CAPCO

JOURNAL

THE CAPCO INSTITUTE JOURNAL OF FINANCIAL TRANSFORMATION

CURRENCY

Quantitative investing and the limits of (deep) learning from financial data

J. B. HEATON

DIGITIZATION

#47
04.2018

JOURNAL

THE CAPCO INSTITUTE JOURNAL OF FINANCIAL TRANSFORMATION

RECIPIENT OF THE APEX AWARD FOR PUBLICATION EXCELLENCE

CONTENTS

ORGANIZATION

07 Implications of robotics and AI on organizational design
Patrick Hunger, CEO, Saxo Bank (Schweiz) AG
Rudolf Bergström, Principal Consultant, Capco
Gilles Ermont, Managing Principal, Capco

15 The car as a point of sale and the role of automotive banks in the future mobility
Zhe Hu, Associate Consultant, Capco
Grigory Stolyarov, Senior Consultant, Capco
Ludolf von Maltzan, Consultant, Capco

25 Fintech and the banking bandwagon
Sinziana Bunea, University of Pennsylvania
Benjamin Kogan, Development Manager, FinTxt Ltd.
Arndt-Gerrit Kund, Lecturer for Financial Institutions, University of Cologne
David Stolin, Professor of Finance, Toulouse Business School, University of Toulouse

35 Can blockchain make trade finance more inclusive?
Alisa DiCaprio, Head of Research, R3
Benjamin Jessel, Fintech Advisor to Capco

45 The aftermath of money market fund reform
Jakob Wilhelmus, Associate Director, International Finance and Macroeconomics team, Milken Institute
Jonathon Adams-Kane, Research Economist, International Finance and Macroeconomics team, Milken Institute

51 Costs and benefits of building faster payment systems: The U.K. experience
Claire Greene, Payments Risk Expert, Federal Reserve Bank of Atlanta
Marc Rysman, Professor of Economics, Boston University
Scott Schuh, Associate Professor of Economics, West Virginia University
Oz Shy, Author, How to price: a guide to pricing techniques and yield management

67 Household deformation trumps demand management policy in the 21st century
Iordanis Karagiannidis, Associate Professor of Finance, The Tommy and Victoria Baker School of Business, The Citadel
D. Sykes Wilford, Hipp Chair Professor of Business and Finance, The Tommy and Victoria Baker School of Business, The Citadel

CURRENCY

81 Security and identity challenges in cryptotechnologies
José Vicente, Chairman of the Euro Banking Association's Cryptotechnologies Working Group
Thomas Egner, Secretary General, Euro Banking Association (EBA), on behalf of the working group

89 Economic simulation of cryptocurrencies
Michael R. Mainelli, Chairman, Z/Yen Group, UK and Emeritus Professor of Commerce, Gresham College
Matthew Leitch, Z/Yen Group
Dionysios Demetis, Lecturer in Management Systems, Hull University Business School

101 Narrow banks and fiat-backed digital coins
Alexander Lipton, Connection Science Fellow, Massachusetts Institute of Technology (MIT), and CEO, Stronghold Labs
Alex P. Pentland, Toshiba Professor of Media Arts and Sciences, MIT
Thomas Hardjono, Technical Director, MIT Trust::Data Consortium, MIT

117 Quantitative investing and the limits of (deep) learning from financial data
J. B. Heaton, Managing Member, Conjecture LLC

SECURITY

125 Cyber security ontologies supporting cyber-collisions to produce actionable information
Manuel Bento, Euronext Group Chief Information Security Officer, Director, Euronext Technologies
Luis Vilares da Silva, Governance, Risk and Compliance Specialist, Euronext Technologies, CISSP
Mariana Silva, Information Security Specialist, Euronext Technologies

133 Digital ID and AML/CDD/KYC utilities for financial inclusion, integrity and competition
Dirk A. Zetzsche, Professor of Law, ADA Chair in Financial Law (Inclusive Finance), Faculty of Law, Economics and Finance, University of Luxembourg, and Director, Centre for Business and Corporate Law, Heinrich-Heine-University, Düsseldorf, Germany
Douglas W. Arner, Kerry Holdings Professor in Law, University of Hong Kong
Ross P. Buckley, King & Wood Mallesons Chair of International Financial Law, Scientia Professor, and Member, Centre for Law, Markets and Regulation, UNSW Sydney

143 Digital identity: The foundation for trusted transactions in financial services
Kaelyn Lowmaster, Principal Analyst, One World Identity
Neil Hughes, Vice President and Editor-in-Chief, One World Identity
Benjamin Jessel, Fintech Advisor to Capco

155 Setting a standard path forward for KYC
Robert Christie, Principal Consultant, Capco

165 E-residency: The next evolution of digital identity
Clare Sullivan, Visiting Professor, Law Center and Fellow, Center for National Security and the Law, Georgetown University, Washington D.C.

171 The future of regulatory management: From static compliance reporting to dynamic interface capabilities
Åke Freij, Managing Principal, Capco

Quantitative investing and the limits of (deep) learning from financial data

J. B. HEATON | Managing Member, Conjecture LLC

ABSTRACT

The idea of quantitative investing – using robust computing power and algorithms to trade securities – inspires both awe and fear. Reality is less exciting. With a tiny handful of exceptions, most quant funds have been unimpressive. I explore some limits of quantitative investment, with a focus on the promise – or lack thereof – of techniques from deep learning and artificial intelligence. These limitations help explain the disappointing performance of many quant strategies and cast doubt on the promise of artificial intelligence techniques for improving returns. The main problem is that financial market data is unlike the data that machine learning works well on computer vision, speech recognition, and natural language processing. While deep learning and artificial intelligence are changing the world in many ways, they are unlikely to generate fortunes for investors, who will continue to remain best-served by inexpensive and passive index products that themselves will be augmented by machine learning techniques to drive costs even lower.

1. INTRODUCTION

Quantitative investing – using robust computing power and algorithms to trade securities – inspires awe and fear. Awe arises from the idea that the use of mathematics, statistics, and computer learning might be the closest thing possible to the real-world Philosopher's Stone. Fear comes from the worry that traders using computer algorithms to trade securities – often at the "high frequency" of microseconds and faster – can disrupt capital markets and delink prices from fundamentals. Investors have responded more to the awe than to the fear. Investment industry sources estimate that quant funds managed more than U.S.$1 trillion by the beginning of 2018. The strategies include everything from relatively simple regression-based "factor models" from firms like AQR (founded by fellow finance PhDs from the University of Chicago) to highly-complex computer learning models employing the latest ideas from artificial intelligence, including the deep learning models I refer to in my title.

