is roughly one-third of the total equities available in the bond market (by market value). This lower liquidity (i.e., supply) has the natural effect of increasing margins despite utilizing the same infrastructure. Tab. 4 shows the ten-year historical trend for primary market bond issuance for both investment grade (IG) and high yield (HY) rated corporate issuers.

TABLE IV.
TOTAL BONDS ISSUED IN THE U.S.

| **Annual Bond Issuance in The United States** | | | |
|---|---|---|---|
| ***Year*** | ***IG Issuance (Billions) [16]*** | ***HY Issuance (Billions) [17]*** | ***Total Fees (Billions)*** |
| 2018 | 1,229.6 | 420.8 | 11.2 |
| 2017 | 1,410.5 | 612.0 | 14.5 |
| 2016 | 1,335.9 | 471.4 | 13.0 |
| 2015 | 1,308.7 | 506.7 | 13.0 |
| 2014 | 1,171.9 | 616.9 | 15.0 |
| 2013 | 1,123.6 | 554.7 | 13.4 |
| 2012 | 1,095.9 | 617.5 | 15.0 |
| 2011 | 851.0 | 492.0 | 10.7 |
| 2010 | 832.6 | 425.5 | 11.4 |
| 2009 | 1,053.0 | 280.7 | 9.9 |
| **Average** | **1,141.3** | **499.8** | **12.7** |

You will notice that issuance volumes in the primary market for bonds are materially more substantial than the primary market for equity. There are technical drivers for this related to the macroeconomic environment over the last ten years, more than a fundamental difference in how the market for these two asset classes operates. Primarily, a low-interest-rate environment following the financial crisis in 2008 has led many corporate issuers to prefer to issue cheaper debt to fund capital expenditures instead of issuing equity.

The considerations that go into capital structure management and the drivers between primary equity and debt issuance extend beyond the scope of this analysis. It is fair to caveat that over any economic cycle, certain asset classes such as equity and debt will ebb and flow as the corporate finance best practices dictate, and the economic environment changes. Since we argue that capital markets infrastructure is agnostic in many ways to the asset that travels through it, this makes the revenue and cost structure of CMIP somewhat malleable when viewed on a single market basis. That said, for purposes of weighing the relative benefits of transitioning to blockchain infrastructure, we will assume CMIPs in the U.S. primary bond market receive, on average, \$12.7 billion of revenue per annum.

We have also leveraged the same Oliver Wyman revenue estimates to approximate the total secondary market costs to attribute to the financial infrastructure that supports the U.S. bond markets. Similar to the equity market estimates, we adjusted the Oliver Wyman revenue estimates to reflect the U.S. primary market fees on a pro forma basis. We have then further adjusted those estimates to reflect a pro-rata portion of CMIP revenues that derive from debt capital markets revenues.

Tab. 5 below is a summary of the revenues earned in the capital markets value chain for bonds [18].

TABLE V.
REVENUE ESTIMATE FOR U.S. BOND VALUE CHAIN

| *Value Chain* | **Per Annum Revenue (Billions) [a]** | | | |
|---|---|---|---|---|
| | ***Sell-Side*** | ***Venues [b]*** | ***CSDs*** | ***Other [c]*** |
| Primary | $12.7 | $0.6 | $0.0 | $0.0 |
| Execution | $117.1 | $8.3 | $0.0 | $4.5 |
| Clearing | | $2.5 | $0.0 | $0.6 |
| Services [d] | | $0.6 | $1.9 | $24.8 |
| Post-Trade | $0.0 | $0.0 | $2.5 | $12.7 |
| *Sub-Total* | $129.8 | $12.1 | $4.5 | $42.6 |
| ***Total*** | **$188.9** | | | |

a. Adjusted for pro-rata share of U.S. primary market bond revenues

b. Includes exchanges, inter-broker dealers, and central counterparties

c. Includes custodians, data and technology service providers, and other third parties

d. Services include custody, settlement, and collateral management

Relative to the $12.7 billion of average revenues produced by the primary market each year, CMIPs see a total of $188.9 billion of revenue in support of the U.S. bond market annually.

