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Blockchains, Real-time Accounting, and the Future of Credit Risk Modeling: Open Review

Authors: Hans Byström[†]

Reviewers: Reviewer A, Reviewer B, Reviewer C, Reviewer D, Reviewer E

Abstract. The final version of the paper "Blockchains, Real-time Accounting, and the Future of Credit Risk Modeling" can be found in Ledger Vol. 4 (2019) 40-47, DOI 10.5915/LEDGER.2019.100. There were five reviewers involved in the review process, none of whom have requested to waive their anonymity at present, and are thus listed as Reviewers A, B, C, D, and E. After initial review by Reviewers A, B, and C (1A), the editors requested that the authors respond to the reviewer concerns and make revisions (1B) before resubmitting. Another round of review then took place involving Reviewers A, B, and D (2A). The author responded to Reviewer D (2B) and resubmitted. A final review was carried out by Reviewer E (3A), suggesting minor changes. These were carried out by the author, completing the peer-review process. Author responses are bulleted for clarity.

1A. Initial Review

Reviewer A:

The paper by Professor Byström "Blockchains, real-time accounting and the future of credit risk modeling" (ISSN 2379-5980) attempts to demonstrate the benefits of the blockchains for the real-time accounting and credit risk modeling. The paper suggests that the blockchains innovation will have material positive impact on both. To establish that, the paper provides a description of the bitcoin blockchain system and, subsequently, extrapolates the application of the bitcoin blockchain system on the operations of the public accounting and auditing reporting. On the basis of the proposed prove that bitcoin blockchain improves public accounting reporting, the paper proposes that this will lead to the improvements in the credit risk modeling (represented by Z-score and Merton models) due to the fact that those models will using more accurate data.

On a conceptual level, I would agree with the sentiment of the paper that the utilization of the

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distributed ledger technology (DLT) could contribute to the improvements in the financial disclosure as well as risk modeling. However, to a larger degree this is dependent on the design of the DLT system. The paper assumes that "pure" bitcoin blockchain model will be adopted. This is a questionable hypothesis based on the technical specifications of the DLT platforms that are currently tested in the area of financial reporting and modeling (Ethereum, Hyperledger, Corda, Ripple, etc.) The paper would benefit from explaining why the "pure" bitcoin blockchain should be implemented and why currently developed solutions that do not rely on it are less optimal. The currently presented discussion does not seem to address the current status of affairs or recognizes the alternative approaches.

The overarching premise of the paper is that (1) transparent, accurate and timely financial data improves credit risk modeling; (2) blockchain technology will make data more transparent, accurate and timely. Those are two separate (even if somewhat related) assertions that require an independent evaluation.

Starting from premise (2) blockchain technology will make data more transparent, accurate and timely – the paper would benefit from defining the concepts being used and the meaning of real-time accounting. It appears that there is somewhat a substitution between the data quality controls and public accounting. The suggestion that a firm will make public all its internal recordkeeping seems to be unrealistic. Unless the paper can explain the motivation and incentives for a firm to do that, it is unclear why this type of a DLT implementation will take place. Considering the broad adoption of permissioned (closed) DLT platforms, this assumption of open access requires details explanation and analysis to be credible. As a side point, there is little recognition of new risks (such as operational risk) in leveraging the DLT solution. While benefits could outweigh the risk, certain considerations of those risks are needed to establish the superiority of the DLT solutions for accounting.

The premise (1) transparent, accurate and timely financial data improves credit risk modeling would also benefit from further development. First, the description/definition of credit risk modeling is needed. I was a bit surprised to see the description of Z-score and Merton models in the context of credit risk modeling. While I could be biased, I would normally think of products/trades risk assessment (probability of default, loss given default, exposure at default, credit conversion factor, etc.) when I hear the concept of credit risk modeling. The paper's reference to credit risk managers, who are utilizing the above concepts, makes it more confusing. The paper uses more of an investment risk/credit scoring risk definition of credit risk modeling that needs to be explained. Probably the paper will benefit from using a different reference to credit risk modeling in the title and throughout the text to reflect the focus of the credit analysis in question.

I think the paper can be improved in a number of ways. First, it could be worthwhile to consider to split the paper into two documents around premises (1) and (2). Secondly, more work on assumptions and factual description would be beneficial to allow establishing what is

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being discussed and how the conclusions are made. Third, updated description of the current developments in the areas of accounting and credit risk modeling would be beneficial to compare theory and practice. Finally, another term would likely to covey the content of the work better than the currently used “credit risk modeling” term.