The reality is less impressive than awe or fear suggest. One of the biggest fund implosions of all time was Long-Term Capital, a quant fund run by former Salomon Brothers proprietary traders and Nobel Prize winners Robert Merton and Myron Scholes. More recently, BlueTrend, a Geneva-based fund and Winton Capital, a large London-based fund, have had unimpressive years, as has AHL, one of the main funds of the Man Group, and Aspect Capital, another large quant fund. With only a handful of exceptions – most notably Renaissance Technologies, the hedge fund that mathematician James Simons founded in 1982 – most quant funds do not have consistently impressive performance. Consider Citadel LLC, a huge hedge fund headquartered in Chicago. The hedge fund returned only about 13% in 2017, short of the S&P 500 Index's 20% gain, a return available quite inexpensively to anyone with the money to open an account at Vanguard Group. The explanation for the difference in returns is not lower risk. Citadel fell nearly 60% in 2008, far more than the S&P 500 index. More recently, when market turmoil hit in early February 2018, some of the biggest names in quant fell hard again, including Winton and AHL, and a large quant fund managed by Lynx Asset Management.

In this article, I explore some limits of quantitative investing, with a focus on the promise – or lack thereof – of techniques from deep learning and artificial intelligence more generally. As deep learning – a subset of machine/computer learning – has achieved more and more success in image and speech recognition, product recommendations, and self-driving vehicles, hope has escalated that the techniques allowing advances in other domains will pay off for quant investors as well. Deep learning is a form of machine learning, the use of data to train a model to make predictions from new data. Recent advances in deep learning have dramatically improved the ability of computers to recognize and label images, recognize and translate speech, and play games of skill, in each case sometimes at better than human-level performance. In these applications of deep learning, the goal is to train a computer to perform, even better, certain tasks – such as recognizing the content of an image – that a human usually is able to do quite well.

Financial markets present far different problems than those presented in computer vision, speech recognition, and natural language processing. Unlike recognizing an image or responding appropriately to verbal requests, humans have no innate ability to, for example, select a stock that is likely to perform well in some future period. These limitations are related to the disappointing performance of many quant strategies and cast doubt on the promise of artificial intelligence techniques for improving matters.

2. STATISTICAL MODELING, MACHINE LEARNING, AND DEEP LEARNING

The idea behind many quant strategies is that some variable of interest – say, a move in a security price – can be modeled as some function of available data. The function of the data could be something as simple as a factor regression model or something as complex as a many-layered deep learning computation. We can conceive of the problem as approximating for the variable of interest some existent, but unknown, true function of the data. The problem is to use available data to estimate the relationship or "train the model" and then test the model on new data or data that we set aside from the initial estimation. The basic tools of quant strategies are mathematics (including optimization, probability, information theory, and statistics) and numerical methods using computers.

The problem is that financial markets generate data that is not like the data on which machine learning works well. Machine learning is incredibly powerful with data patterns that are stable. A vision system may take a while to learn all the ways to recognize a dog in an image, since there are so many different angles from which to capture the dog and so many objects that might interfere with the dog's image (e.g., the

dog might be partially hidden by a fire hydrant!). But a dog is a dog and remains so, and the algorithm can learn to distinguish dogs of different types from cats and cacti. The same is true of chess patterns, the game of Go, speech recognition, you name it. The computer is allowed to train on data and learn relationships that remain relatively stable and eventually gets it right.

Financial market data is different. First, the algorithm may identify a relationship that does not actually exist. "Signals" in financial markets come with enormous amounts of "noise." A quant system may falsely identify a signal that does not actually exist or may overestimate the effect of an actual signal. Second, even if the relationship did exist at one time in the data, it may disappear quickly. The behavior causing the relationship might change as investors learn something that alters their expectations. Alternatively, arbitrage – the actions of the quants themselves – might cause the signals to disappear as investors who see the relationship compete them away. Anyone who has taken an introductory economics course has encountered the model of perfect competition where buyers and sellers are equally well informed and there is no market power. Quants are all trying to hire the same kinds of people, educated at the same institutions, and trained in the same methodologies. As a result, quant trading is largely (Renaissance Technologies excepted?) a commodity business and competition to exploit signals looks a lot like competition to buy and sell identically-graded wheat. Third, if a relationship does not disappear – that is, a signal continues to "work" – the relationship may indicate the presence of a risk-return tradeoff, not an arbitrage opportunity. If a relationship that everyone can see continues to exist, then – like the fact that stocks on average return more than U.S. treasuries – it is more likely that the return is compensation for real risk. Indeed, the marketing genius of firms like Dimensional Fund Advisors and AQR is that they implemented simple academic factor model-based investing as if it offered superior risk-adjusted performance when that superior performance is probably just compensation for economic risk that occasionally bites the investors who bear it.

3. FOOLING THE MACHINE

A human – though perhaps quite fallible – is often able to notice or "get the feeling," through some mechanism of intuition we do not yet understand, that something is not quite right. This can allow a human trader to put the brakes on a strategy. Computers are not always good at this. Sometimes this is what allows algorithms to make better decisions, as they are not prone to wrong intuitions. But sometimes intuitions are right. Livermore (1940), the famed speculator of the early 20th century, writes: "A speculator of great genius once told me: "When I see a danger signal handed to me, I don't argue with it. I get out! A few days later, if everything looks all right, I can always get back in again. Thereby I have saved myself a lot of worry and money. I figure it out this way. If I were walking along a railroad track and saw an express train coming at me sixty miles an hour, I would not be damned fool enough not to get off the track and let the train go by. After it had passed, I could always get back on the track again, if I desired."

> "The problem is that financial markets generate data that is not like the data on which machine learning works well."

Because computers interpret information differently than humans, they may miss some trains coming. Recent analysis of image-recognition deep-learning algorithms, for example, reveals that tiny errors – the change of a single pixel in an image, for example – can lead algorithms to fail miserably. This raises the possibility that some market participants may create just such tiny errors in financial data on purpose as a way to change the trading behavior of other active algorithms, using a tiny perturbation of the price or other data to shift a competing trading algorithm from buy to sell or no action at all, or to increase or decrease the size of buy and sell orders.

