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BLOCKCHAINS, REAL-TIME ACCOUNTING AND THE FUTURE OF CREDIT RISK MODELING

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March 2, 2016

In this paper (letter) I discuss how blockchains potentially could affect the way credit risk is modeled, and how the improved trust and timing associated with blockchain-enabled real-time accounting could improve default prediction. To demonstrate the (quite substantial) effect the change would have on well-known credit risk measures, a simple case-study compares Z-scores and Merton distances to default computed using typical accounting data of today to the same risk measures computed under a hypothetical future blockchain regime.

JEL classification: G33; G39; M41; M42

Keywords: blockchain; credit risk modeling; real-time accounting

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1. INTRODUCTION

Most finance people have heard of *bitcoins*, the virtual currency. Less, though, have probably heard of the technology behind the bitcoin, a technology labeled *blockchain*. While, to date, the blockchain technology has been used primarily as the plumbing for the bitcoin, blockchains can also be used for the infrastructure of traditional financial products such as debt contracts and financial derivatives.¹

In accounting, blockchains could potentially improve the quality of information reaching investors in two ways; by making the accounting information more trustworthy and by making the information more timely. As for trust, if firms were to keep their financial records on blockchains, the opportunities for accounting gimmicks etc. could drop dramatically. Inter-firm transactions would also become much more transparent (Yermack (2015)). 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.² Moreover, this information would be made instantaneously available not only to insiders within the firm but to (chosen) outsiders like investors and regulators.

In this paper, my focus is on credit risk modeling and on how a possible future wide-spread use of blockchains could affect the way we model credit risk. It is well known that accounting information, such as balance sheet data and income statements, is imperfect (Duffie and Lando (2001)). Accounting data suffers from problems such as ambiguous and non-uniform accounting practices, managers engaging in creative accounting or by reports lagging real events. Therefore, since most credit risk models rely on accounting data, the increased transparency, accuracy and

¹ One recent example is the February 2016 decision by the Australian Stock Exchange to become the world's first market to settle equities trades using blockchains (Financial Times (2016)).

² While real-time accounting traditionally often means that the books of a firm are updated monthly or quarterly, in the future world of blockchains envisioned in this paper the term really means near-instant (daily) updating of accounting information.

timeliness of financial statements brought about by firms keeping their books on blockchains could significantly improve credit risk modeling.

2. BLOCKCHAINS

Bitcoin was first proposed in 2008 by an unknown author writing under the pseudonym Satoshi Nakamoto. Bitcoin is a virtual currency resembling cash, offering a way of exchanging ownership on a peer to peer basis. Importantly, bitcoin does not rely on a central clearing place, such as a bank. Instead, every historical bitcoin transaction is stored in a globally distributed electronic ledger called the blockchain that keeps track of all bitcoin transactions throughout history (Nakamoto (2008)).

The ledger is called a blockchain because blocks of new bitcoin transactions are added to the chain of historical transactions, as they happen, by special bitcoin users called miners. The miners verify that every bitcoin transaction in the block is legitimate by solving a difficult cryptographic problem.³ This technology significantly reduces transactions costs. It is also fully transparent and it is secured by sophisticated cryptography (using hash functions) and through the work of the miners.

3. BLOCKCHAINS AND REAL-TIME ACCOUNTING

The blockchain is basically a ledger that can never be altered with and whose records can never be destroyed. As such, it could, among other things, be useful as a trustworthy and continuously updated ledger for a firm's accounting records (Lazanis (2015)). This is due to the fact that the blockchain technology can be used not only to transfer digital currency between a buyer and a

seller but also to transfer the ownership of any other asset between two firms in a cheap, efficient and trustworthy way.⁴

Financial statements are prepared at regular intervals and sum up what has happened in a firm's ledger throughout a certain period. An auditor then issues an opinion on the accuracy of the financial statements. Outsiders, such as investors and credit risk managers, have to trust both that the auditing is thorough and unbiased and that the firm has not given false information to the auditor. That is, the concept of trust is critical in both the preparation of the financial statement and in the auditing process. This is where the blockchain technology behind the bitcoin can play an integral role (Lazanis (2015)).