Reviewer B:

Thank you for the opportunity to review your work. I remain quite intrigued to understand more about the bookkeeping, credit risk, and accounting changes that blockchain technology can bring to bear on this question. I found a number of significant weaknesses with this manuscript. As you look at improving the work, I would recommend that you focus on the main research question you present and take a deep dive into how the technology operates. Which protocols would allow what?, etc.

Your introduction and discussion throughout seems to come from a number of assumptions you hold, and it is overly simplistic. You have many different parts that are overly basic descriptions of blockchain technology, and not enough emphasis on how this technology really would allow for the results that you model to become apparent if there was a blockchain-based bookkeeping technology available for companies to adopt.

See below for descriptions of what I mean.

1. Trustworthy-"Keep their financial records on blockchains" Which records are on blockchain, which records are on a public chain, which records are on a private chain, in what form do they upload these records, what kind of risks do they run with the publicly available metadata? Is there a requirement in place that every transaction immediately be booked? Is that plausible? You still have a lag, but it now becomes days and minutes, which is better than weeks and months. If the financial records being kept on the blockchain are inaccurate or incomplete, so will any analysis of the gross data.

2. Timely-"each and every transaction in a firm's ledger instantaneously available" I'm not quite sure how this type of scale would be achieved. How many transactions does a firm the size of Walmart do in a day vs. how many transactions can ethereum operate on in a day for example. If Walmart kept their records on ethereum's chain, it would be far more transactions than eth can dream of processing at this point.

So when you say put their records on a blockchain, I'm not really sure what you mean because of the simplistic nature of your descriptions.

Proprietary information. I would buy a few shares of company X to gain access to firms transactions, and I'm not a competitor. How would public/private key technology from blockchain tech allow for greater sharing while protecting the credit applicant company? This

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could probably be a paper in and of itself.

Section 2. Blockchains -- this section does not seem to be especially accurate with terminology etcl, advance the point of the paper, or be all that relevant to the audience of Ledger. Focus on the actual story...Accounting changes resulting from incorporating blockchain technology on the credit risk model. This is where you absolutely need to focus your paper on...it is an interesting finding that 1) if you look at daily Z scores, they are different than quarterly scores. 2) has this research been done in the accounting field? I'm not familiar enough with that literature to know. If not, it seems you should be trying to publish your findings in accounting literature, as you predominantly have an accounting model finding. Regardless, you are demonstrating this knowledge with a case study but never really digging into how the technology enables the types of outcomes you are discussing. You need to bring the blockchain description into the state of the art and look at the how much much more deeply.

Section 3. Blockchains and Real-Time Accounting -- this seems to be a simplistic understanding of how blockchains work. Please see https://azure.microsoft.com/en-us/solutions/blockchain/ for help in beginning to understand how enterprise level blockchain applications are developing. Another protocol level solution that shows promise for enterprises https://eos.io/

Case study

Although Apple doesn't make it's statement's publicly available, it likely provides updated unaudited statements to creditors in the event it decides to borrow money. I used to do a lot of big ($500mil to multi-billion dollar) credit docs, and we always had statements that were updated since the last quarterly filing. So to say that you are stuck with quarterly information, that is correct on the market, but not upon those that are making actual credit decisions.

Also, your point is taken that randomly assign values, you get drastically different outcomes on a day-to-day basis. 1) Why blockchain then? Why not just a manual data entry into accounting software that does this? In fact, it seems clear to me that blockchain is a bit slower way of handling this than a traditional relational database.

I would assume your initial answer is that the blockchain is more trustworthy as you state, but to the extent that trustworthiness relies on a management team's good faith input of transactions...well then that becomes another story. If you automated transactions etc., that might be a different matter. But again, you would need to describe in detail how that would work. Blockchain doesn't eliminate all other forms of IT, it works with companies IT landscape to provide better solutions.

The fact of the matter is that your manuscript has signficant holes in how this bookkeeping

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would actually work, and on top of that, it presupposes that the blockchain is the best solution because of it's immutability. A bad input is a bad data point, regardless of whether it is immutable. Tell us (in depth) why it is the best solution for this problem, why the current solutions are unable to handle this, and then I think there is an interesting paper in the works.

Reviewer C:

As an accountant I am very interested in how Blick technology could affect the accounting industry. I found this article to be interesting and informative but would have liked a litt more detail. some of the info is s but to general too really be able to know Blockchain's affect.