This is an interesting turn of events. Research suggests that manipulating the prices of securities through mere trading (as opposed to fraud) is quite difficult, at least when humans oversee trading decisions [Fischel and Ross (1991), Kyle and Viswanathan (2008)]. But we know far less about how price manipulation might work in a computer-driven market, and there are reasons to believe stock manipulation is more widespread than recognized [Comerton-Forde and Putnins (2014)]. Quant trading is likely to raise important regulatory issues in the future [Korsmo (2014), Mahoney and Rauterberg (2017)]. The temptation to manipulate markets may be particularly large for some quants as they find themselves unable to generate promised returns legitimately.

4. COGNITIVE BIASES, OR, HOW TO MAKE MONEY AS A QUANT WITHOUT REALLY TRYING

One way to understand quant funds – like most hedge funds – is to realize they are not about superior investment performance. Most hedge funds charge enormous fees to deliver performance that consistently underperforms passive (and very inexpensive) index funds. Investors in hedge funds may be the dumb money in the market. They are optimistic and overconfident gamblers who think they can pick a winner notwithstanding the failures of similarly-situated investors to do so. To them, hedge funds – including quant funds – are like casinos. And like the real casino business, hedge fund investors like to frequent the shiniest and brightest. Hedge funds build their casinos accordingly: hiring lots of people with no proven ability to beat the market, but who look awfully smart. This includes data scientists.

Take a firm like AQR. Their results speak for themselves; it is not a performance powerhouse. But its founder, Cliff Asness, is a master marketer of academic research. He has an unparalleled advantage at making investors feel he is implementing for them the lessons of tried and true academic research. By hiring (co-opting?) incredibly smart academics and appealing to academic journal results, he builds a casino that attracts the gamblers who want a University of Chicago patina of academic rigor. But is he adding much value over Vanguard's cheaper index funds? It doesn't appear so. BlackRock is the world's largest asset manager, but it makes far more money on its most expensive products than the passive products that are best for customers (I think of passive index customers as the non-gamblers who come to the casino for the great food at rock-bottom prices). BlackRock has now set up a group to research artificial intelligence in investment. That seems more about marketing than anything else.

This window dressing is unlikely to generate returns for the reasons I reviewed above, but it is likely to exploit investor optimism and overconfidence and make considerable sums for the quant managers, especially those who were fortunate to generate high returns long ago on much smaller asset bases and who can, therefore, still claim they have high "average" returns. Optimism is an important cognitive bias that draws investors to overpriced active management, including quant strategies. Much psychological research shows that individuals do not base predictions upon objective evidence, e.g., the evidence that the median active manager does not beat passive indices and the evidence that the only reliable persistence in returns is that really bad active managers tend to remain really bad. In a widely cited paper in Nature Neuroscience, Sharot et al. (2011) suggest that optimism may arise because desirable information is integrated into prior beliefs more readily than undesirable information. When newly encountered information – the underperformance of your hedge fund investment in Citadel or Winton, say – is worse than expected, people largely ignore it, perhaps consoling themselves with that "average" return that places significant weight on big returns from the 1990s.

5. THE TASK IS HARDER THAN YOU MIGHT THINK

Quant strategies face a bigger problem than the limits of data science with financial data. In prior work with co-authors [Heaton et al. (2017)], confirmed by related work [Bessembinder (2018)], I find that active managers are probably doomed to underperform large passive (and inexpensive) indexes, like the S&P 500, in most years because active strategies miss the handful of stocks that drive market results. An underemphasized empirical fact is that the best performing stocks in a broad index often perform much better than the other stocks in the index, so that average index returns depend heavily on a relatively small set of winners. Quant strategies that select subsets of securities from an index are likely to underperform it.

To illustrate the idea, consider an index of five securities, four of which (though it is unknown which) will return 10% over the relevant period and one of which will return 50%. Suppose that active managers choose portfolios of one or two securities and that they equally weight each investment. There are 15 possible one or two security "portfolios." Of these 15, 10 will earn returns of 10%, because they will include only the 10% securities. Just five of the 15 portfolios will include the 50% winner, earning 30% if part of a two-security portfolio and 50% if it is the single security in a one security portfolio. The mean average return for all possible actively-managed portfolios will be 18%, while the median portfolio of all possible one- and two-stock portfolios will earn 10%. The equally-weighted index of all five securities will earn 18%. Thus, in this example, the average active-management return will be the same as the index [see Sharpe (1991)], but two-thirds of the actively-managed portfolios will underperform the index because they will omit the 50% winner. Quant strategies face a daunting task in beating the odds of missing the best performing trades. And by constant trading, they create even more positions that are likely to underperform market indexes.

6. CONCLUSION

In this article, I explore some limits of quantitative investment with a focus on the promise – or lack thereof – of techniques from deep learning and artificial intelligence more generally. In prominent applications of deep learning, the goal is typically to train a computer to do as well or better at a task – such as recognizing the content of an image – that a human usually does quite well. But financial markets present far different problems than those presented in computer vision, speech recognition, and natural language processing. Given the mostly unimpressive performance of quant funds – with a tiny handful of exceptions – it is more reasonable to view quantitative investment management as more marketing than effective trading technique. Moreover, there are empirical reasons that it is very difficult to beat large passive portfolios consistently, and those empirical facts are just as hard for quants to overcome as for other active managers. While deep learning and artificial intelligence are changing the world in many ways, they are unlikely to generate fortunes for investors, who will continue to remain best-served by inexpensive and passive index products that will be augmented by machine learning techniques to drive costs even lower.

