

Friction reduction in municipal bond market through blockchain technology¹

A report to CitiVentures

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1. Executive Summary

The purpose of this report is to highlight the numerous challenges in the municipal bond market that serve as impediments to retail investing. The solution proposed uses “mini-bonds” that integrate blockchain technology, thereby democratizing the market, lowering both issuance and trading costs and increasing secondary market liquidity.

- Municipal bonds are known to be an attractive investment due to their tax benefits, low volatility and negligible default risk.
- However, excessive rents in both the primary and secondary markets of municipal bonds limit their effectiveness in capital formation and investing.
- In the primary market, high issuance costs decrease the amount of capital that can be deployed by municipalities.
- From a secondary market perspective, minimum denominations, illiquidity and asymmetric information cause high commissions to be imposed on investors. This ultimately creates entry barriers for small, retail investors.
- The current solution designed to address this issue are mini-bonds, which are small denomination municipal bonds.
- However, mini-bonds have not yet been widely adopted throughout the financial industry, primarily due to the physical delivery required and marketing challenges.
- To increase retail investor demand in municipal bonds, blockchain concepts can be combined with mini-bonds to create a permissioned blockchain platform that issues “muni tokens” through smart contracts.
- This blockchain platform would eliminate centralized clearinghouses, remove unnecessary entities from the issuance process and create a more liquid secondary market.

2. Introduction

The municipal bond market has an aggregate value of \$3.8 trillion, making it the 4th largest fixed-income market in the United States (Muni Facts, 2019). Out of all financial investments, municipal bonds are considered to be one of the most socially impactful; funding from these bonds jumpstarts projects in state, local and township governments, thereby directly influencing a large majority of the nation's population.

However, numerous challenges currently plague the primary and secondary markets of municipal bonds, affecting both municipalities and retail investors. High issuance costs have decreased the amount of capital that can be deployed by municipalities, and may threaten the quality of infrastructure projects. Additionally, frictions such as minimum denominations, illiquidity and asymmetric information lead to barriers to entry for retail investors, and excessive rents for industry players such as broker-dealers.

For years, solutions have been hypothesized to democratize the municipal bond market and to provide retail investors with the ability to invest. Mini-bonds, which are low-denomination bond offerings typically below \$500, have been adopted by many cities as a way to increase retail participation. However, due to frictions in the issuance process, mini-bonds have not been widely adopted by the finance industry.

To address this problem, we propose a combination of blockchain concepts and mini-bonds in order to create a permissioned blockchain platform that issues “mini-tokens” through smart contracts. This platform would reduce frictions, lower costs and create a more liquid secondary market, thus enabling retail investors to reap the benefits of municipal bond investing.

3. Benefits of Municipal Bond Investment

A municipal bond is a debt security issued by a state, municipality or county to finance its capital expenditures, including the construction of highways, bridges or schools (Chen, 2019). In 2018, the municipal bond market had an aggregate value of \$3.8 trillion, roughly one-third that of the corporate bond market (Muni Facts, 2019). There are, however, many more issuers of bonds in the municipal market. For example, there are 10,000 corporate bond issuers compared to 50,000 municipal bond issuers. Furthermore, municipal bonds can be complex or simple, depending on the underlying characteristics of the security -- for example, bonds with attached calls, sinking funds, credit enhancement, etc (Harris, Piwowar, 2006). Thus, the municipal bond market is an important source of capital in the economy for local and state governments, as it offers a wide selection of securities from which investors can choose.

There are two general types of municipal bonds: general obligation and revenue. A general obligation bond is backed solely by the issuing entity's taxing power, such as property taxes or general funds. A revenue bond, on the other hand, is one that is repaid from a specific revenue stream, such as the construction of a new interstate highway tollbooth. Due to the uncertainty of the revenue stream itself, revenue bonds are typically seen as riskier than general obligation bonds (Chen, 2019).

Municipal bonds offer a plethora of benefits, such as tax-savings, low volatility and low default risk, that attract investor funds. These benefits have allowed the municipal bond market to become one of the largest in the world, and also one of the most socially impactful. The ability of municipalities to effectively deploy capital ultimately depends on the level of demand from both institutional and retail investors.

Tax-Exempt Status

Both institutional and retail investors are attracted to municipal bonds for their beneficial tax implications. The majority of municipal bonds are exempt from federal taxes, and can also be free of state and local taxes under certain circumstances. For example, an investor that purchases a bond from his or her own state will be exempt from state income taxes. The capital gains tax and other little-known taxes, such as the de minimis tax and alternative minimum tax (AMT), are often still imposed on municipal bond investors (Howard, 2019). However, in general, municipal bonds enjoy a more favorable tax treatment than other securities.

Low Volatility

Municipal bonds are also considered to be one of the safest assets to invest in. During turbulent periods in the stock market, municipal bonds offer protection from widely variable returns. Because of this, they are often included in many investors' portfolios to increase diversification and reduce risk.

Low Default Risk

When compared to corporate bonds, municipal bonds have considerably lower default risk. Bonds issued by entities such as cities, counties and state governments experienced a near 0% default rate from 1970 to 2015 (VanEck, 2017). Additionally, only a few sectors of municipal bonds, such as housing and hospitals, accounted for almost 70% of all defaults.

Even though municipal bonds may be attractive to investors because of their favorable characteristics, there are a number of challenges municipalities face when raising capital.

4. Current Challenges

Despite the benefits highlighted above, excessive rents may be available to those involved in municipal bond primary and secondary markets. Due to their importance and greater bargaining power in these markets, investment banks and broker-dealers are able to levy high fees for their services. These costs trickle down to both municipalities and investors. For municipalities, high issuance fees reduce the total amount of capital that can be deployed for various projects. From an investor perspective, trading commissions are high because of illiquidity, lack of information and transaction costs. These commissions negatively affect the net return on investments and may cancel out the tax-free benefits. In total, many of these challenges may undermine the effectiveness of municipal bonds as a form of capital formation.

These frictions begin with the issuance process and continue once the bonds begin trading. Below is a discussion of how new bonds are issued and the institutional details of the secondary trading market, with an emphasis on the costs to retail investment.

4.1 Primary Market

The municipal bond issuance process is rather complex and involves several different entities. *Exhibit 1* highlights that as many as 10 different external agents can be involved in a single issuance. For the sake of brevity, an explanation of the parties pertinent to our argument are provided in Appendix 9.1. As the appendix highlights, the players that impose the greatest cost on municipalities are the municipal advisors, underwriters, bond counsels and rating agencies. In aggregate, they represent more than 83% of all the costs involved in the issuance process.