## V. ALTERNATIVE OPEN-LEDGER INFRASTRUCTURE

As we have described, the equity and debt markets in the United States are massive. However, this only begins to scratch the surface of the value that can be unlocked through the implementation of new capital markets infrastructure. For example, more esoteric markets like currency exchanges are almost unfathomable in total size and can see many trillions traded in a single day [19].

But for all the money flowing through the market, and irrespective of what assets ultimately trade, all of these markets have similar operational layers to the PTS that we described. A software solution centered around implementing an open ledger, or blockchain system, could be leveraged centralize the roles of the exchange, the custodian, the trustee, the broker, and the underwriters.

Fig. 3 is an example of STS repurposed to resemble an open ledger system.

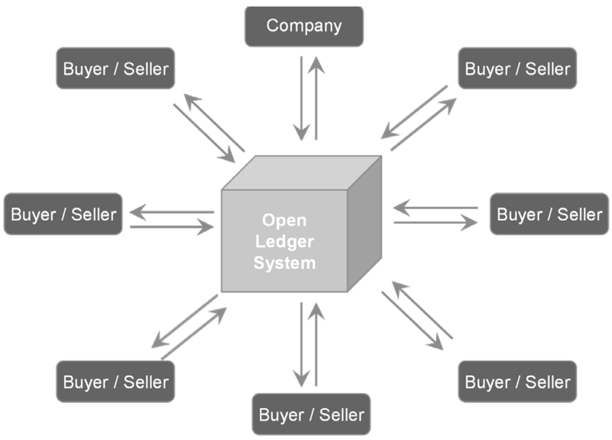


Fig. 3. Illustrative example of parties involved in open ledger STS

This analysis will not walk through a thorough design of a blockchain system. Instead, we will highlight key services offered by current CMIPs that are already offered through blockchain-focused financial technology companies. Therefore, we assume that it is possible to envision a system where all technologies are coordinated through a single system.

A system could be designed that incorporates components of technology that have already implemented in some form. Assets and asset prices could be negotiated on an open-ledger-based exchange, using electronic trading platforms. The blockchain itself could hold information on key attributes of the security, such as terms and disclosures, and the current ownership structure would be open to the public. With all information, such as trades and ownership, in the public domain, traditional trade analytics could be applied. [20]

Unlike a traditional custodial and trustee relationship in the current system, where only one party controls access to key information, each market participant in a blockchain system would have a copy of the critical data. This feature will inherently lead to more liquidity across the market as parties are able to negotiate bilaterally, circumventing traditional market makers who may act as hurdles to transaction flow instead of enablers, as they may prioritize certain participants based on either economic incentives or regulatory incentives. Additionally, the real-time access to crucial information may allow for quicker and more informed investment decisions, further increasing the efficiency of the market, or cannot provide.

A system will also need to incorporate a means to debit and credit real monetary currency and not a cryptocurrency (which is unregulated and not used by any corporation as an operational currency currently). As previously discussed, any transfer of a security, like a stock or bond, precipitates a transfer of money in the system. To bring all CMIPs onto the blockchain, it will be necessary to 'tokenize' the movement of cash [21]. In effect, this is equivalent to having a concurrent blockchain system running alongside the blockchain controlling the underlying asset class — one for the security, and one for the corresponding cash movements. Fig. 4 provides an illustrative UML diagram to demonstrate the potential design of a system.

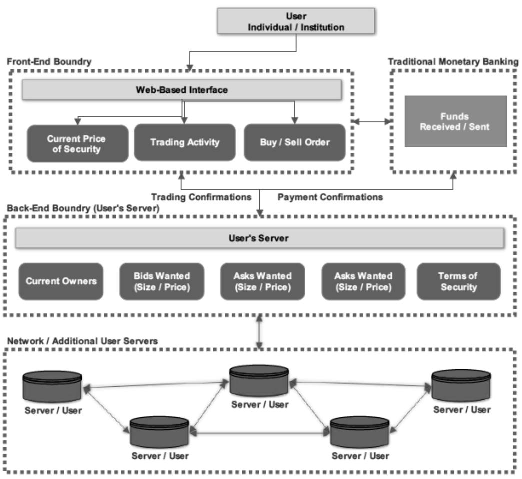


Fig. 4. Illustrative UML for open-ledger trading system

## A. *Example Technology Applications*

Open ledger, or distributed ledger technology, has been implemented in a myriad of forms. There are many fintech-focused businesses looking to disrupt different segments of the CMIP value chain. The key to replacing the overall infrastructure will be harmonizing these separate systems into one contiguous system. However, the key components have already been proven to work in concept [23].