If a firm were to voluntarily post all of its business transactions on a blockchain, with a permanent time stamp on each transaction, the firm's entire ledger would be instantaneously visible and anyone could aggregate the firm's transactions into income statements and balance sheets in real-time (Yermack (2015)). That is, many of the things the auditor does in today's accounting world, the blockchain can possibly do much more efficiently and much more timely in tomorrow's. By construction, if a firm kept all its transactions and balances on a blockchain, then the blockchain itself could, to a large extent, replace the auditor in confirming the accuracy of the firm's accounting (avoiding potential moral hazard or agency problems). Since past transactions in the blockchain cannot be tampered with, the issue of mistrust is intelligently removed from the firm's financial statements.

In addition to the issue of trust, the automatic updating of the ledger in real time, where each and every transaction is (more or less) instantaneously included in the firm's blockchain, could

³ The fastest miner is rewarded with a number of bitcoins for this service. A new block is won approximately every ten minutes and since the losing miners get nothing, bitcoin mining is sometimes called "competitive bookkeeping" (Harvey (2016)).

⁴ There is already some experimenting going on along this avenue. NASDAQ, for instance, is experimenting with "colored coins" as a way to use blockchains to record equity transactions (Guardian (2015)).

potentially make a firm's accounting information as timely and dynamic as, let's say, its stock price. In other words, due to the natural parallels between blockchains and accounting, the blockchain technology could improve the quality of accounting information reaching investors in two ways; by making the information more trustworthy and by making the information more timely.

4. BLOCKCHAINS AND CREDIT RISK MODELING

Two of the most well-known credit risk models are the Altman Z-score (Altman (1968)) and the Merton (1974) model. The Z-score formula for predicting bankruptcy was developed by Edward Altman in the late 1960s and uses various corporate income and balance sheet variables, i.e. accounting information, plus stock prices, to predict whether a firm will go bankrupt or not.

The Z-score is a linear combination of five financial ratios, weighted by coefficients. The coefficients were estimated by Altman using discriminant analysis on a matched set of bankrupt and non-bankrupt firms. The Z-score is calculated as

$$Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 0.99X_5 \quad (1)$$

where

X_1 = working capital/total assets

X_2 = retained earnings/total assets

X_3 = earnings before interest and taxes/total assets

X_4 = market value of equity/book value of total liabilities

X_5 = sales/total assets

and the larger the Z-score the smaller the probability that the firm will default on its debt.

The Merton (1974) model, in turn, also relies on accounting information and stock prices as inputs, but views a firm's equity and debt as contingent claims issued against the firm's underlying assets.⁵ In the Merton (1974) model

$$V_E = V_A N(d_1) - e^{-r(T-t)} DN(d_2) \quad (1)$$

where $N(\cdot)$ is the cumulative normal distribution, and

V_E is the firm's market value of equity,

V_A is the firm's market value of assets,

D is the total amount of firm liabilities,

$T-t$ is the time to maturity of the firm's liabilities,

r_f is the risk-free interest rate,

$$d_1 = \frac{\ln\left(\frac{V_A}{D}\right) + \left(r + \frac{\sigma_A^2}{2}\right)(T-t)}{\sigma_A \sqrt{T-t}},$$

$$d_2 = d_1 - \sigma_A \sqrt{T-t}.$$

Moreover, the equity volatility σ_E and the asset volatility σ_A are related through the equation

$$\sigma_E = \frac{V_A N(d_1) \sigma_A}{V_E} \quad (2)$$

and one can solve the nonlinear system of equations (1) and (2) for V_A and σ_A . The distance to default is then defined as

$$DD = \frac{\ln\left(\frac{V_A}{D}\right) + \left(r - \frac{\sigma_A^2}{2}\right)(T-t)}{\sigma_A \sqrt{T-t}}$$

⁵ By backing out asset values and volatilities from stock prices and balance sheet information the model produces estimates of a firm's default probability. The Merton (1974) model uses the Black and Scholes (1973) framework to solve for the asset value and volatility implied by the stock

and the larger the value of DD the smaller the probability that the firm will default on its debt.