Based upon a study conducted by the Haas Institute at the University of California at Berkeley, the average cost of issuing municipal bonds from 2012 to 2015 was 1.02% of the total issuance principal. Out of the 812 issuances included in the study, however, there is significant variation from this average, with some entities paying as much as 9% of the principal for the entire issuance process (Joffe, 2015). A complete breakdown of all the costs from the municipal bond issuance process is shown in *Exhibit 2*. As previously mentioned, the majority of costs stem from the municipal advisors, underwriters, bond counsels and rating agencies.

For many of the issuing municipalities, these costs can be in the millions of dollars. In total, issuance costs for municipal bonds in the United States are estimated to be \$3-4 billion annually. Higher fees mean that there is less money available for capital deployment, and the quality of some municipalities' infrastructure may suffer. These costs are particularly significant for smaller issuers -- such as poorer, rural governments -- and may act as a deterrent for those municipalities to enter the bond market (Joffe, 2015).

In addition, the minimum capital required to invest in municipal bonds is \$5,000, essentially preventing the majority of retail investors from entering the market. In addition, underwriters find selling to retail customers prohibitively expensive. Assume that a municipality is intending to raise \$100 million. It is much easier and certainly less costly for an underwriter to place the issue with 10 institutional customers who each purchase \$10 million, than with 10,000 smaller retail customers who each purchase \$10,000. Thus, there is a disincentive to place a significant portion of the issue with retail customers.

4.2 Secondary Market

Previously issued municipal bonds are traded in a dealer dominated, decentralized over-the-counter (OTC) market. At the center of this network is a small number of highly interconnected dealers. These dealers handle the majority of order flow in the secondary market. In addition, there are around 2,000 sparsely connected peripheral dealers that are located at the edge of the network structure.

Central dealers consistently achieve faster trade execution than their peripheral counterparts by utilizing well-established trading networks. These networks offer immediate access to clients and more information about which securities are available and who wants to trade them -- resulting in shorter intermediation chains. Additionally, central dealers are able to trade on a principal basis, meaning they take the bonds into inventory. In contrast, peripheral dealers take the time to pre-arrange a trade by finding counterparties beforehand, resulting in slower execution speeds (Li and Schürhoff, 2019).

The structure of the dealer network makes trading in the secondary market expensive for the retail investor because they get “crowded-out” by large institutions and lack easy access to pre-trade information, resulting in higher transaction costs. Harris and Piwovar (2006) analyze a sample of 167,000 municipal bonds from 1999 to 2000 to discover the primary sources of transaction costs in the secondary market. They show that contributing factors include trade size, credit quality, instrument complexity, and counterparty search costs. For retail-sized trades under \$20,000, effective spreads average about 2% of the price compared to less than 1% for institutional-size trades of \$200,000 (Harris, Piwovar, 2006).

Illiquidity

One issue that affects all investors is that following the initial distribution period, it is extremely common for a bond to trade infrequently. According to a 2012 SEC document titled “Report on the Municipal Securities Market,” around 99% of outstanding municipal bonds did not trade on any given day in 2011 (United States). Because of this illiquidity, investors are often forced to take “haircuts¹²” if they sell their bond prior to maturity. This can ultimately lead to lower portfolio returns and can nullify the tax and creditworthiness benefits previously mentioned.

Asymmetric Information

While large institutions are connected to the central dealers, and thus have more information available to them and can achieve faster execution speeds, retail investors lack the same kind of knowledge. Therefore, they have far less bargaining power to reduce transactions cost when trading. Additionally, retail investors must rely on dealer quotes to gain pre-trade pricing information. Many of these quotes are available on municipal bond alternative trading systems (ATSS) – electronic venues where dealers post quotes, request quotes, and execute trades. However, Craig, Kim, and Woo (2018) explain how only subscribers to the ATSS can view the information, which is limited to a small group of market participants. As a result, while dealers may use available quote information to negotiate prices with customers, retail customers generally do not have direct access to quote information when negotiating prices with dealers. This lack of transparency and the resulting information asymmetry between dealers and customers is one of the main drivers for high transaction costs.

These costs ultimately reduce investor returns and can therefore be an important factor in deciding which type of security to purchase. Explained further in Appendix 9.2, there are initiatives in place to provide pre- and post-trade pricing data to retail investors, in hopes of increasing transparency and reducing asymmetric information among dealers and customers. However, the extent of their success is still an outstanding issue.

5. Retail Investment in Municipal Bonds Through Mini-Bonds

The market frictions highlighted above make encouraging retail investment in municipal bonds challenging (Backman, 2018; MSRB, 2018). A study by the Municipal Securities Rulemaking Board (MSRB) -- an entity responsible for overseeing the municipal securities market -- finds that since 1970, market makers have commonly preferred high-denomination municipal bonds to target large institutional investors (MSRB, 2018). The market convention of high-value

¹² The difference between the intrinsic value of an asset and the final selling price due to illiquidity

offerings, i.e. over \$5,000, effectively excludes small investors from participating in both the primary and secondary markets.

In order to tackle these challenges, various municipalities such as the cities of Cambridge, Denver, and Vancouver started offering low-denomination alternatives. The following sections will discuss in more detail the concept of mini-bonds, the issuance processes employed by cities, and additional socioeconomic benefits of offering mini-bonds.

5.1 Low-Denomination Bond Offerings (Mini-Bonds)

A mini-bond is a type of bond offering with a denomination typically smaller than \$5,000 (Syndicate Room, 2019). While the characteristics of mini-bond offerings vary by municipality, they retain similarity to other high-denomination municipal bonds. While no municipal mini-bonds have identical terms, typical characteristics include a maturity between three to five years with regular interest payments (Syndicate Room, 2019).

The issuance process of mini-bonds is another important differentiating factor. In a traditional municipal bond issuance, cities work with investment banks to handle the issuance of high-denomination bonds. The bond is held in the name of the brokerage firm, and individual investors' names are recorded in a book i.e. book-entry form. This is called a brokerage model (Fu, 2018). However, due to the complexity of municipal bond offerings and counterparty search costs, the brokerage model does not allow for a cost-effective issuance of small denomination bonds (Fu, 2018). Instead, cities assume the administrative responsibilities for issuance, including marketing and processing the bonds directly for retail participants. To assist cities in handling these responsibilities, private firms such as Neighborly¹³ serve as the broker-dealer for the physical issue of mini-bonds. Many municipalities rely on these private firms when offering mini-bonds, including the City of Cambridge, one of the mini-bond case studies discussed below. While there are system challenges in issuing mini-bonds, many small municipal projects may only be funded using the mini-bond model (Orcutt, 2018).