To address the feasibility of replacing existing infrastructure, we will identify several of these fintech disruptors to highlight that the key components of capital markets infrastructure can be treated with an open ledger system. These examples will run the gamut from 'proof of concept' examples in the news to early-stage start-ups that have attracted large rounds of financing to expand on their business models. Key components of functioning infrastructure based on distributed ledger technology will need to be brought together if an open ledger system becomes an alternative to the traditional infrastructure providers in today's market:

1. Pricing and issuing an asset: Capital markets infrastructure begins with the creation of an asset, either by an entity issuing it, such as an equity IPO, or creating it, such as when the government prints new currency. Regardless, the creation of the asset must occur, and it must occur within a framework of certain rules. It must be created in a way that no person can copy that exact asset, and that asset must have some perceived value, such as a contract with the right to cash flow (e.g., a bond) or intrinsic value like cash. Cryptocurrencies are a perfect example of this technology. While there may be much debate about the value of things like Bitcoin to the broader society, the technology that underpins Bitcoin is demonstrable proof that an asset can be supported by a distributed ledger technology [24]. Additionally, there have been 'proof of concept' designs already implemented, which show that not only can a currency be replicated, but so can a security, as Overstock issued one of the first 'crypto bonds' in 2015 [25].
2. A way to trade or exchange an asset: As discussed, one of the primary functions of capital market infrastructure is moving an asset from a sender to a receiver. For that sender and receiver to meet, however, a central point in the system must exist where buyers and sellers can meet, and price discovery can occur. Blockchain-based exchanges are abundant, and many include features similar to other components of CMIPs. For example, Coinbase offers the ability to buy and sell multiple types of cryptocurrencies (similar to a broker), store that currency (like a bank or custodian), and helps maintain a roster of current owners (like a trustee) [26]. The last feature is an incredibly important and often overlooked feature, as there must be a record of the legal owners of a security in order to leverage this technology for existing assets like stocks and bonds, which often need to vote on issues considered with the issuer.
3. Accessing the traditional monetary system: Issuing or obtaining an asset for the first time is the point of entry into the infrastructure that supports the capital markets. However, for each of these transactions, there also needs to be an exit point, where a transacting party can exchange that digital asset for a 'real-world' asset. Therefore, interlinking an open ledger system with traditional banking is imperative. To do this, the concept of "tokenization" has developed. Whereby a digital token can be obtained. This token is similar to a cryptocurrency, with the exception that its value is tied to and can be exchanged for a traditional currency like U.S. Dollars. JP Morgan has released plans to pursue this exact strategy with 'JPM Coin'. A digital token that represents U.S. Dollars but is supported by underlying blockchain technology [27].

While none of these systems have already been built at the scale of the global financial system, the proof that this technology can be implemented in select scenarios helps underscore the suitability of this technology and the feasibility of pulling each component together into a homogenous system.

## A. *Public and Permission Ledger Architectures*

Blockchain-based architectures can be broadly categorized into public (permissionless) and permissioned ledger models, each of which presents distinct trade-offs relevant to capital markets infrastructure.

Public ledgers are typically open networks where any participant may validate transactions and access transaction data. These systems emphasize transparency, resilience, and censorship resistance, attributes that may be appealing in markets where open access and auditability are prioritized. Public blockchains also reduce reliance on a single operating entity, which may increase trust among participants who are otherwise dependent on centralized intermediaries.

Permissioned ledgers, by contrast, restrict participation to approved entities and often operate under defined governance frameworks. These systems are generally optimized for higher throughput, predictable performance, and alignment with regulatory and compliance requirements. For financial institutions operating in heavily regulated environments, permissioned architectures may offer a more practical path to adoption by allowing known counterparties to transact within a controlled network.