References

Bessembinder, H. 2018, "Do stocks outperform treasury bills?" Journal of Financial Economics, forthcoming

Comerton-Forde, C., and T Putnins, 2014, "Stock price manipulation: prevalence and determinants," Review of Finance 18, 23-66

Fischel, D., and D. Ross, 1991, "Should the law prohibit 'manipulation' in financial markets?" Harvard Law Review 105, 503-553

Heaton, J. B., N. Polson, and J. H. Witte, 2017, "Why indexing works," Applied Stochastic Models in Business and Industry 33, 690-693

Livermore, J., 1940, How to trade stocks, Duell, Sloan & Pearce

Korsmo, C., 2014, "High-frequency trading: a regulatory strategy," University of Richmond Law Review, 48, 523-609

Kyle, A., and S. Viswanathan, 2008, "How to define illegal price manipulation," American Economic Review 98, 274-279

Lin, T., 2017, "The new market manipulation," Emory Law Journal, 66, 1253-1314

Mahoney, P., and G. Rauterberg, 2017, "The regulation of trading markets: a survey and evaluation," working paper

Merton, R., 1980. "On estimating the expected return on the market," Journal of Financial Economics 8, 323-361

Sharot, T., C. W. Korn, and R. J. Dolan, 2011, "How unrealistic optimism is maintained in the face of reality," Nature Neuroscience, 14, 1475-1479

Sharpe, W. F., 1991, "The arithmetic of active management," Financial Analysts Journal 47:1, 7-9

Taylor S., and J. Brown, 1988, "Illusion and well-being: a social psychological perspective on mental health," Psychological Bulletin 103, 93-210

Weinstein, N., 1980, "Unrealistic optimism about future life events," Journal of Personality and Social Psychology, 39, 806-820

cannot, and will not, allow a wider range of corporate or individual participants (particularly, if they wish to be anonymous) to have account with them. This is for a variety of reasons, including, but not limited to, being unable to solve the KYC/AML problem, not to mention potential political complications.

Thus, we need to build a bank, which cannot default, at least due to market and liquidity risks. One needs to be cognizant of the fact that, regardless of the amount of effort, it is not possible to build a bank impervious to operational risks, although proper design can minimize them to an acceptable degree.

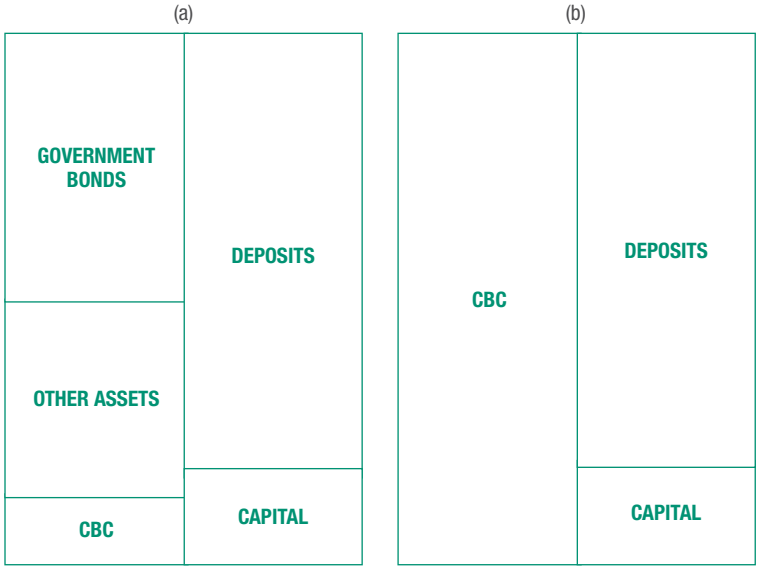
3.3 Types of NBs

Several approaches for designing a NB have been summarized in Pennacchi (2012):

- 100 percent reserve bank (C-PeRB): Assets – central bank reserves and currency; liabilities – demandable deposits and shareholder equity. Depending on the circumstances, these deposits can be either noninterest-bearing, or interest paying, or interest charging. The latter set-up might be necessary if interest rate paid by central bank is negative. C-PeRB is financed by a combination of deposits (debt) and shareholders' equity.
- Treasury money market mutual fund (TMMMF): Assets – Treasury bills or repurchase agreements collateralized by Treasury bills; liabilities – demandable equity shares having a proportional claim on the assets. TMMMF is financed solely by equity.
- Prime money market mutual fund (PMMMF): Assets – short term Federal agency securities, short-term bank certificates of deposits, bankers' acceptances, highly rated commercial paper, and repurchase agreements backed by low-risk collateral; liabilities – demandable equity shares having a proportional claim on the assets. As before, PMMMF is financed solely by equity.
- Collateralized demand deposit bank (CDDB): Assets – low-credit- and interest-rate-risk money market instruments, which are fully (over)-collateralized; liabilities – demandable deposits that have a secured claim on the collateral.
- Utility bank (UB): UB is similar to a CDDB, except for the fact that collateral can include retail loans in addition to money market instruments;

Putting aside operational risks inherent in the banking business, the reliability of a NB varies from completely stable (C-PeRB), to stable under most plausible circumstances (UB).

Figure 5: Balance sheets of a fractional reserve bank and an NB



The difference between balance sheets of a fractional reserve bank and a NB is shown in Figure 5.

3.4 The time for a NB is now

Whilst running a NB is relatively easy from a market perspective, and the required capital for doing so is comparatively small (under current Basel regulations its size is determined by leverage alone), it naturally has to possess bullet-proof security and reliability. These requirements can be met by judiciously building the corresponding ledger software and hardware. Of course, in addition to pure operational aspects, the NB has to satisfy the KYC/AML requirements. It is clear that a liberal usage of "artificial intelligence," "machine learning," and "big data analytics" is necessary to accomplish this task efficiently. In this regard, TRUST::DATA, a new framework for identity and data sharing currently being developed at MIT, is particularly promising [see Hardjono et al. (2016)].

There is a perennial question of profitability of a NB. Whilst a fractional reserve bank earns its living first and foremost via the "net interest margin" (NIM), i.e., the difference between the interest it charges its borrowers and interest it pays its depositors, a NB seemingly is deprived of this all important source income. However, this is only partially true, since at present some central banks, including the Federal Reserve, do pay substantial interest on excess deposits. Besides, NBs can earn interest on securities, charge reasonable fees

for transaction services, etc. While their operational margins are certainly low (by yesteryear standards), so are their capital requirements, operating costs (due to an efficient infrastructure), and regulatory burdens. Thus, NBs could generate competitive returns on equity, which are very favorably compared to the ones generated by their fractional reserve cousins. The quote from Friedman (1959) captures the essence of the problem: "I shall depart from the original 'Chicago Plan of Banking Reform' in only one respect, though one that I think is of great importance. I shall urge that interest be paid on the 100% reserves. This step will both improve the economic results yielded by the 100% reserve system, and, also, as a necessary consequence, render the system less subject to the difficulties of avoidance that were the bug-a-boo of the earlier proposals. ... This problem of how to set the rate of interest is another issue that I feel most uncertain about and that requires more attention than I have given to it."