5.2 Socioeconomic Benefits of Mini-Bonds

In contrast to the high-value municipal bond, mini-bonds have been used by a variety of cities to fund smaller municipal projects that the high-denomination bond structure does not allow. These smaller projects are often more effective in city-building and enable sustainable incremental development (Orcutt, 2018). Small denominations also have the potential to allow a larger pool of retail investors to invest in bonds, many of whom may wish to engage in socially responsible

¹³ Read more about Neighborly in Appendix 9.4

investing. A study conducted by the University of Cambridge shows that geographically-based financial instruments have increased the participation of local retail investors in providing capital to municipalities (Rau, 2016).

While the economic success of the issuance is an important aspect of municipal projects, the social impact of the securities offering plays an important role in the long-term investment success within a city. With the increased interest of retail investors in socially responsible investing (Connaker and Madsbjerg, 2019), municipalities may be overlooking an important source of sustainable capital: members of their own community. Because municipal bond proceeds are often used to finance highly important local projects such as hospitals, affordable housing, nursing homes, and infrastructure, members of the community are typically motivated to help fund the projects (Schueth, 2003). In addition to the tangible financial returns, municipal bond investors also play an important role as a participant in the improvement of the community through their investment. Thus, by offering low denomination mini-bonds, retail investment may increase and municipalities will reap the benefits provided by additional funding.

5.3 Implementation of Mini-Bonds

Mini-bonds are not new and have been sporadically used since the late 1800's in New Orleans (Axelrod, 2018). Despite this, the issuance of mini-bonds is still not a common practice and has not been widely supported by traditional brokerage models. Three offerings (highlighted in Appendix 9.3) in the cities of Cambridge, Denver, and Vancouver, show cases of successful mini-bond projects and highlight several benefits of offering low denomination bonds. The bond offerings in each of these cities were all completed within a very short period of time, from a few minutes to a few days. This evidence supports the claim that there is significant demand for low-denomination bonds from retail investors and that the municipal mini-bond market is a viable one to pursue.

While a number of mini-bond offerings were successful, they still face many challenges, namely the lack of an infrastructure suited to mini-bond issuance. Cities creating mini-bonds require processes that differ from those currently offered by investment banks. These may include new logistics and management of retail sales, marketing and other issuance operations. For example, to have successful retail sales, online portals must be utilized to allow order submissions by a large group of investors. At this time, the cities that have conducted a mini-bond offering have issued physical bonds that are mailed to investors -- a process that is highly inefficient.

5.4 Blockchain and Mini-Bonds

Major frictions to mini-bonds exist in the issuance, management, and marketing process of mini-bonds for retail investors. Since there have been few cases of mini-bond offerings, established market makers to facilitate this process do not exist. Due to the high cost of setting up new market makers and relevant human-based trading platforms, the blockchain offers an opportunity to automate and minimize human-related costs in the establishment of a new mini-bond market (Amante, 2018). The process of setting up a mini-bond market and the required functionality to trade those bonds can be programmed into a smart contract (described in section 6.2). Thus, it is a market that can most benefit from new technology implementation, such as blockchain. After realizing the success of mini-bond programs in other cities and the challenges of creating a platform for customers to purchase the bonds, the city of Berkeley sought to incorporate the blockchain into their municipal bond issuance. However, the process is currently under review and blockchain solution has not been implemented¹⁴.

6. Blockchain Technology Applied to Mini-Bonds

For municipal bonds, a private blockchain network is a possible solution to resolve some inefficiencies. A private and permissioned blockchain allows for permissions to regulate how parties can transact, would reduce issuance costs by removing certain entities involved in the issuance process, and may eliminate asymmetric information problems in the secondary market.

6.1 Proposed Solution

In order to successfully transition the municipal bond issuance process onto the blockchain, smart contracts need to be utilized.

Smart contracts are code that can execute and enforce the terms of the agreement¹⁵. Smart contracts are able to use the computational power of blockchain to distribute the assets once the contract conditions are met.

Another feature of the proposal is to use a permissioned blockchain where a centralized figure acts as an administrator who determines who is able to join the network and their respective permissions. In this situation, this could be delegated to a role that Citibank plays or a similar entity. By offering mini-bonds on the blockchain, some of the entities currently involved in the traditional issuance process may be completely eliminated.

¹⁴ Read more about the city of Berkeley in Appendix 9.3

¹⁵ Read more about Smart Contract in Appendix 9.6

Beginning at the start of the issuance process, the issuers and municipal advisors upload new “muni token” contracts and to accept a price bid transaction. They code the term structure of the new “muni token” and upload it to the permissioned blockchain. Once sent, it must wait to receive a credit rating from the agencies on the network. The rating agencies must assign a “grade” transaction to the “muni token” to determine the risk of default by the token’s issuer.

Each node on the network has a unique private key to identify themselves and provide relevant details. The issuer’s details may include: municipal government background, financial statements, debt liabilities, sources of funds for repayment, etc. The rating agency can use this information and any other outside material needed for their rating. Once a credit rating is determined, the rating agencies send the “rating” transaction request to the “muni token” address. The token is created, which in turn invokes a new transaction request with the newly assigned credit rating of the “muni token.”

At this point, the contract is visible to underwriters on the network and they are able to send pricing bids to the issuer within a specified time frame. This bid will state both the interest rate paid to investors and the amount of compensation to the underwriting group for selling the bonds. After the time period for bidding has ended, the issuer sends an “accept” to the underwriter who has the winning bid. Once the transaction has been accepted by both parties, the underwriter and issuer are locked in on this contract and must await the other nodes on the network to approve the token agreement.

The next step is to have the underwriter and issuer counsels both confirm the issuer’s authority to issue the bonds and attests to the validity and enforceability of the tokens. Although smart contracts act as a legal contract, having an outside third-party ensure these are legal contracts in the eyes of the law may give investors additional reassurance about the validity of the terms. The counsels will send an “approval” transaction stating that token is a legal obligation of the issuer.