4.1 A Case Study

To demonstrate the effect of going from a quarterly updating of accounting information to a near instantaneous updating I look at the two credit risk models described above applied to the two well-known US-based companies *Apple* and *Groupon*. Since these firms' accounting information is sampled quarterly, i.e. the risk measures cannot be updated more frequently than once every three months, I have to simulate *hypothetical* (blockchain-enabled) day-to-day movements of the Z-score and the DD measure.⁶ These daily movements are generated by sampling normally distributed random numbers with means and standard deviations estimated from the *actual* history of quarterly sampled Z-scores and Merton DD measures, respectively, using the square-root rule assuming that the daily movements are independent. In this way I get reasonably realistic realizations of potential future blockchain-induced real-time Z-scores and DDs.

Figure 1 shows the Z-score and the Merton distance to default (DD) measure for the two firms, with daily and quarterly accounting data, respectively.^{7,8} Since the volatility of the hypothetical daily changes in risk is chosen based on the volatility of the firms' actual quarterly changes in risk, the (fairly substantial) fluctuations in the two figures give a reasonably realistic demonstration of how, and of how much, the estimated risk measures would change as a result of the introduction of blockchains in firms' book keeping. The intra-quarterly fluctuations are not

price and volatility. The asset value and the asset volatility can then be combined into a risk measure called distance to default (DD) that is inversely related to the default probability of the firm.

⁶ The necessary accounting variables are *total assets*, *total liabilities*, *working capital*, *retained earnings*, *EBITDA* and *sales* for the Z-score and *total liabilities* for the Merton model. The data is downloaded from Yahoo Finance and covers the time-period October 2014 to October 2015 for Apple and January 2015 to October 2015 for Groupon.

⁷ To isolate the effect of the real-time accounting on the dynamics of the two credit risk measures I sample the stock price on a quarterly basis all through the analysis. While this might be typical in applications of the Z-score, it is more common to update the stock price on a daily basis when using the Merton model.

⁸ In the Merton model, the stock return volatility is computed using daily data from the past quarter, and the risk-free interest rate is set to 10bp.

insignificant, indicating improved credit risk modeling when going from quarterly to daily updating of accounting information.

Figure 1 shows that the dynamics are similar for the Z-score and the Merton DD measure but, considering the more typical dynamic (daily) implementation of the Merton model, the Z-score is probably the measure that, in practice, would be most affected by the introduction of real-time accounting. It is even possible that the (rather dated) Z-score could experience a renaissance as a result of the introduction of blockchains. In fact, with the drastic changes to the accounting and auditing practice described above the current Z-score would probably be replaced with a new score containing other financial ratios and/or coefficients.

It is also possible that the entire area of bankruptcy prediction could change, with a focus on new instruments (smart contracts in blockchain jargon) or financial ratios directly tailored to the likelihood of default. With not only insiders having access to all of a firm's transactions, the process of bankruptcy might also change fundamentally with managers, creditors, investors and regulators playing by entirely new rules. Issues such as reflexivity could affect a firm's path towards bankruptcy to a larger extent than today.

Finally, it should be stressed that even if the process of firms posting all of its business transactions on a blockchain was to be more limited than that hypothesized above it is still likely that credit risk models would be affected in one way or the other. For instance, even if not all accounting information would be instantaneously available on the blockchain, perhaps some will.

5. CONCLUSION

Above, I have discussed how the blockchain technology behind the bitcoin could improve credit risk modeling through improved trust and better timing of accounting data releases. If the

suggested changes were to materialize over the coming years the impact on the way we model credit risk could be substantial, and with a simple case-study I find that blockchains would have a material effect also on credit risk measures widely used today.