If NBs in different jurisdictions organize themselves as a network of sister banks, they can earn substantial (but fair) transactional fees on foreign exchange transactions.

In principle, NBs can be affiliated with lending organizations with uninsured funding, the so-called lending affiliates. In view of this fact, lending facilities can be left to their own devices and be regulated by market forces.

It is clear that the adoption of narrow banking in its entirety would require a massive transformation of the financial ecosystem and should not be undertaken until numerous and nuanced questions dealing with the pros and cons of such a transformation are answered in sufficient detail. While we list some of the pros and cons below, we are interested in a less ambitious project – that is an introduction of an NB, which would coexist with fractional reserve banks, rather than supplant them completely. An interesting analogy jumps to mind – currently electric cars (NBs), coexist with conventional gasoline cars (fractional reserve banks). While in the long run electric cars are likely to prevail over gasoline cars, in the short run they can peacefully cohabit. In order to avoid academic discussions related to the transformation of the banking system from the fractional reserve to the narrow setup, we advocate creation of a few NBs as needed for achieving our specific goals. We anticipate coexistence of fractional reserve and NBs for a long time to come.

4. PROS AND CONS OF A NB

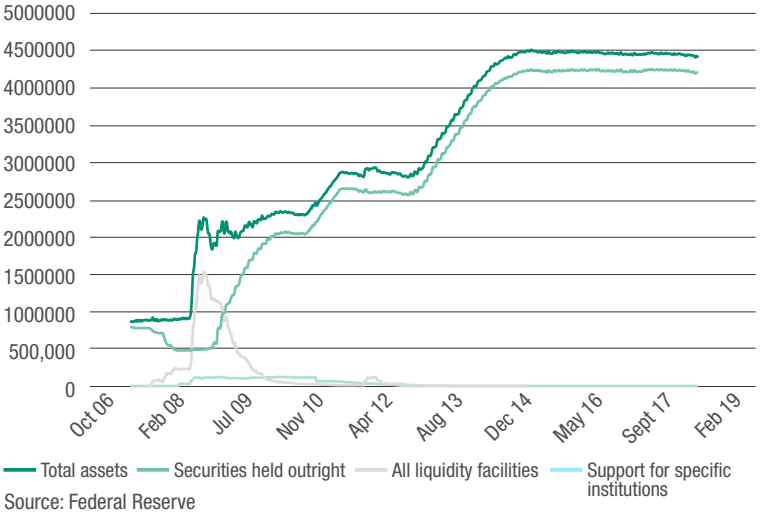
4.1 Pros

There are many leading economists who advocate narrow banking because some of its benefits are self-evident. First, by construction, and in contrast to fractional reserve banks, assets and liabilities of NBs are perfectly aligned, so that conventional stabilization mechanisms such as deposit insurance, discount window lending, rigorous regulation and control of balance sheet, without which fractional reserve banks cannot exist, are simply not necessary. We emphasize, however, that other types of regulation are certainly needed, not least because NBs, like any other organizations, are subject to operational risks, particularly from electronic attacks.

"Fortunately, remarkable technological breakthroughs – mostly related to cryptocurrencies, distributed ledgers, and related concepts – simultaneously focused attention of key decision-makers and technical experts on the glaring need for transforming the financial infrastructure, and, at the same time, indicated how such a transformation can be accomplished."

Second, since lending is performed by non-banking institutions on an uninsured basis, governmental interference in bank lending and other activities can

Figure 6: Assets of the Federal Reserve Bank



Source: Federal Reserve

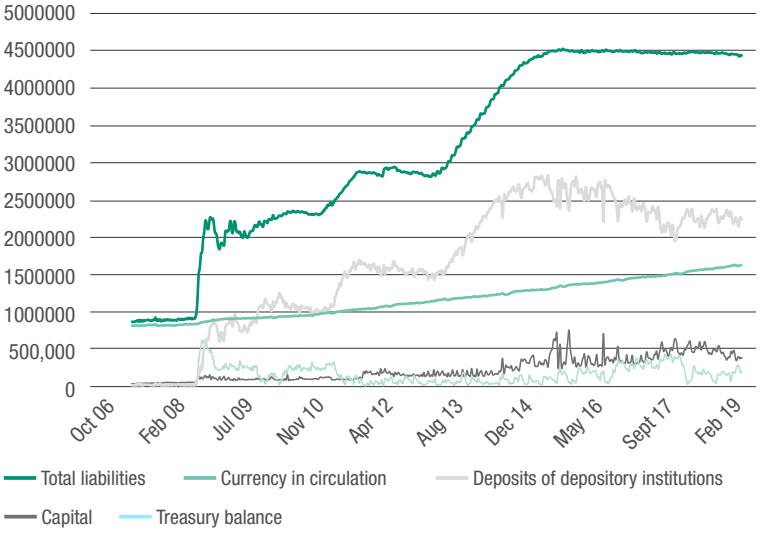
be dramatically reduced, if not completely eliminated. Third, deposit insurance can be reduced in size and eventually phased out.

4.2 Cons

Needless to say, narrow banking is not without its detractors. Some economists argue that NB will not be a silver bullet needed to kill financial instability, particularly because lending affiliates would suffer from the same issues as fractional reserve banks. Although it is true to some extent, it is clear that narrow banking can serve as a cornerstone of a stable and reliable payment system, capable of operating on its own even under the most extreme conditions, so that the pressure on the financial ecosystem as a whole would be significantly less compared to fractional reserve banking. To attract investors, lending affiliates would have to maintain their own strong capital cushion and look for long-term financing opportunities. Still, these measures in and by themselves might not be sufficient to ensure the financial stability under all circumstances, so that the "lender of last resort" in the form of a central bank would still have to be present in the system. Such a bank will provide required liquidity to uninsured lenders including affiliates of NBs against illiquid, but sound, collateral, thus avoiding a systemic credit collapse. This is to be compared with the current setup, where financial authorities support private banks through deposit insurance, access to the discount window, and implicit government guarantees.