The blockchain overcomes the need for either physical delivery of paper certificates or book-entry recording of securities. By distributing the “muni tokens” on the blockchain, the proof of ownership is immutable once purchased. This removes the reliability of a third-party organization keeping track of which investors own which particular bond(s). By removing the central clearinghouse from the process, the fees originally required to print and mail paper certificates or pay for recordkeeping will be eliminated.

The trustee who is responsible for transmitting principal and interest payments to the investors, as well as maintaining records of the investor is no longer needed. With the use of smart contracts, the investors are paid the specified interest once a certain time period is reached. Also,

the blockchain maintains an immutable record of the investors all the way back to when the “muni token” was created.

6.2 Benefits of the Blockchain

There are multiple parties involved in the process of creating a bond and all of those parties need different levels of permission to perform their duties. The ability to create different levels of permissions is one of the main advantages of a private and permissioned network. Some of those parties, such as a bond rating agency, only need permission to update the rating of the bond. Other agencies such as the issuer and bond advisor would need permissions that enable them to create and distribute tokens.

There are a number of other benefits that could be generated by using the blockchain for issuance. For example, the current system of issuance requires that each bond have a unique Committee on Uniform Security Identification Procedures (CUSIP) identification number (MSRB). When tokens are generated, they will each have their own unique hash value that can act as an identifier. Therefore, CUSIP numbers will not be needed if the distinctive hash value is used to identify the newly created token. This will eliminate the fees required to be paid to the Committee on Uniform Security Identification Procedures.

Furthermore, the use of blockchain as a platform for the municipal bond market would likely disrupt the dealer network structure that currently exists. By extrapolating from the experience of the trading of OTC derivatives market implemented on the blockchain, it is possible to make reasonable assumptions about how the blockchain would function in the secondary market for municipal bonds given the similarities between them. Both markets are over-the-counter and decentralized, with broker-dealers involved in most of the order flow due to the high search frictions and transaction costs. Ryan Surujnath (2017), hypothesizes that parties in a blockchain derivatives transaction would submit bids and asks as usual. However, the use of the blockchain would lessen the role of dealers. It would make it possible for parties to send a “bid or ask” transaction and upload bids or asks directly to specific municipal token addresses on the blockchain. The blockchain could then be programmed to automatically match the ask with the corresponding highest bid.

In addition, parties could also take advantage of the anonymity provided by the blockchain, rather than relying on dealers to match buyers and sellers together. Since the data about transactions is public to those involved in the network, there will be a reduction in asymmetric information in the market. By eliminating the search frictions that currently exist in the municipal bond market as well as trading transparency, it is reasonable to assume that transaction costs would likely be reduced, thereby making the market more efficient.

7. Remaining Challenges

While a permissioned blockchain platform that issues “muni tokens” solves frictions in the municipal bond market, some challenges remain. First, there is no clear solution for successfully marketing mini-bonds to prospective investors. The lower transaction costs as a result of the digital processing of bonds will be irrelevant without significant consumer demand/traffic. The viability of this idea is solely dependent on the assumption that municipalities can make consumers aware of this financial product.

Additionally, the platform will only reach its full potential in an ecosystem where all market players adopt similar blockchain technologies. Because there will always be a need for third-party entities such as credit rating agencies, there could exist adoption frictions.

Lastly, automating municipal bond markets with blockchain technology will result in infrastructure investment costs for market players. While there is not an exact estimate of this cost, it could be significant depending on the type of blockchain application adopted and the associated computing power required for each transaction.

8. Conclusion

The municipal bond market faces several major challenges, including illiquidity, asymmetric information, high issuance costs and high transaction costs. These market frictions are attributed to the structural inefficiencies driven by the market’s preference toward large institutional investors. This predilection has led to the market convention of high-denomination bond offerings, creating entry barriers for small retail investors. As a result, the brokerage model employed by the current market makers is optimal only for the large institutional players investing in large municipal projects. In these recent years, some cities have begun to realize the importance of small municipal projects and socially responsible investment for the long-term success of municipal development. Mini-bond issuances have become an outlet for several cities, with a number of successful projects proving the viability of a mini-bond structure. This requires different market structures and platforms that will allow for low-denomination bond offerings.

This paper suggests the use of private and permissioned blockchains as a solution for the existing frictions relating to mini-bonds. These frictions include the high cost of setting up a new market maker and the corresponding human-based trading platform. While the type of blockchain proposed in this paper can be applied to the larger municipal bond market, its application on the mini-bond market could yield the highest benefit, as the lack of established infrastructure means low switching costs for the market.

While a blockchain-applied municipal mini-bond structure presents exciting opportunities and benefits to municipal issuers and retail investors, there are still challenges that have not been tackled, including retail marketing of mini-bond sales, costs due to the computing power required for blockchain solution, and third-party technology adoption in the issuance and transaction process.

9. Appendix

9.1 Municipal Bond Primary Market Agents

Municipal Advisor

The issuing entity calls upon a municipal advisor, who assists in the debt and capital planning process. Additionally, the advisor develops requests for proposals and qualifications for underwriters, bond and disclosure counsels. An advisor acts in a fiduciary capacity, meaning that it must keep the issuing entity's best interest a priority.

Underwriter

The underwriter, which is typically a large investment bank, often guarantees proceeds at closing and obtains funds from investors after conducting "roadshows"¹⁶. The underwriter is crucial in the pricing of the bond itself. In many cases, the lead underwriter of the issuance also manages the affairs of the underwriting syndicate, which disperses the risk among multiple investment banks.

Bond Counsel

The primary purpose of the bond counsel is to deliver legal opinion to the issuing entity. Due to the complexity of the issuance process, the bond counsel must draft numerous documents regarding bond resolution, indenture, loan agreement and other financing. Additionally, it provides guidance in properly following tax law and ensures the tax-exempt status of the bonds.

Rating Agencies

The goal of rating agencies is to assess the credit quality of bonds and to ensure that consumers have adequate information before investing. These agencies have an extremely important role, as their ratings directly affect the coupon rates of municipal bonds. When a bond is considered safer and given a higher rating, investors can expect a lower return and vice versa. The three most prominent firms currently in the rating industry are S&P's, Moody's and Fitch.

¹⁶ A sales pitch by the underwriting firm to potential investors, prior to an issuance (Murphy, 2019)

9.2 Recent Regulatory Changes

Because municipal bonds trade infrequently, the last-trade information is often stale by the time of the next trade, providing less useful information to customers. In 2005, the MSRB created the Real-Time Transaction Reporting System (RTRS), which requires dealers to publicly disseminate transaction information 15 minutes after the trade, increasing post-trade price transparency.