1B. Authors' Response to Initial Review

Reviewer A:

The paper by Professor Byström "Blockchains, real-time accounting and the future of credit risk modeling" (ISSN 2379-5980) attempts to demonstrate the benefits of the blockchains for the real-time accounting and credit risk modeling. The paper suggests that the blockchains innovation will have material positive impact on both. To establish that, the paper provides a description of the bitcoin blockchain system and, subsequently, extrapolates the application of the bitcoin blockchain system on the operations of the public accounting and auditing reporting. On the basis of the proposed prove that bitcoin blockchain improves public accounting reporting, the paper proposes that this will lead to the improvements in the credit risk modeling (represented by Z-score and Merton models) due to the fact that those models will using more accurate data.

On a conceptual level, I would agree with the sentiment of the paper that the utilization of the distributed ledger technology (DLT) could contribute to the improvements in the financial disclosure as well as risk modeling. However, to a larger degree this is dependent on the design of the DLT system. The paper assumes that "pure" bitcoin blockchain model will be adopted. This is a questionable hypothesis based on the technical specifications of the DLT platforms that are currently tested in the area of financial reporting and modeling (Ethereum, Hyperledger, Corda, Ripple, etc.) The paper would benefit from explaining why the "pure" bitcoin blockchain should be implemented and why currently developed solutions that do not rely on it are less optimal. The currently presented discussion does not seem to address the current status of affairs or recognizes the alternative approaches.

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Starting from premise (2) blockchain technology will make data more transparent, accurate and timely – the paper would benefit from defining the concepts being used and the meaning of real-time accounting. It appears that there is somewhat a substitution between the data quality controls and public accounting. The suggestion that a firm will make public all its internal recordkeeping seems to be unrealistic. Unless the paper can explain the motivation and incentives for a firm to do that, it is unclear why this type of a DLT implementation will take place. Considering the broad adoption of permissioned (closed) DLT platforms, this assumption of open access requires details explanation and analysis to be credible. As a side point, there is little recognition of new risks (such as operational risk) in leveraging the DLT solution. While benefits could outweigh the risk, certain considerations of those risks are needed to establish the superiority of the DLT solutions for accounting.

The premise (1) transparent, accurate and timely financial data improves credit risk modeling would also benefit from further development. First, the description/definition of credit risk modeling is needed. I was a bit surprised to see the description of Z-score and Merton models in the context of credit risk modeling. While I could be biased, I would normally think of products/trades risk assessment (probability of default, loss given default, exposure at default, credit conversion factor, etc.) when I hear the concept of credit risk modeling. The paper's reference to credit risk managers, who are utilizing the above concepts, makes it more confusing. The paper uses more of an investment risk/credit scoring risk definition of credit risk modeling that needs to be explained. Probably the paper will benefit from using a different reference to credit risk modeling in the title and throughout the text to reflect the focus of the credit analysis in question.

I think the paper can be improved in a number of ways. First, it could be worthwhile to consider to split the paper into two documents around premises (1) and (2). Secondly, more work on assumptions and factual description would be beneficial to allow establishing what is being discussed and how the conclusions are made. Third, updated description of the current developments in the areas of accounting and credit risk modeling would be beneficial to compare theory and practice. Finally, another term would likely to covey the content of the work better than the currently used "credit risk modeling" term.

- Do you mean private vs public blockchain? If so, you have a point. My thoughts are that the blockchain I refer to is a public one. Conceptually. Perhaps driven public by the regulators or, perhaps, by market forces; if some company starts putting its numbers on a public ledger, perhaps other firms feel forced to follow suit. One could also think of a situation where the most important accounting variables (such as sales, leverage etc.) are made public while the rest stay private. In addition, even if a future blockchain environment will be populated by numerous private blockchains hidden from the public eye, it is possible that certain entities, such as regulators and credit

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rating agencies could be provided with readily updated balance sheet information through the distributed ledger. An alternative possible avenue is the use of so-called sidechains, where companies use private blockchains that are periodically (partly) connected to the main (public) blockchain. I have added some on this in the paper.

- Of course, new kinds of risk linked to the creation of huge blockchains of company accounting information, perhaps operational risk in association with the administration of the blockchains, should not be ignored. I have added a note on this in the paper but do not take it further.