Specifically, Miles (2001) argues that separation of deposit taking and lending would result in elevated agency costs and reduce stability of the supply of lending. In all likelihood, this is not going to happen since lenders would become much more efficient to survive without a cushion provided by depositors. Bossone (2002) emphasizes that benefits of NB in terms of financial stability are much smaller than its drawbacks associated with cutting the link between bank money and economic activity and creating "market incompleteness." He thinks that this void will be filled by financial firms, whose operations will be as risky as the ones conducted by fractional reserve banks, so that overall stability of the financial ecosystem will not improve. Most interestingly from our standpoint, Bossone (2002) is not opposed to voluntary creation of NBs, or segregated NB subsidiaries within existing bank holding companies.

Figure 7: Liabilities of the Federal Reserve Bank



Source: Federal Reserve
Notes: Excess reserves kept by commercial banks increased enormously since 2008

The other danger is the risk of flight to quality from fractional reserve banks to NBs during the times of financial instability, i.e., precisely when the former can least afford to lose their liquidity. This danger is not as acute as it might sound, because the actual amount of liquidity NBs can absorb is limited by their capital size.

5. NBS AS PART OF THE FINANCIAL ECOSYSTEM

5.1 Current trends in banks' behavior

In the build-up to the GFC, banks tried to stay as leveraged as possible, by simultaneously reducing their capital ratio and choosing progressively riskier asset mix. However, after 2008, their group behavior changed dramatically. The balance sheet of the Federal Reserve is shown in Figures 6 and 7. Comparison of these figures shows that the asset and liability mix of the banking sector underwent a dramatic transformation after the GFC. One of the most striking aspects of this change is the precipitous increase in excess reserves depositary institutions keep with the Federal Reserve. We are observing interesting and somewhat perplexing developments: until the onset of the GFC, central banks were run as NBs, and commercial banks were run as fractional reserve banks, while after the crisis the situation flipped, although not completely. This fact shows that banks prefer to keep a considerable cash cushion, partly because they put an extra premium

on maintaining high liquidity, and partly due to lack of demand for loans. Besides, attractive interest rate paid by the Federal Reserve on the excess deposits is clearly an additional motivation.

In view of the above, it is clear that building a NB cannot and should not upend the overall balance of the banking ecosystem, since it is pretty much aligned with prevailing trends anyway.

5.2 What can an NB do for you?

A properly designed NB is a natural repository of funds for those who highly value their funds' stability (either by inclination, such as wealthy individuals and organizations, or by necessity, such as central clearing counterparties). It is also a natural emitter of FBDC. In addition, such a bank can do many other things. For instance, it can be used to hold non-operational deposits, which conventional commercial banks do not want and cannot hold at a profit. Besides, it is a custodian for initial margins (IM) supplied by investment banks as part of their regular over-the-counter derivatives business. These funds are naturally paid via FBDC and are kept safe by construction. Moreover, if so desired, the NB, being a neutral custodian, can provide value-added services, such as calculating the size of the required collateral and administering its allocation. Besides, a NB can be a very useful source of digital identity.

5.3 Lending affiliates – credit money creators of the future

If banking institutions all become narrow, then credit creation will be performed by lending affiliates and other lenders, for instance, mutual funds or hedge funds. In fact, after the GFC, a considerable portion of credit is issued by non-banks, while many banks keep massive excess reserves with central banks, thus becoming de-facto more narrow. By reorganizing themselves into transaction-oriented NBs and lending affiliates, fractional reserve banks can become much more cost-efficient, nimble, and stable.

By construction, NBs offer their depositors a high level of safety, handle regulatory burden with relative ease, require a low capital cushion, derive a stable and considerable flow of income from their transactional activities, and benefit from the interest paid on bank reserves by central banks. Transactional cash flow can be increased manifold if foreign exchange and, especially, cryptocurrency issuance are included into the mix. At the same time, since NBs require very limited capital cushion, which is needed to satisfy leverage ratio constraints and cover operational risks, they can offer very attractive return on equity (ROE) to their investors. Recall that a non-risk-based leverage ratio is calculated by dividing Tier-1 capital by the bank's average total consolidated assets, which, for NBs, boil down to central banks reserves and short-term government paper. Under Basel III rules, banks have to maintain a leverage ratio in excess of 3%.

Given the simplicity of their balance sheet and efficiency of the state-of-the-art IT systems, NBs can use technological advancements, such as distributed ledgers and blockchain, to provide excellent transactional banking services and successfully complete with transactionally-oriented fintech startups [see Lipton (2016a), Lipton et al. (2016), He et al. (2017), Powell (2017), among others].

At the same time, uninsured lending affiliates of NBs, unencumbered by the requirement to provide utility-like transactional services, can better serve the needs of the real economy, by offering traditional as well as innovative credit financial products. Given that lending affiliates would not have cheap sources of funding in the form of deposits, they would have to maintain healthy capital cushions and choose the quality of assets aligned with their risk appetite, in order to attract savings and other forms of funding from investors. Lending affiliates would be stratified depending on the level of their speculative activities. Denuded of all amenities related to deposit insurance, lending affiliates will have their own skin in the game, and be open to scrutiny by their investors.

Thus, splitting fractional reserve banks into NBs and lending affiliates would increase investment value of both, much like nuclear fission releases enormous energy in nature.

5.4 Limited impact of narrow banks on the ecosystem at large

Even though an NB by construction is impervious to market and liquidity shocks, it can suffer from operational risks. Hence, it requires capital cushion. The size of this cushion is determined by the leverage ratio, and is of the order 3%-4% of its assets.

Thus, the size of the available capital effectively limits the amount of central bank money a NB can attract from fractional reserve banks. As a result, potential systemic impact of such an institution on the financial system as a whole is limited. Besides, since a NB does not lend its funds, it is unable to create money “out of thin air,” so from this angle, its impact is limited too.