At present, it remains unclear which model—or combination of models—will ultimately prove most suitable for large-scale capital markets applications. It is likely that different asset classes and transaction types will favor different architectural approaches depending on their specific operational and regulatory constraints.

## A. *Real-Time Settlement Risk Implications*

A defining characteristic of blockchain-based infrastructure is the ability to maintain a shared, authoritative record of asset ownership that is updated in near real time. Unlike traditional capital markets infrastructure—where trades are executed quickly but settled days later—an open-ledger system can update ownership records shortly after trade execution, subject to network consensus and validation rules.

This reduction in settlement latency has meaningful implications for market efficiency. Under the current T+2 settlement model prevalent in U.S. equity and bond markets, counterparties are exposed to the risk that the opposing party may fail to deliver either the security or the corresponding cash. As a result, additional layers of infrastructure, such as central counterparties and margin requirements, are required to mitigate this risk.

By contrast, a blockchain-based system that records ownership changes closer to the point of execution could materially reduce the duration of counterparty exposure. While such a system would not eliminate risk entirely, the compression of the settlement window has the potential to lower the probability and impact of settlement failures.

### B. *Reductions to Counterparty Risks*

Counterparty risk in today's markets is managed through collateralization, margin posting, and clearing guarantees, all of which impose capital costs on market participants. These requirements are directly linked to the time between trade execution and final settlement.

If settlement cycles are shortened through the use of a shared ledger, the amount of capital required to secure open positions could be reduced accordingly. Lower margin requirements would free capital currently held for risk mitigation purposes, potentially increasing liquidity and reducing the overall cost of participation in capital markets.

While the precise magnitude of these reductions is difficult to quantify without large-scale implementation, the relationship between settlement speed, counterparty exposure, and collateral requirements suggests that improvements in settlement infrastructure could yield meaningful economic benefits independent of broader structural changes to market organization.

### C. *Incentives and Pediments to Adoption*

There are legitimate expenses that are incurred because of this current system, often daily, by quite literally countless companies involved in the system — looking on Bloomberg each day, one can see the day's tally of IPOs on any global stock exchange, or a debt offering to understand the fees imposed. These costs are borne because the system that lets companies and individuals access capital and investments dictates them.

This factor inherently creates some incentive to change. Take a global car manufacturer or even a large telecom company. Each very likely issues bonds to help them pay for significant expenditures every few years, such as updating equipment, buying spectrum, or marketing. Each of these issuers has less money to put towards these causes because of fees incurred by the current system that's in place. By simplifying the process and removing as many of these third parties as possible, we can, in effect, minimize the amount of overhead inflicted on the market for doing business.

Conversely, there remain challenges to change as well. As we demonstrated, the revenues earned by CMIP are significant. It's unlikely that these companies will willingly assist in the transition to a different infrastructure that effectively circumvents them. Instead, the counterparties that bear the burden of supporting the existing infrastructure must force change.

Additionally, the legal and regulatory frameworks that a blockchain system would need to operate under are unclear. Security law is quite rigorous in not only the disclosure requirements required by issuers to adequately protect investors, but also all the existing CMIPs that may touch an asset to protect the transacting participants. Without guidance on how to treat blockchain-based securities, it will be difficult to understand how to build a system to accommodate them [22].

### D. *Enterprise Blockchain Consortium*

Alongside public blockchain development, a number of enterprise-focused blockchain consortia have emerged with the explicit goal of adapting distributed ledger technology to existing financial market structures. These initiatives reflect an effort to explore blockchain's potential benefits while remaining compatible with institutional requirements around governance, performance, and compliance.

R3, through its Corda platform, has focused on building distributed ledger solutions tailored to financial institutions, emphasizing bilateral data sharing, legal contract alignment, and interoperability with existing systems. Corda's design departs from traditional blockchain models by limiting data visibility to relevant parties, addressing confidentiality concerns common in capital markets.

The Hyperledger project, hosted by the Linux Foundation, represents a collaborative effort among technology firms and financial institutions to develop modular, open-source blockchain frameworks. Hyperledger Fabric, in particular, has been adopted in several pilot projects exploring applications in payments, trade finance, and post-trade processing.