- Sorry, but I do not understand the point about credit risk modelling! I have worked on credit risk for 15 years and the Z-score as well as the Merton model are both fine examples of credit risk models. And as for default probability, the distance to default measure that I compute using the Merton model is very very close to a default probability. I mention this in a footnote in the paper. You just have to map it through a distribution, such as the normal distribution, to get a default probability. I have chosen not to add anything more on this in the paper. Of course, I could change the title of the paper if needed, but I really do not see why! Please explain, if warranted!

- Please see the links below, where you can see the word credit risk model being used in association with the z-score model and the merton model:

    - https://www.amazon.com/Financial-Risk-Models-its-Measurement/dp/3659240451
    - https://financetrainingcourse.com/education/2012/09/calculating-probability-of-default-pd-using-mertons-structured-approach/

- I have addressed some of the final comments above but regarding some of them I think going into that level of detail is beyond the scope of this paper. Furthermore, at this point, I choose to keep the paper as one single paper. And, finally, thanks for all the comments!

Reviewer B:

Thank you for the opportunity to review your work. I remain quite intrigued to understand more about the bookkeeping, credit risk, and accounting changes that blockchain technology can bring to bear on this question. I found a number of significant weaknesses with this manuscript. As you look at improving the work, I would recommend that you focus on the main research question you present and take a deep dive into how the technology operates. Which protocols would allow what?, etc.

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See below for descriptions of what I mean.

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2. Timely-"each and every transaction in a firm's ledger instantaneously available" I'm not quite sure how this type of scale would be achieved. How many transactions does a firm the size of Walmart do in a day vs. how many transactions can ethereum operate on in a day for example. If Walmart kept their records on ethereum's chain, it would be far more transactions than eth can dream of processing at this point.

So when you say put their records on a blockchain, I'm not really sure what you mean because of the simplistic nature of your descriptions.

Proprietary information. I would buy a few shares of company X to gain access to firms transactions, and I'm not a competitor. How would public/private key technology from blockchain tech allow for greater sharing while protecting the credit applicant company? This could probably be a paper in and of itself.

- The Reviewer makes some interesting points in the introductory comment, but I believe that going into that level of detail is beyond the scope of this paper (see below).

- I have added some more discussion on the details as well as the risks of blockchain-based bookkeeping in footnotes in the paper. However, I believe that going into a detailed description of these things is beyond the scope of this paper. I do see your point, but I do not want to make the paper too much of a technology paper.

- Generally, my thoughts are that the blockchain I refer to is a public one. Conceptually. Perhaps driven public by the regulators or, perhaps, by market forces; if some company starts putting its numbers on a public ledger, other firms could feel forced to follow suit. One could also think of a situation where the most important accounting

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variables (such as sales, leverage etc.) are made public while the rest stay private. In addition, even if a future blockchain environment will be populated by numerous private blockchains hidden from the public eye, it is possible that certain entities, such as regulators and credit rating agencies could be provided with readily updated balance sheet information through the distributed ledger. An alternative possible avenue is the use of so-called sidechains, where companies use private blockchains that are periodically (partly) connected to the main (public) blockchain. I have added some on this in the paper.

- As for the lag that you mention, I am of course not sure about how long it will be but the assumption of this paper is that it will be short, much shorter than today. Perhaps once a day?!

- And, of course, new kinds of risk linked to the creation of huge blockchains of company accounting information, perhaps operational risk in association with the administration of the blockchain, should not be ignored. There will be errors and unexpected problems also in a fully public blockchain, I am sure about that. I have added a note on this in the paper but do not take it further.

- As for the sheer scale of the ledger necessary to harbor all this data, some kind of change to the general blockchain design will undoubtedly be necessary; perhaps a block size adjustment, like the “hard fork” leading to the launch of bitcoin cash. I have added a bit on this in a note in the paper but, again, a more technical discussion is probably beyond the scope of this paper.

- Finally, privacy issues are of course important to most firms and forces that want to minimize the number of actors getting full access to one’s financial statements in real-time will probably always exist. For example, one could think of situations where only shareholders who hold a certain minimum number of shares get access to the ledger (if it is not fully public, that is). I have added a bit on this in a note in the paper.

Section 2. Blockchains -- this section does not seem to be especially accurate with terminology etcl, advance the point of the paper, or be all that relevant to the audience of Ledger. Focus on the actual story...Accounting changes resulting from incorporating blockchain technology on the credit risk model. This is where you absolutely need to focus your paper on...it is an interesting finding that 1) if you look at daily Z scores, they are different than quarterly scores. 2) has this research been done in the accounting field? I'm not familiar enough with that literature to know. If not, it seems you should be trying to publish your findings in accounting literature, as you predominantly have an accounting model finding. Regardless, you are demonstrating this knowledge with a case study but never really digging into how the technology enables the types of outcomes you are discussing. You need

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to bring the blockchain description into the state of the art and look at the how much much more deeply.