In 2008, the Electronic Municipal Market Access (EMMA) was developed, merging real-time trade data with important disclosure documents, and further expanding public availability of secondary trading information. Similar to the RTRS, though, the usefulness of this data is limited given the illiquid market.

As stated earlier, electronic trading systems have progressed in the inter-dealer municipal bond market, improving trading efficiency and reducing counterparty search costs, possibly passing savings onto retail investors. But since the pricing information posted on these systems is only available to subscribers of ATSS -- typically dealers and institutional investors -- the retail customer still lacks the kind of bargaining power that larger institutions have.

9.3 Mini-Bond Case Studies

The city of Cambridge proceeded with a mini-bond offering in February 2018 for the purpose of supporting the city's capital budget and more specifically to fund physical infrastructure. The city reached their target investment in less than a week with 217 Cambridge residents participating and about \$1.8 million in mini-bond proceeds (Brode, 2018). The bonds were available in minimum denominations of \$1,000, interest was paid semiannually, and the minibonds were set to mature in five years.

In 2015, the city of Vancouver issued \$500 denomination bonds to fulfill a general obligation capital fundraising, raising \$1.3 million of a \$1.5 million target (Fu, 2016). The secondary goal of the fundraising was to foster community engagement in a sound financial investment. Vancouver was interested in automating the order process, but ran into hurdles, ultimately making the process difficult. This led to the purchase method for investors being restricted to mail or hand delivery.

The city of Denver completed a mini-bond capital raise in 2014 totaling \$12 million in sales in less than 20 minutes (Denver, 2014). These bonds were offered in \$500 denominations with the purpose to improve the city's outstanding cultural facilities. The success was a result of the purchase options for investors. Denver's bonds were accepted online, through the mail, or by hand delivery, making the process more accessible for the city's residents. The city hired a

third-party to develop the offering's platform because of the time-consuming and resource-intensive nature of the project (Fu, 2016).

The city of Berkeley have expressed interest in incorporating blockchain solution into their municipal bond issuance. The city saw three main advantages of such a strategy. First, they sought to cut down on the third-party service providers that are required in the bond-issuance process. Each intermediary charges fees and mark-ups, and by removing even a few, there can be substantial savings for the local government. For example, the UC Berkeley Haas Institute estimates that bond issuers lose approximately \$4 billion annually as a result of this process, and adapting this process to blockchain allows for removal of the middle man (Orcutt, 2018). Secondly, the blockchain would add greater security and transparency to the offer process. Lastly, they expected to see a reduction in issuance costs. As Berkeley's Mayor Ben Bartlett said, "Blockchain technology is attractive because it allows you to instantly record transactions indelibly, and it can't be altered. When you can do that, you lower the cost so much on issuance that you can make the bond available for 25 cents, honestly." (Cullinan, 2018) This lower cost is compared to the currently available issuance process that involves many different layers on intermediaries throughout the process.

9.4 Neighborly - Municipalities' crowdfunding and trading platform

Neighborly allows for the easier marketing of municipal bonds to retail investors. Founded in 2012, Neighborly is an electronic crowdfunding and trading platform for civic projects through municipalities' municipal bonds offerings. As an investing platform, Neighborly allows investors to trade municipal securities through its affiliated registered broker-dealer, Neighborly Securities. In contrast to the existing brokerage model, Neighborly allows for lower transaction costs and easier access of information, submission of trading orders, and portfolio management for retail investors (Orcutt, 2018). Neighborly has helped the cities of Cambridge, Massachusetts and Denver executing their successful mini-bond sales. In collaboration with the city of Berkeley, Neighborly is developing a blockchain-based solution for municipal issuance and trading (Amante, 2018).

9.5 Blockchain Technology Introduction

Blockchain technology has been known as a tool to create an ecosystem that removes rent seekers and dramatically reduces the costs of transactions. It is imperative to understand what a blockchain is and how a blockchain works. Simply put, a blockchain is a ledger distributed among multiple parties that has a special protocol for updating all the copies of the ledger when parties transact. Blockchains allow transactions to be made without a central authority, reducing the costs and making them highly traceable. While blockchains were initially designed as an

efficient payment system, their use cases have evolved to include applications spanning from tracking leafy greens from farm to table to the settlement of financial assets.

The term “blockchain” is derived from how the network validates transactions and prevents fraud. Every transaction is encrypted and then stored in a block with other transactions. This encrypted value is called the hash. The subsequent block of transactions is encrypted using the hash of the previous block, creating a chain of connected blocks. The hash can also be partially decrypted to reveal the values it was encrypted with; an identifier of the person initiating the transaction and the hash of the previous block. The encryption mechanism is designed so that any change in one of the values used to encrypt the transaction would completely change the value of the transaction. The encryption mechanisms makes it almost impossible to defraud the system because any change in a previous transaction would completely change the encrypted values further down the chain. The only way to gain control of such a network would be to perform what is called a 51% attack where the entity controls over 51% of the validators and any change it makes to the ledger is falsely thought to be approved by the ‘majority’ of validators.

There are two main classes of blockchains: public and private networks. Public networks were initially designed as a way of circumventing traditional financial institutions and are most known for their use as payment systems. Bitcoin and Ethereum are the two most popular public blockchain networks and they share many similarities. For example, public blockchains have no central authority and require a vast network of unrelated and individual entities to validate transactions. The mechanism most public blockchains use to achieve consensus among the distributed ledgers utilizes the same fundamental concepts. Since there is no central authority, the consensus mechanism acts as the administrator to keep everyone in check.

Private or permissioned blockchains achieve their goals differently. Many of them are not truly blockchains, but rather, as IBM describes them, distributed ledger technologies that use fundamental blockchain concepts to achieve consensus. Their consensus mechanisms vary from a complex one similar to that of Bitcoin to a simple one like a basic democratic voting system. Private networks allow for some form of central authority that can control who is allowed to participate in the network and how those members can transact. They also allow for different levels of permissions for different types of parties involved in a transaction. One could imagine a scenario where there would be a need for a regulator to freeze an account but that regulator should not be able to transact on behalf of an individual. These types of permissions make private and permission blockchains very flexible. While public networks count on all parties assuming everyone is a stranger and there is zero trust between each other, a private network assumes that every participant has some level of trust in each other; like how banks sometimes perform certain transactions only with other banks because they know that the other party is indeed a trusted bank.