The Enterprise Ethereum Alliance (EEA) seeks to extend Ethereum-based technologies for enterprise use cases by defining standards and best practices that support permissioned deployments, improved scalability, and enterprise-grade security. By leveraging the existing Ethereum ecosystem, the EEA aims to balance innovation with institutional adoption.

While these consortia are still in relatively early stages, their existence underscores growing interest among incumbent financial institutions in exploring blockchain-based infrastructure as an incremental evolution of current systems rather than a wholesale replacement.

### E. *Cost of Implementation*

As discussed, replacing existing infrastructure means combining different implementations of technology that already exist in some form. To estimate a replacement cost, we have first looked at existing functioning businesses focused on implementing facets of capital markets infrastructure with open ledger technology.

Globally, we have identified over 4,200 start-up companies focused on creating businesses centered on blockchain technology [28]. Many of these companies are pursuing business models that look to replicate components of financial infrastructure rather than replacing it end-to-end. For example, one already discussed, Coinbase, has features that are similar to exchanges, depositories, and payment systems.

Other early-stage fintech companies have similar business models or address alternative steps in the CMIP value chain. Overall, however, there are no examples that we are aware of of fully functioning open ledger systems operating at the same scale as the existing financial system where cost comparisons can be drawn. For example, the exchanges focused on Bitcoin saw on average only 368,000 transactions per day (through April 2019) [29]. This notion is across the entire market for Bitcoin and shared amongst many exchanges. This number is much smaller than, say, the foreign exchange market, which can see trillions of transactions a day [30]. Building a system that can replace the entirety of existing capital markets infrastructure is not a small task.

Looking at the fintech industry as a proxy for costs is difficult. There is a general lack of public disclosures, as well as the early-stage nature of these businesses. Instead, we are using initial funding as a proxy for implementation costs. Our methodology, therefore, will identify blockchain-focused companies with the most significant funding as a proxy for the cost to build similar businesses. This methodology obviously ignores key individual line items, such as running data centers. However, we are ultimately looking to approximate the relative cost (or lack thereof) of utilizing blockchain. By assuming these expenses are de minimis when scaling up the underlying businesses, we will at least be able to ascertain the initial costs to implement a competitive alternative to existing CMIPs.

Tab. 6 below identifies a selection of fintech companies leveraging blockchain technology in various forms that have also come to market and received early-round financing.

TABLE VI.
FUNDING ACQUIRED BY BLOCKCHAIN START-UPS

| ***Company*** | ***Focus*** | ***Announced Funding*** |
|---|---|---|
| Bakkt | Payment, Futures | $182 million [31] |
| Robinhood | Trading | $176 million [a] [32] |
| Coinbase | Exchange, Payment | $106 million [33] |
| Gate.io | Exchange | $64 million [34] |
| Diginex | Mining | $63 million [35] |
| **Average** | | **$118.2 million** |

a. Funding acquired up to the blockchain features being implemented

What is striking is that the costs to finance and build these (in some cases) vastly different businesses that focus on open ledger technology are all relatively similar. The largest, Bakkt, an exchange and futures contracts provider for Bitcoin backed by the NYSE, in addition to the funding it already raised, only needs $20 to $25 million a year in additional funding to continue to grow [36]. If Bakkt is an example of open ledger technology being implemented at the highest funding requirement, this bodes well for developing tangential technologies at similar cost points.

Clearly, without a comparable benchmark, it will become much more challenging to analyze the exact cost for the build-out of this system on a granular basis. The cost will also vary considerably in our view if new infrastructure is adopted by existing CMIP, which may have some synergistic cost savings, or from an outside disruptor looking to implement the new system from scratch.

Regardless, what we are left with is the practical starting point for implementation in the form of early-stage companies. What is worth noting, however, is that on a relative basis, the funding needed to start these businesses represents an extremely low floor when compared to the cost existing CMIPs exert on the capital markets. Therefore, one aspect is certain, that on a relative basis, the cost for an open ledger replacement will be considerably lower than the ongoing cost of today's infrastructure.