Section 3. Blockchains and Real-Time Accounting -- this seems to be a simplistic understanding of how blockchains work. Please see https://azure.microsoft.com/en-us/solutions/blockchain/ for help in beginning to understand how enterprise level blockchain applications are developing. Another protocol level solution that shows promise for enterprises https://eos.io/

- I do not know, either, exactly what level of detail is relevant to the readers of Ledger. However, the other two reviewers want me to add more detail (not only on the credit risk part) so it is a hard balancing act. As for the accounting literature, I do not know either since I do not follow that literature. Or publish there. And as for "…digging into how the technology enables…" and "simplistic understanding of how blockchains work", again, a more technical discussion is probably beyond the scope of this short paper/letter.

Case study

Although Apple doesn't make it's statement's publicly available, it likely provides updated unaudited statements to creditors in the event it decides to borrow money. I used to do a lot of big ($500mil to multi-billion dollar) credit docs, and we always had statements that were updated since the last quarterly filing. So to say that you are stuck with quarterly information, that is correct on the market, but not upon those that are making actual credit decisions.

Also, your point is taken that randomly assign values, you get drastically different outcomes on a day-to-day basis. 1) Why blockchain then? Why not just a manual data entry into accounting software that does this? In fact, it seems clear to me that blockchain is a bit slower way of handling this than a traditional relational database.

I would assume your initial answer is that the blockchain is more trustworthy as you state, but to the extent that trustworthiness relies on a management team's good faith input of transactions...well then that becomes another story. If you automated transactions etc., that might be a different matter. But again, you would need to describe in detail how that would work. Blockchain doesn't eliminate all other forms of IT, it works with companies IT landscape to provide better solutions.

The fact of the matter is that your manuscript has signficant holes in how this bookkeeping would actually work, and on top of that, it presupposes that the blockchain is the best solution because of it's immutability. A bad input is a bad data point, regardless of whether it is immutable. Tell us (in depth) why it is the best solution for this problem, why the current solutions are unable to handle this, and then I think there is an interesting paper in the works.

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- A good point! Although I do not (I think) really stress anywhere in the paper that accounting information is typically updated quarterly (the quarterly updating in the case study is just an example since that's the highest data frequency I have) I have added some short discussion on the practice you mention of borrowers providing updated accounts between regular reports, and how that is different from the real-time accounting I have in mind.

- Yes, as I discuss in ch. 3, my idea is that the blockchain mechanism will be more trustworthy than just auditing as normal but increase the frequency drastically to once a day, let's say. The numbers that are used as input in the preparation of the book should all come from the blockchain, and therefore be more difficult to tamper with. The accounting data of the firm would be permanently recorded in the ledger, with a time-stamp, leaving no possibility of ex-post changes. The entire ledger would be publicly available to anyone interested. Ideally, yes, this whole process should be fully automatic. Of course, this is a huge step and it might take many years (or never) to reach this point.

- Finally, thanks for all the comments!

Reviewer C:

As an accountant I am very interested in how Blick technology could affect the accounting industry. I found this article to be interesting and informative but would have liked a litt more detail. some of the info is s but to general too really be able to know Blockchain's affect.

- One of the other reviewers wants me to describe blockchains less so it is a hard balancing act. I have added some more details in footnotes. I hope that strikes a balance. I am happy to hear that you found my article interesting!

2A. Second Round of Review

Reviewer A:

The paper by Professor Byström "Blockchains, real-time accounting and the future of credit risk modeling" (ISSN 2379-5980) attempts to demonstrate the benefits of the blockchains for the real-time accounting and credit risk modeling. The paper suggests that the blockchains innovation will have material positive impact on both. To establish that, the paper provides a description of the bitcoin blockchain system and, subsequently, extrapolates the application of the bitcoin blockchain system on the operations of the public accounting and auditing reporting. On the basis of the proposed prove that bitcoin blockchain improves public accounting reporting, the paper proposes that this will lead to the improvements in the credit

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risk modeling (represented by Z-score and Merton models) due to the fact that those models will using more accurate data.