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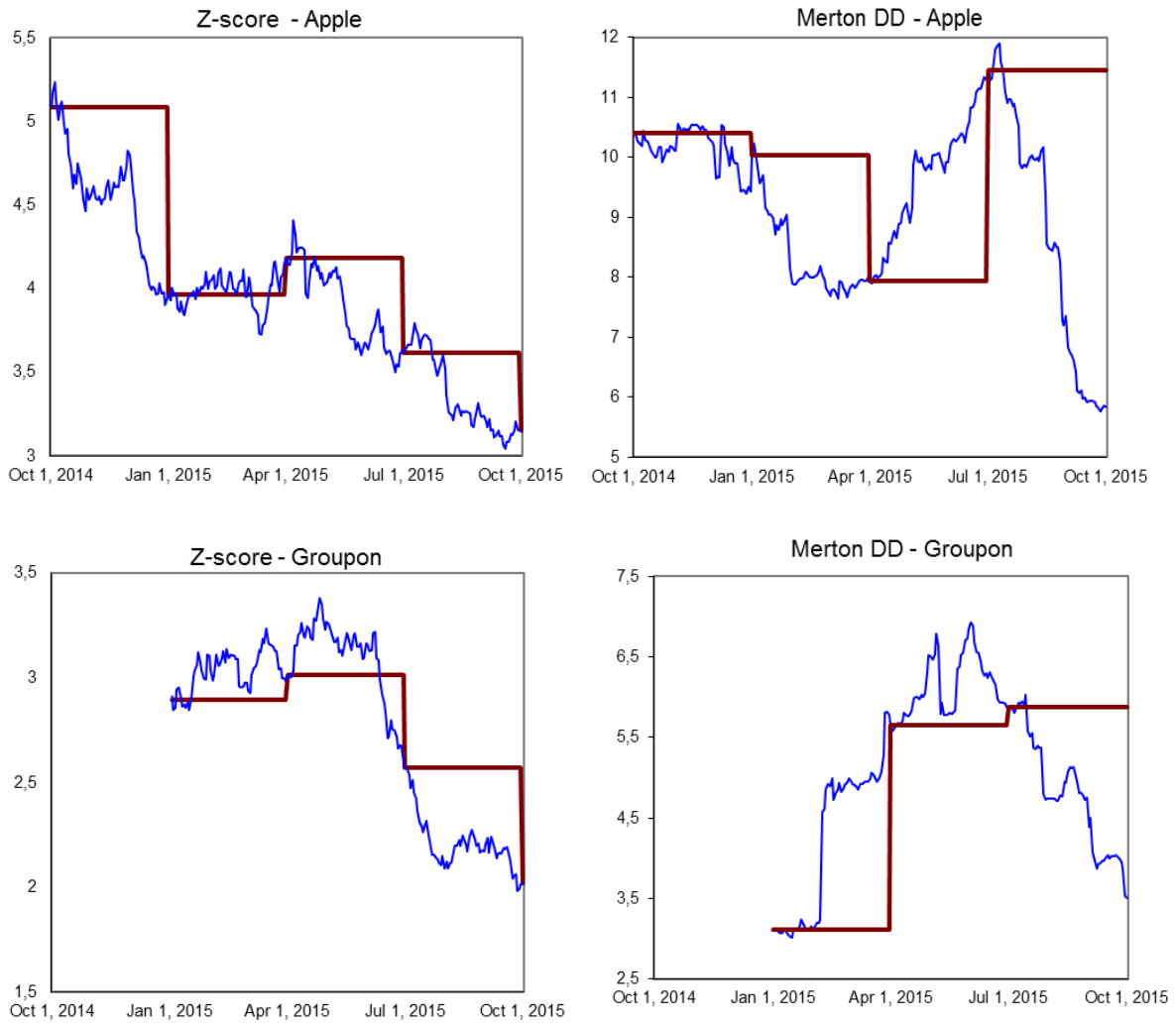


Figure 1. Z-score and Merton DD (Distance to Default) for Apple and Groupon with daily and quarterly accounting data, Oct 2014 - Oct 2015.