Like most things, there are benefits and drawbacks to both types of networks. Public blockchain networks allow anyone that has access to the internet to partake in their financial ecosystem. This removes any potential conflict of interest with a financial intermediary. Since there are no third-party institutions processing payments and the transfer of assets, there is less friction when parties transact, creating benefits such as lower fees. Often there is a fee per transaction and each transaction takes, when compared to credit card transactions, longer to process because consensus across a fairly large network needs to be obtained. Another drawback is that there is generally no central authority regulating the market and protecting its participants in the event of fraud.

Since private blockchains allow for a central authority to act as an administrator, it makes the networks better suited to comply with regulatory standards. These networks can control who is allowed to see transactions and who is allowed to partake in transactions, whereas on a public network those controls do not exist. The big drawback to private networks is that the network is sacrificing decentralization for control, but for many applications of private blockchains, decentralization is less important.

9.6 Smart Contract

Smart contracts were first defined by a lawyer and computer programmer Nick Szabo, who described them as:

[A] computerized transaction protocol that executes the terms of a contract. The general objectives . . . are to satisfy common contractual conditions (such as payment terms, liens, confidentiality, and even enforcement), minimize exceptions both malicious and accidental, and minimize the need for trusted intermediaries. Related economic goals include lowering fraud loss, arbitration and enforcement costs, and other transaction costs (Tapscott).

Unlike traditional contracts or obligations that have excessive amounts of text and paperwork, smart contracts reduce them to their basic components in the form of “if/then” statements (Surujnath, 2017).

10. Exhibits



Exhibit 1 — Professionals Involved in a Competitive Muni-Bond Financing Transaction (MSRB, 2018)

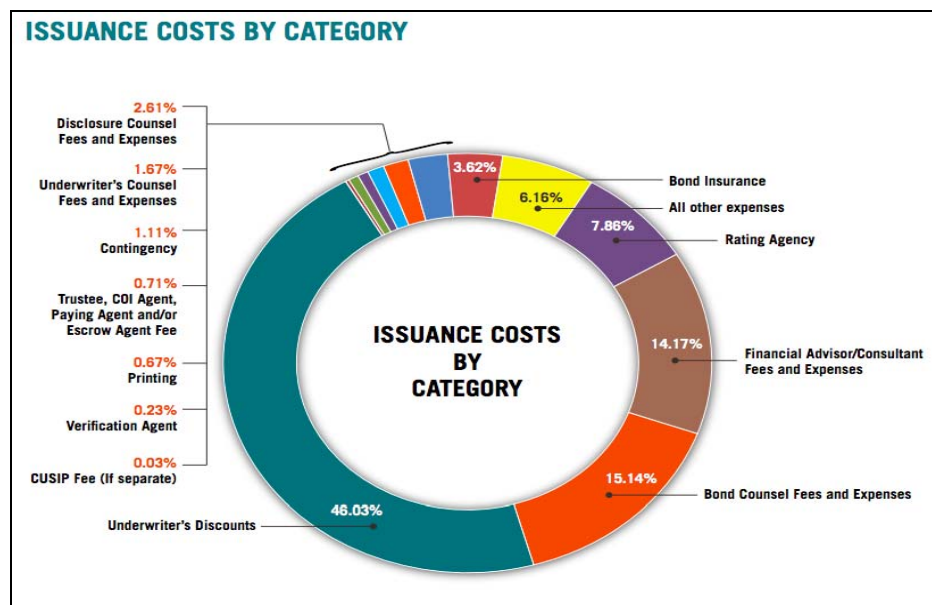


Exhibit 2 — Issuance Costs by Category (Joffe, 2015)

11. References

- Amante, Maria. "Berkeley working to finalize first-ever blockchain microbond issuance." *DebtWire*, 12 Sep. 2018.
<https://www.debtwire.com/info/berkeley-working-finalize-first-ever-blockchain-microbond-issuance>. Accessed 3 May 2019.
- Axelrod, Jason. "The Mini-bond Issue." American City and County, 7 Nov. 2018.
<https://www.americancityandcounty.com/2018/11/07/the-mini-bond-issue/>. Accessed 29 Apr. 2019.
- Backman, Maurie. "Your Complete Guide to Municipal Bonds." *The Motley Fool*, 7 Dec. 2018,
www.fool.com/investing/2018/12/07/your-complete-guide-to-municipal-bonds.aspx.
Accessed 29 Apr. 2019.
- Belz, Sage. "Key Changes in the Municipal Bond Market since 2007." Brookings, Brookings.
www.brookings.edu/blog/up-front/2017/07/14/key-changes-in-the-municipal-bond-market-since-2007/. Accessed 3 Oct. 2017.
- Bourgi, Sam. "How Municipal Bonds Can Help You During Volatile Markets." *MunicipalBonds.com*.
www.municipalbonds.com/investing-strategies/municipal-bonds-help-during-volatile-markets/. Accessed 12 Apr. 2018.
- Brode, Gary. "City Of Cambridge Sells Over \$800,000 In Mini-Bonds In One Day." CBS Boston, 21 Feb. 2018.
<https://boston.cbslocal.com/2018/02/21/city-cambridge-mini-bonds-investments/>.
Accessed 26 Apr. 2019.
- Chen, James. "Municipal Bond." Investopedia, Investopedia.
www.investopedia.com/terms/m/municipalbond.asp. Accessed 12 Mar. 2019.
- City of Cambridge Minibonds*.
minibonds.cambridgema.gov/how_are_minibonds_different_from_regular_municipal_bonds. Accessed 30 Apr. 2019.
- "CoinDesk ICO Tracker." CoinDesk, www.coindesk.com/ico-tracker.