This is the second version of the paper. The original version was provided in August 2018. There are no material changes between first and second versions. The comments provided to the first version of the paper are relevant for the current version.

On a conceptual level, I would agree with the sentiment of the paper that the utilization of the distributed ledger technology (DLT) could contribute to the improvements in the financial disclosure as well as risk modeling. However, to a larger degree this is dependent on the design of the DLT system. The paper assumes that "pure" bitcoin blockchain model will be adopted. This is a questionable hypothesis based on the technical specifications of the DLT platforms that are currently tested in the area of financial reporting and modeling (Ethereum, Hyperledger, Corda, Ripple, etc.) The paper would benefit from explaining why the "pure" bitcoin blockchain should be implemented and why currently developed solutions that do not rely on it are less optimal. The currently presented discussion does not seem to address the current status of affairs or recognizes the alternative approaches.

The overarching premise of the paper is that (1) transparent, accurate and timely financial data improves credit risk modeling; (2) blockchain technology will make data more transparent, accurate and timely. Those are two separate (even if somewhat related) assertions that require an independent evaluation.

Starting from premise (2) blockchain technology will make data more transparent, accurate and timely – the paper would benefit from defining the concepts being used and the meaning of real-time accounting. It appears that there is somewhat a substitution between the data quality controls and public accounting. The suggestion that a firm will make public all its internal recordkeeping seems to be unrealistic. Unless the paper can explain the motivation and incentives for a firm to do that, it is unclear why this type of a DLT implementation will take place. Considering the broad adoption of permissioned (closed) DLT platforms, this assumption of open access requires details explanation and analysis to be credible. As a side point, there is little recognition of new risks (such as operational risk) in leveraging the DLT solution. While benefits could outweigh the risk, certain considerations of those risks are needed to establish the superiority of the DLT solutions for accounting.

The premise (1) transparent, accurate and timely financial data improves credit risk modeling would also benefit from further development. First, the description/definition of credit risk modeling is needed. I was a bit surprised to see the description of Z-score and Merton models in the context of credit risk modeling. While I could be biased, I would normally think of products/trades risk assessment (probability of default, loss given default, exposure at default, credit conversion factor, etc.) when I hear the concept of credit risk modeling. The paper's reference to credit risk managers, who are utilizing the above concepts, makes it more

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confusing. The paper uses more of an investment risk/credit scoring risk definition of credit risk modeling that needs to be explained. Probably the paper will benefit from using a different reference to credit risk modeling in the title and throughout the text to reflect the focus of the credit analysis in question.

I think the paper can be improved in a number of ways. First, it could be worthwhile to consider to split the paper into two documents around premises (1) and (2). Secondly, more work on assumptions and factual description would be beneficial to allow establishing what is being discussed and how the conclusions are made. Third, updated description of the current developments in the areas of accounting and credit risk modeling would be beneficial to compare theory and practice. Finally, another term would likely to covey the content of the work better than the currently used “credit risk modeling” term.

Reviewer B:

At this point, most people in finance have heard of blockchain.

"As for timing, since blockchain-based book keeping would make each and every transaction in a firm’s ledger instantaneously available, real-time updating of accounting information would be possible." instantaneously and real-time rely upon which consensus metric. I agree that it is much more quickly available, but I find this conceptualization too simple of what is actually happening. Your note is acknowledged on the difference between summary leadership reports and real-time accounting.

Notes 3-5 are also acknowledged.

I wholeheartedly agree that DLT/Blockchain has the potential to remove the auditor from the process.

With regard to this paper, it is purely conceptual with regard to putting all of the transactions on the ledger. It then drives at a possibly social/business use for doing so where efficiency is gained. I do not think blockchain alleviates the problem of garbage in, garbage out...i.e. if I slow play posting my transactions that look poor, the public-at-large doesn't know about them. If I manipulate what I include for transactions, or make transactions up, or input the wrong number...we still have a significant error. So now you will move the auditor's job to auditing the blockchain.

At the end of the day, I find the paper to be an overly simplified explanation of a theoretical situation with very little substance about how the ledger interacts with the process.

Reviewer D:

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Does this paper represent a novel contribution to cryptocurrency or blockchain scholarship?:
Yes

If you answered "yes" to the previous question, in one sentence, describe in your own words the novel contribution made by this paper:
Consideration of credit risk modeling if data was provided in real-time

Is the research framed within its scholarly context and does the paper cite appropriate prior works?:
Yes

Please assess the article's level of academic rigor.:
Good (not excellent but a long way from poor)

Please assess the article's quality of presentation.:
Good (not excellent but a long way from poor)

How does the quality of this paper compare to other papers in this field?:
Top 20%

Please provide your free-form review for the author in this section.:

The author of this paper describes an interesting possibility of better (more nuanced?) credit risk modeling on the basis that the relevant financial information could be provided on a daily basis instead of at quarterly intervals.