## VI. DISCUSSION OF RESULTS

Ultimately, success in comparing traditional capital markets infrastructure versus an open ledger-driven system is a quantifiable objective. That said, given the nebulous nature of how costs are exerted on market participants by existing capital markets infrastructure providers and costs accumulated in implementing competing technology, many indirect and direct assumptions must be made. As such, we are left with a view in broad strokes on the quantitative difference in the relative cost-benefit of analysis between the two systems, while from a qualitative standpoint, it is much easier to make definitive arguments.

From a quantitative standpoint, I would highlight what we have identified as the total cost of today's infrastructure providers. There is, without question, a lot of revenue being generated by traditional CMIPs. While obscured by the sheer number of participants that act as intermediaries in the system today, this is still a cost that arguably is passed through to the ultimate market participants in the form of fees and transaction expenses.

Tab. 7 summarizes the cost estimates for the CMIPs, which support the payment, equity, and bond markets in the United States.

TABLE VII.
ANNUAL COSTS OF TRADITIONAL INFRASTRUCTURE

| ***Market*** | ***Annual Infrastructure Cost*** |
|---|---|
| U.S. Payments | $425.0 billion |
| U.S. Equity Markets | $105.6 billion |
| U.S. Bond Markets | $188.9 billion |
| **Total** | **$719.5 billion** |

In this analysis, we examined the sheer scale, as well as the convoluted nature of capital markets infrastructure. The network of financial institutions that support the capital markets is so integral to our lives that it is impossible to avoid using them in some capacity. As an extension of this integration, we also learned that there are a few bright-line tests in determining where to start to attribute costs in the infrastructure that supports one financial transaction and where those costs end. We also learned that the technology to disrupt existing infrastructure already exists in certain forms; it just has not been tested at scale or as an integrated solution to replace the system supporting global capital markets.

The ultimate conclusion that we can draw from this analysis lies in the scale of potential costs incurred by market participants. For companies using blockchain technology today, many have built working business models with only a few hundred million dollars of capital, with development costs feasibly passed through to clients that use their services. While this is certainly not a small investment, in absolute terms, it pales in comparison to the $720 billion of costs incurred by market participants per annum in the U.S. equity, bond, and payment systems. This differential could only be expected to increase further when expanding this analysis to other asset classes and adding a global scale.

At face value, the economics of moving to an open ledger-based infrastructure appear to make sense. However, many challenges still exist in implementing this system, and there are many nuances to the analysis just described that could shift the beneficial economics of transitioning.

For example, one issue that deserves more attention is the legal and regulatory frameworks that an open ledger system must live within. For example, it is surprising that for the amount of attention that cryptocurrencies have received and the amount of funding fintech companies have acquired, there is very little in the way of guidance from regulatory agencies in the U.S. or abroad on how to structure securities on the blockchain.

It was also surprising how little information is available on a granular level regarding the CMIPs and how their revenues are derived. A methodology for attributing costs on a market, asset class, or even transactional basis is easy enough to calculate with consensus. The steps for transacting in the market are well understood and governed by known rules. The margins obtained by the CMIPs on a transactional basis are not. This lack of information is mostly why the analysis presented here relied on a top-down approach, starting with gross revenue to approximate cost.

Utilizing a bottom-up approach might be better suited to understanding the actual recapturable costs under the current infrastructure. An alternative analysis that might have reached a similar conclusion but provided a more comprehensible argument would have been to choose a single asset class or transaction and follow that trade step by step through each leg of the existing infrastructure to analyze the cost-benefit of blockchain at each part of the value chain.

Lastly, we did not fully address the incentives for changing this system. While the potential cost savings to transacting parties are attractive, the cohort of existing infrastructure providers will make it challenging to transition to a new regime. Financial players primarily earn their living by interjecting themselves between transactions as much as they do by helping to steer the flow of capital. It's highly unlikely, given the amount of remuneration CMIPs earn today, that they will go quietly into the night while a new system develops around them.

## VII. Conclusion

In the end, measuring the trade-offs between traditional and open ledger infrastructure is a straightforward process. The overall cost savings will become apparent and drive further interest in exploring ways to implement the blockchain into conventional services. With that, it will be the ultimate users of the capital markets, those that have capital, and those that need it, who will ultimately push for how quickly and how effectively they see change.

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