- Connaker, Adam, and Saadia Madsbjerg. "The State of Socially Responsible Investing." *Harvard Business Review*, 17 Jan. 2019.
hbr.org/2019/01/the-state-of-socially-responsible-investing. Accessed 29 Apr. 2019.
- Craig, Louis, et al. *Pre-trade Information in the Municipal Bond Market*. 12 July 2018. U.S. Securities and Exchange Commission. Accessed 29 Apr. 2019.
- Cullinan, David. "Blockchain Bonds - Raising Money For City Projects." CryptoDisrupt.
<https://cryptodisrupt.com/blockchain-bonds-raising-money-for-city-projects/>. Accessed 3 May 2019.
- Denver. "2014 Denver Mini-Bonds." Department of Finance, 2014.
<https://www.denvergov.org/content/denvergov/en/denver-department-of-finance/cash-risk-capital-funding/better-denver-mini-bond-program.html>. Accessed 3 May 2019.
- Ditto. "Stash H1 2017 Case Study." Ditto, 2017.
<https://k9q3a2m4.stackpathcdn.com/wp-content/uploads/2017/10/Ditto-StashH12017CaseStudy.pdf>. Accessed 3 May 2019.
- Donovan, William. "The Origins of Socially Responsible Investing." *The Balance, Dotdash Publishing Family*, 26 Mar. 2019,
www.thebalance.com/a-short-history-of-socially-responsible-investing-3025578.
 Accessed 29 Apr. 2019.
- Fu, Elizabeth. "Mini-Bonds: Public Engagement and Public Investment." *Government Finance Officers Association*, October 2016.
<https://www.gfoa.org/sites/default/files/GFR101616.pdf>. Accessed 29 Apr. 2019.
- Goldman, Elizabeth. "The Complete Guide to Mini Bonds." *Alternative Investment Coach*,
www.alternativeinvestmentcoach.com/mini-bonds/. Accessed 29 Apr. 2019.
- Gordon, Tracy. "Assessing Fiscal Capacities of States: A Representative Revenue System—Representative Expenditure System Approach, Fiscal Year 2012." Urban Institute. Accessed 31 Oct. 2017.
- Harris LE, Piwowar MS. *Secondary Trading Costs in the Municipal Bond Market*. Journal of Finance. 2006. doi:10.1111/j.1540-6261.2006.00875.x

Howard, Cooper J. "Not Always Tax-Free: 7 Municipal Bond Tax Traps." Schwab Brokerage, 5 Feb. 2019.

www.schwab.com/resource-center/insights/content/not-always-tax-free-7-municipal-bond-tax-traps.

Hume, Lynn. "Laws and Rules That Reshaped the Muni Market." Bond Buyer.

www.bondbuyer.com/news/10-years-later-rules-and-legislation-reshaped-muni-market. Accessed 22 Oct. 2018.

"Impact Investing with Municipal Bonds." *Evercore Wealth Management*.

www.evercorewealthmanagement.com/impact-investing-with-municipal-bonds-2/. Accessed 29 Apr. 2019.

Joffe, Marc. "Doubly Bound: The Cost of Issuing Municipal Bonds." 2015.

Li, Dan, and Norman Schürhoff. "Dealer Networks." *Journal of Finance*, vol. 74, no. 1, Feb. 2019, pp. 91-144, DOI:10.1111/jofi.12728. Accessed 29 Apr. 2019.

Luby, Patrick. "Muni Fund Ownership Growing." *ETF Report*, 18 Mar. 2016.

www.etf.com/sections/features-and-news/muni-bond-difm-ownership-growing.

Mercado, Darla. "Here's How Much Your Broker Makes When You Buy a Bond." *CNBC*, 14 May 2018.

www.cnbc.com/2018/05/14/heres-how-much-your-broker-makes-when-you-buy-a-bond.html.

"Milestones in Municipal Market Transparency." *Municipal Securities Rulemaking Board*, Apr. 2018,

www.msrb.org/~media/Files/Resources/MSRB-Report-Milestone-in-Municipal-Market-Transparency.ashx?la=en. Accessed 29 Apr. 2019.

MSRB. "Municipal Securities Rulemaking Board." *Municipal Securities Rulemaking Board*.

<https://emma.msrb.org/AboutEmma/aboutMSRB>. Accessed 1 Jan. 2019.

MSRB. "Minimum Denominations of Municipal Securities." *Municipal Securities Rulemaking Board*, 12 March 2018.

<http://www.msrb.org/~media/Files/Resources/MSRB-Minimum-Denominations-of-Municipal-Securities.ashx?la=en>. Accessed 1 Apr. 2019.

“Muni Facts.” *Municipal Securities Rulemaking Board*.
www.msrb.org/msrb1/pdfs/MSRB-Muni-Facts.pdf.

Murphy, Chris B, and James Chen. "What Happens at an IPO Roadshow with a Look into Alibaba's IPO." Investopedia, 28 Mar. 2019,
www.investopedia.com/terms/r/roadshow.asp.

"New York Stock Exchange." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 29 Apr. 2019. Web. Accessed 30 Apr. 2019.

Orcutt, Mike. “Berkeley, California, is considering an ICO unlike any other.” Technology Review.
<https://www.technologyreview.com/s/610442/berkeley-ca-is-considering-an-ico-unlike-a-ny-other/>. Accessed 30 Apr. 2019.

Professionals Involved in a Competitive Municipal Bond Financing Transaction. Municipal Securities Rulemaking Board,
www.msrb.org/msrb1/pdfs/Professionals-In-Competitive-Transaction.pdf.

Rau, P. Raghavendra, and Robert Wardrop. "Evangelical investors and the evolution of local bias." (2016).

Roles and Responsibilities: The Financing Team in an Initial Municipal Bond Offering. Municipal Securities Rulemaking Board, Jan. 2018,
msrb.org/msrb1/pdfs/Financing-Team.pdf.

Schueth, S. Journal of Business Ethics (2003) 43: 189. <https://doi.org/10.1023/A:1022981828869>

Schwert, Michael. "Municipal Bond Liquidity and Default Risk." *The Journal of Finance*, vol. 72, no. 4, Aug. 2017, pp. 1683-722, doi:10.1111/jofi.12511. Accessed 29 Apr. 2019.

Secondary Market Process. Municipal Securities Rulemaking Board,
www.msrb.org/EducationCenter/Municipal-Market/Lifecycle/Primary/Secondary-Market-Process.aspx

Social Investment Forum. “Socially Responsible Investing: Top 10 Questions & Answers.” Social Investment Forum.
http://mercyinvestmentservices.org/storage/documents/SRI_Top_10_Questions_and_Answers.pdf Accessed 29 Apr. 2019.