The idea is very interesting, but the paper still feels a little rough around the edges. I have a few concrete recommendations below that I think would go a long way towards helping this paper be suitable for Ledger (listed *roughly* in order of importance):

- One of the "major" issues of this paper is that readers may argue that blockchains will not (or cannot) be used the way the author has described them. However, that is besides the point! The author, thus, should make clear that the main discussion of the paper (i.e., improved credit risk modeling) rests on certain *assumptions* of blockchain use. I believe it would significantly improve the paper to add a short section, either at the end of Section 3 or the beginning of Section 4 that says (more or less) "In the following analysis, we assume that XXX, YYY, ZZZ." Presumably the author would want to state that (a) it is being assumed the publicly traded firms will be using a *public* blockchain to reveal their financial data, and (b) that the data will be uploaded daily, and (c) that all of the data required in the credit risk modeling section will be uploaded. These assumptions will put to rest any arguments over whether companies will actually do this, which does not seem to be the point of the paper to

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discuss (although if the author would discuss the incentives of companies to participate in such a scheme, that certainly would be welcome).

- The next most important part to address, in my opinion, is the bottom-line conclusion of the updated credit risk modeling. Figure 1, which compares the model values for quarterly vs. daily results, certainly makes the case that the daily results model is more nuanced... but to a reader that does not have a credit risk modeling background, it's unclear whether this is better... what actionable differences would this make? Can you make the case to a reader that it would be better (or not) to switch the "real-time" model?

- In Figure 1, for both Apple and Groupon the Merton DD scores, for the daily results, seem to travel very far away from the quarterly score for the final period (whereas for all of the prior periods, the two models line up (as expected) on the start/ends of the periods). Is this intentional? Is there something different/special about the final period (I am referring to the period ending on Oct 1 2015)? Along the same lines, since the daily-results model is stochastic, it would be helpful to see a few different sets of randomly generated daily-results data (either as a separate chart or super imposed).

- Section 2 "Blockchains" is unnecessary for Ledger

- The language in some places is too colloquial, which can also make the meaning unclear. For example, the author writes "accounting gimmicks" on the first page. A reader may be able to guess what is meant by "gimmicks" but I think it would be clearer to write "fraud" if that is what the author means. Even then, it would be helpful to be specific. Presumably switching from LIFO to FIFO when doing inventory accounting could be considered a "gimmick" but that might not be what the author is referring to.

- The citation format is incorrect. Notes and citations should be shared in the same numbered list (rather than two separate lists), and each citation should be indicated by a superscript, rather than (Author, Year).

2B. Author Response to Second Round

Reviewer D:

Does this paper represent a novel contribution to cryptocurrency or blockchain scholarship?:
Yes

If you answered "yes" to the previous question, in one sentence, describe in your own words the novel contribution made by this paper:
Consideration of credit risk modeling if data was provided in real-time

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Is the research framed within its scholarly context and does the paper cite appropriate prior works?:
Yes

Please assess the article's level of academic rigor.:
Good (not excellent but a long way from poor)

Please assess the article's quality of presentation.:
Good (not excellent but a long way from poor)

How does the quality of this paper compare to other papers in this field?:
Top 20%

Please provide your free-form review for the author in this section.:
The author of this paper describes an interesting possibility of better (more nuanced?) credit risk modeling on the basis that the relevant financial information could be provided on a daily basis instead of at quarterly intervals.

The idea is very interesting, but the paper still feels a little rough around the edges. I have a few concrete recommendations below that I think would go a long way towards helping this paper be suitable for Ledger (listed *roughly* in order of importance):

- One of the "major" issues of this paper is that readers may argue that blockchains will not (or cannot) be used the way the author has described them. However, that is besides the point! The author, thus, should make clear that the main discussion of the paper (i.e., improved credit risk modeling) rests on certain *assumptions* of blockchain use. I believe it would significantly improve the paper to add a short section, either at the end of Section 3 or the beginning of Section 4 that says (more or less) "In the following analysis, we assume that XXX, YYY, ZZZ." Presumably the author would want to state that (a) it is being assumed the publicly traded firms will be using a *public* blockchain to reveal their financial data, and (b) that the data will be uploaded daily, and (c) that all of the data required in the credit risk modeling section will be uploaded. These assumptions will put to rest any arguments over whether companies will actually do this, which does not seem to be the point of the paper to discuss (although if the author would discuss the incentives of companies to participate in such a scheme, that certainly would be welcome).