Yet, such a bank would have a great impact in other ways. First and foremost, it will create an honest competition in the banking ecosystem and will force conventional banks to pay a fair interest to their depositors. Second, it would make FBDC expansion above and beyond its original narrow base a reality. Finally, for the first time in recent history, such a bank would provide a venue for both retail and institutional depositors who are particularly concerned about availability and stability of their deposits even under the most extreme conditions. Among the institutional depositors, central clearing counterparties are the primary candidates, given that they have all kind of negative externalities including the fact that some of their largest clearing members are, at the same time, their bankers. Thus, a potential default of a clearing member can cause a double loss for such a CCP.

NB, being a radical departure from the familiar financial setup, naturally raises numerous questions of monetary policy, particularly regarding the manner of money creation and who should be responsible for it. The main issue is that to a large extend money will be created or destroyed by central banks, which would have to exercise preternatural abilities to do so properly. Money creation along these lines would be a de facto tool of central planning. Given that central planning is next to impossible to execute efficiently, the dangers can outweigh the benefits. The behavior of credit markets would be affected in a very profound way, since banks will no longer be natural sources of credit. All these effects have to be analyzed in detail before narrow banking is implemented in its entirety.

6. CBDC VERSUS FBDC

In principle, distributed ledgers can potentially become a truly transformative force by making central bank digital currency (CBDC) a reality, in a dramatic departure from the past. A variety of viewpoints on this subject, some of which are mutually exclusive and contradictory, can be found in Ali et al. (2014), Andalfatto (2015), Barrdear and Kumhof (2016), Broadbent (2016), Danezis and Meiklejohn (2015), Fung and Halaburda (2016), Koning (2016), Lipton (2016b), Bordo and Levin (2017), Dyson and Hodgson (2016), Mersch (2017), Scorer (2017), among many others.

If central banks start to issue CBDC, they can not only abandon physical cash in favor of its electronic equivalent, as is advocated in Rogoff (2016), but, eventually, retire a substantial portion of the government debt in its favor. This would be a very impactful development for society at large. Taken to its logical limit, CBDC can eliminate fractional banking raison d’être and dramatically improve financial ecosystem resilience, by allowing economic agents to have accounts at the central bank directly. As a result, these

will dramatically reduce the ability of the banking sector to create money "out of thin air" and transfer this all-important function to central banks. However, central banks are not equipped to address the large-scale KYC/AML problem, which they would have to solve if they open their balance sheets to a large portion of economic agents, rather than licensed banks and selected financial institutions alone. While developments in this direction are inevitable, their timing and magnitude cannot be ascertained at present.

Realistically, we do not expect central banks' balance sheet to be open to all economic agents. Accordingly, we think that FBDC, being a private coin, is a much more convenient solution to digitization of the fiat currency than CBDC. Issued by a purpose-built NB, FBDC will be as reliable as fiat. At the same time, the corresponding bank can satisfactorily solve the KYC/AML problem and navigate the complicated political landscape. Moreover, NBs, organized as a network of sister banks incorporated in different jurisdictions, can simplify and cheapen foreign exchange transactions.

7. DIGITAL IDENTITY AND KYC/AML

With the emergence of blockchain and DLT, and their usage for cryptocurrencies, the question of digital identity in the context of KYC/AML has come to the foreground. A major shortcoming in current identity systems on the internet is the lack of privacy with respect to transactions performed using these identities. This deficiency is also true in the context of blockchain-based currencies, such as Bitcoin, namely the disclosure of identities through the reverse engineering and analytics of the public-keys used in transactions recorded on the blockchain.

We believe a new breed to "crypto-identities" may need to be devised that not only provides transaction confidentiality, but more importantly exhibit the features necessary to make it compliant to KYC/AML regulations. These crypto-identities must be based on and derive from the appropriate combination of highly private and accurate personal data, and must yield truthful assertions or claims regarding the owner relevant to the KYC/AML requirements. Additionally, for transaction confidentiality, these identities must be conditionally anonymous-verifiable, meaning that the identities must seemingly be anonymous to non-participants and be reversible by KYC/AML processes. In this way, a chain of provenance (or chain of verifiability) can be established for a given digital identity from the transaction on the blockchain to the legal owners of the digital identity.

The area blockchain and DLT is currently still nascent, and additional infrastructure technologies will be needed in order for the full benefits of blockchains to be realized in a transformative manner in connection to digital identities. The report by Hardjono and Maler (2018) provides a broad industry review of identity technology and the relevance of blockchain to identity management.

8. MORAL HAZARD

One of the greatest hazards of a widely used digital currency is enabling a repressive surveillance state. If the government can track all of its citizens' payments, then they can exert unprecedented control over their lives. Nor is this situation just some science fiction fantasy; in parts of Northern China virtually all payments – for transportation, food, entertainment, communication, everything – are logged by just two companies, both of whom collaborate closely and share data with the government.

To avoid this situation, small financial transactions, such as currently performed with cash, must be anonymous. Exceptions to this anonymity should be few and far between. For instance, in serious criminal investigations or similar situations, where there is an overriding social imperative, society may decide that it should be possible to override this anonymity using carefully vetted and expensive methods such as legal court orders.

Fortunately, there are a range of cryptographic methods to enforce levels of anonymity ranging from technologies that allow complete unbreakable anonymity, to methods that provide anonymity for payers but not for sellers, to frameworks that provide anonymity except for court orders. For instance, a narrow bank can follow the Chaumian scheme and issue numbered and blind signed currency units onto a distributed ledger, whose trust is maintained either by designated notaries or by the bank itself. KYC/AML requirements could be limited to large deposits or withdrawals, much as cash transactions are today.

9. CONCLUSION

In this document, we have outlined an efficient framework, which can be used in order to extend the domain of applicability of the FBDC from an initial group of bank sponsors to a much wider group of potential users including SMEs. We have argued that a purpose-built NB is necessary (and, hopefully, sufficient) to achieve this goal. Not only can it be used to securely hold collateral, but also to solve the all-important KYC/AML problem. The FBDC, being a stable cryptocurrency, can facilitate both domestic and foreign trade and offer numerous possibilities for streamlining and facilitating commercial and retail transactions.