- Sherman, Barnet. "Municipal Bonds: A Socially Responsible Investment." *Forbes*, 23 Feb. 2016, www.forbes.com/sites/investor/2016/02/23/municipal-bonds-a-socially-responsible-investment/#5dd4944152fe. Accessed 29 Apr. 2019.
- Statman, Meir, What Investors Really Want: Know What Drives Investor Behavior and Make Smarter Financial Decisions (January 18, 2011). SCU Leavey School of Business Research Paper No. 11-03. Available at SSRN: <https://ssrn.com/abstract=1743173> or <http://dx.doi.org/10.2139/ssrn.1743173>
- Surujnath, Ryan. "Off the Chain: A Guide to Blockchain Derivatives Markets and the Implications on Systemic Risk." *Fordham J. Corp. & Fin. L.*, 2017, vol 22, pp. 257.
- Syndicate Room. "What are Mini-Bonds?" Syndicate Room. <https://www.syndicateroom.com/alternative-investments/mini-bonds>. Accessed 29 Apr. 2019.
- Traflet, Jason. "Ending a NYSE Tradition: The 1975 Unraveling of Brokers' Fixed Commissions and its Long Term Impact on Financial Advertising." *Essays in Economics & Business History*, 2007, vol 25, pp. 131-142.
- United States, Congress, "Report on the Municipal Securities Market." Report on the Municipal Securities Market, 2012, pp. 128.
- VanEck. "Municipal Defaults, While Rare, Do Occur." Seeking Alpha. seekingalpha.com/article/4066127-municipal-defaults-rare-occur. Accessed 27 Apr. 2017.
- "What Is an ICO?" Bitcoin Magazine, Bitcoin Magazine. bitcoinmagazine.com/guides/what-ico/. Accessed 10 Aug. 2017
- Wu S. *Transaction Costs for Customer Trades in the Municipal Bond Market: What Is Driving the Decline?* Municipal Securities Rulemaking Board. 2018:1-29.
- Zweig, Jason. "Lessons of May Day 1975 Ring True Today: The Intelligent Investor." *The Wall Street Journal* [New York], 30 Apr. 2015, Markets sec., www.wsj.com/articles/lessons-of-may-day-1975-ring-true-today-the-intelligent-investor-1430450405. Accessed 29 Apr. 2019

12. Biographies

Student Biographies

Andrew Caragher is a junior studying finance and accounting. This summer he will be an intern for PwC's healthcare consulting practice.

Cole Evans is a graduating senior studying business information systems with a minor in computer science and FinTech. He will be joining Charles River Development in Boston upon graduation as an Associate Consultant.

John Greene is a senior graduating in May with a degree in finance. His past experience includes assisting a professor in the finance department in the creation of a database on familial equity ownership of public companies.

Ryan Malloy is a graduating senior majoring in finance at Lehigh University. At Lehigh, he is a member of both the varsity baseball team and the TRAC Writing Program. Following graduation, Ryan will work for Goldman Sachs in New York City in its Private Wealth Management (PWM) division.

Cory Poe is a graduating senior pursuing a B.S. in Finance with a minor in Philosophy. He interned last summer for the managing director of GEN India -- a global entrepreneurship network working to fuel start and scale ecosystems by connecting creative individuals to the international marketplace. He is eager to apply an entrepreneurial mindset during life after college.

Aaron Rotem is a graduating senior studying computer science and business with a concentration in finance. He is passionate about blockchain technology and its ability to disrupt many industries. Next year he is going to work at EY as a technology consultant and is looking forward to solving a wide variety of problems across the financial services sector.

Lindsay Shagrin is a graduating senior studying finance in the College of Business and Economics. Next year she will be joining KPMG in their Financial Services Advisory group in New York City. On campus, Lindsay is involved in the Dreyfus Portfolio and the Thompson International Portfolio, and she was previously Vice President of the Tamid Group, a student club that works with Israeli companies on consulting and investing projects.

Phacharapol (Tech) Tanasarnsopaporn is a senior pursuing 5-year dual degrees in Finance and Materials Engineering. Tech has a strong interest in corporate strategy, entrepreneurial finance, and technology transfer. His experiences span across diverse industries including e-commerce (NYSE: SEA), commodity trading, and semiconductor manufacturing (NYSE: MU). At Lehigh, Tech was the engineering lead and founding member of Lehigh Hyperloop Team. The team was awarded top 10 for engineering design in the international SpaceX Hyperloop Competition 2017. Since 2016, Tech founded and served as the main coordinator for Lehigh Startup & Entrepreneur Meetup, MakerSpace Community, and Make-A-Thon Competition. Tech is currently holding a

part-time position at an IOT startup, Skillion Technology, as a materials engineer and financial analyst. Tech is graduating in May 2020.

Zhijian Yang is a senior in Integrated Business & Engineering Honors Program study in Industrial System Engineering and Finance. He interned in Deloitte Management Consulting last summer and anticipates continuing his studies with a Masters Degree in Machine Learning upon graduation.

Dean Zimberg is a junior/part-time student at Lehigh University studying Financial Engineering in the Integrated Business and Engineering (IBE) Honors Program. Dean is currently based in California, where he is completing a spring internship at Tesla Inc. in FP&A and Business Operations. This summer, Dean will be interning at Stifel Financial Corp. for their Investment Banking rotational program. On campus, Dean founded and currently serves as the President to the Lehigh FinTech Group -- a student club that has raised over \$50K in corporate sponsorship for fintech-related education programs, from hackathons to student projects (such as this research study, for example).

Faculty Advisor Biography

Kathleen Weiss Hanley joined the faculty in 2015 as the Bolton-Perella Chair in Finance and is the Director of the Center for Financial Services. From 2011 to 2013, she was the Deputy Chief Economist of the Securities and Exchange Commission and the Deputy Director in the Division of Economic and Risk Analysis where she oversaw the integration of economic analysis into policy and rulemaking across a broad range of topics in financial economics including the implementation of the Dodd-Frank Wall Street Reform and Consumer Protection Act and the Jumpstart Our Business Startups Act. In addition, she managed the Division's research activities, data analytics and risk assessment initiatives. Prior to that time, she was a Senior Economist at the Board of Governors of the Federal Reserve System in the Risk Analysis section and a Senior Financial Economist at the SEC. She has been on the faculty at the University of Maryland and at the University of Michigan. Her research focuses on capital formation and market pricing and has been published in leading finance journals such as *The Journal of Finance*, *Journal of Financial Economics*, *The Review of Financial Studies*, *Journal of Accounting and Economics*, and the *Journal of Accounting Research*. She is listed as one of the "authors with the most citations to their Journal of Financial Economics papers, 1974-2010."