- I think it is a very good idea to stress the role of “assumptions”. I followed the suggestions by the reviewer and even put the new paragraph in the introduction to early on highlight this important fact, i.e. that the main point of the paper is not to discuss whether companies will or will not participate in a future blockchain scheme.

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- The next most important part to address, in my opinion, is the bottom-line conclusion of the updated credit risk modeling. Figure 1, which compares the model values for quarterly vs. daily results, certainly makes the case that the daily results model is more nuanced... but to a reader that does not have a credit risk modeling background, it's unclear whether this is better... what actionable differences would this make? Can you make the case to a reader that it would be better (or not) to switch the "real-time" model?

- In Figure 1, for both Apple and Groupon the Merton DD scores, for the daily results, seem to travel very far away from the quarterly score for the final period (whereas for all of the prior periods, the two models line up (as expected) on the start/ends of the periods). Is this intentional? Is there something different/special about the final period (I am referring to the period ending on Oct 1 2015)? Along the same lines, since the daily-results model is stochastic, it would be helpful to see a few different sets of randomly generated daily-results data (either as a separate chart or super imposed).

- For the Merton model, I must have missed to add the last value in the Figure. That's why "the Merton DD scores seem to travel very far away....". I have added that last value to the Figure now! Thanks for noticing this! Related to this, I also discovered a typo in the text, where I have now changed the text on the "actual means and standard deviations" slightly in the first two paragraphs in section 4.1.
- By improvement I mean that the measures of risk are more updated, or timely, since more updated input information is used. I have added a footnote on this.

- Section 2 "Blockchains" is unnecessary for Ledger

- At the moment I keep section 2 as it is since I am not able to decide on this. If the editor agrees with reviewer D, I am happy to remove section 2! Or perhaps condense it into a footnote early on in the paper.

- The language in some places is too colloquial, which can also make the meaning unclear. For example, the author writes "accounting gimmicks" on the first page. A reader may be able to guess what is meant by "gimmicks" but I think it would be clearer to write "fraud" if that is what the author means. Even then, it would be helpful to be specific. Presumably switching from LIFO to FIFO when doing inventory accounting could be considered a "gimmick" but that might not be what the author is referring to.

- As suggested, the language has been changed in a few places (less colloquial).

- The citation format is incorrect. Notes and citations should be shared in the same numbered list (rather than two separate lists), and each citation should be indicated by a superscript, rather than (Author, Year).

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- The citation format has been changed.
- The author guidelines have been followed.

3A. Final Round of Review

Reviewer E:

This is an excellent, concise theoretical focus on an application of blockchain technology to the financial sector. The comparison of real world quarterly data along side modeled data theoretically captured via blockchain allows the reader to more quickly and fully grasp what the potential impact could be. The author appropriately states and uses assumptions of this blockchain use (i.e. public chain, no current considerations for motivation by companies to use) to allow for a simple value consideration of using the tech in this application.

There is one major area that could be improved with this paper. The reader is left to draw inferences of impact from Figure 1. There is no quantitative or statistical breakdown of how frequently or by how much the blockchain model would have made a difference in assessing credit risk across the two companies and with the two credit risk modeling approaches. Without the raw data, it is left to the reader to visually assess the graphs. Adding to potential misinterpretation, the graphs for each approach are not to the same scale.

I would highly recommend giving a more detailed quantified analysis of the blockchain model compared to the current quarterly update standard. Raw data in a table and/or statistical analysis of where it could make difference in credit risk assessment would be of significant value to the reader. I would also recommend giving some interpretation of this analysis to provide context of the potential impact.

A couple minor points to strengthen the paper: 1) the background on blockchain is a little bit short and uneven. The author should include a few more references and clarify some of the language usage (a blockchain vs. the blockchain; virtual currency, etc.). This will help novice readers find more info and allow experienced readers to move past distinctions in their own usage.

2) The mix of notes and references is distracting. Footnotes or endnotes with substantive detail should be incorporated into the body of the paper or listed separately with a distinct numbering system. References should be their own distinct list.

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