References

Al-Jarhi, M., 2004, "Remedy for banking crises: What Chicago and Islam have in common: A comment," Islamic Economic Studies 11:2, 23-42

Admati, A. and M. Hellwig, 2014, The bankers' new clothes: what's wrong with banking and what to do about it, Princeton University Press

Ali, R., J. Barrdear, R. Clews, and J. Southgate, 2014, "The economics of digital currencies," Bank of England Quarterly Bulletin 54:3, 276-286

Andolfatto, D., 2015, "Fedcoin: on the desirability of a government cryptocurrency," Web Log post

Barrdear, J. and M. Kumhof, 2016, "The macroeconomics of central bank issued digital currencies," Bank of England Working Paper No. 605

Benes, J. and M. Kumhof, 2012, "The Chicago plan revisited," International Monetary Fund, WP/12/202

Bodenhorn, H., 2000, A history of banking in Antebellum America: financial markets and economic development in an Era of Nation-Building, Cambridge University Press

Bordo, M. D. and A. T. Levin, 2017, "Central bank digital currency and the future of monetary policy," National Bureau of Economic Research No. w23711

Bossone, B., 2002, "Should banks be narrowed? An evaluation of a plan to reduce financial instability," Public policy brief No. 69, Jerome Levy Economics Institute of Bard College

Broadbent, B., 2016, "Central banks and digital currencies," Speech at London School of Economics

Bryan, L., 1991, "Core banking," The McKinsey Quarterly 1, 61-74

Burnham, J. B., 1991, "Deposit insurance: the case for the narrow bank," Regulation 14, 35-43

Buterin, V., 2013, "What proof of stake is and why it matters," Bitcoin Magazine, August 26

Castro, M. and B. Liskov, 1999, "Practical Byzantine fault tolerance," OSDI 99, 173-186

Chamley, C., L. J. Kotlikoff, and H. Polemarchakis, 2012. "Limited-purpose banking-moving from "trust me" to "show me" banking," American Economic Review 102:3, 113-119

Chaum, D., A. Fiat, and M. Naor, 1990, "Untraceable electronic cash," in Proceedings on advances in cryptology, Springer-Verlag, 319-327

Cochrane, J. H., 2014, "Toward a run-free financial system," SSRN 2425883

Danezis, G. and S. Meiklejohn, 2015, "Centrally banked cryptocurrencies," arXiv preprint arXiv:1505.06895

Dittmer, K., 2015, "100 percent reserve banking: a critical review of green perspectives," Ecological Economics 109, 9-16

van Dixhoorn, C., 2013, "Full reserve banking: an analysis of four monetary reform plans," Sustainable Finance Lab

Douglas, P. H., I. Fisher, F. D. Graham, E. J. Hamilton, W. I. King, and C. R. Whittlesey, 1939, A program for monetary reform

Dyson, B., and G. Hodgson, 2016, "Digital cash. Why central banks should start issuing electronic money," Positive Money, http://bit.ly/2Fn26Uf

Fisher, I., 1945, 100% money; designed to keep checking banks 100% liquid; to prevent inflation and deflation; largely to cure or prevent depressions: and to wipe out much of the national debt, City Printing Company

Friedman, M., 1959, A program for monetary stability, Fordham University Press

Fung, B. S., and H. Halaburda, 2016, "Central bank digital currencies: a framework for assessing why and how," Bank of Canada Staff Discussion Paper no. 22

Garcia, V. F., V. F. Cibils, and R. Maino, 2004, "Remedy for banking crises: what Chicago and Islam have in common," Islamic Economic Studies 11:2, 1-22

Garratt, R., A. Martin, J. McAndrews, and E. Nosal, 2015, "Segregated balance accounts," Federal Reserve Bank of New York, Staff Report no. 730

Gorton, G., and G. Pennacchi, 1993, "Money market funds and finance companies: are they the banks of the future?" in Structural change in banking, Irwin Publishing

Hardjono, T., and E. Maler (eds.), 2018, Report from the Blockchain and Smart Contracts Discussion Group to the Kantara Initiative, Kantara Initiative

Hardjono, T., D. Shrier, and A. Pentland, 2016, "TRUST:: DATA: a new framework for identity and data sharing," Visionary Future LLC.

Hart, A. G., 1935, "The "Chicago Plan" of banking reform: a proposal for making monetary management effective in the United States," Review of Economic Studies 2:2, 104-116

He, M. D., M. R. B. Leckow, M. V. Haksar, M. T. M. Griffoli, N. Jenkinson, M. M. Kashima, T. Khiaonarong, M. C. Rochon, and H. Tourpe, 2017, "Fintech and financial services: initial considerations," International Monetary Fund

Huber, J., and J. Robertson, 2000, Creating new money: a monetary reform for the information age, New Economics Foundation

Kay, J., 2010, "Should we have narrow banking," London School of Economics

Knight, F., G. Cox, A. Director, P. Douglas, A. Hart, L. Mints, H. Schultz, and H. Simons, 1933, Memorandum on banking reform, Franklin D. Roosevelt Presidential Library, President's Personal File, 431

Kobayakawa, S., and H. Nakamura, 2000, "A theoretical analysis of narrow banking proposals," Monetary and Economic Studies 18:1, 105-118

Koning, J., 2016, "Fedcoin: a central bank-issued cryptocurrency," R3 Report 15

Kotlikoff, L. J., 2010, Jimmy Stewart is dead: ending the world's ongoing financial plague with limited purpose banking, John Wiley & Sons

Lamport, L., R. Shostak, and M. Pease, 1982, "The Byzantine generals problem," ACM Transactions on Programming Languages and Systems (TOPLAS) 4:3, 382-401

Lipton, A., 2016a, "Banks must embrace their digital destiny," Risk Magazine 29, 8

Lipton, A., 2016b, "The decline of the cash empire," Risk Magazine 29, 53-53

Lipton, A., T. Hardjono, and A. Pentland, 2018, "Digital trade coin (DTC): towards a more stable digital currency," Submitted for publication

Lipton, A., and A. Pentland, 2018, "Breaking the bank," Scientific American 318:1, 26-31

Lipton, A., D. Shrier, and A. Pentland, 2016, "Digital banking manifesto: the end of banks?" Massachusetts Institute of Technology

Litan, R. E., 1987, What should banks do? Brookings Inst Press

Mersch, Y., 2017, "Digital base money: an assessment from the ECB's perspective," Speech at the Farewell ceremony for Pentti Hakkarainen, Deputy Governor of Suomen Pankki--Finlands Bank, Helsinki

Micali, S., 2016, "ALGORAND: the efficient and democratic ledger," arXiv preprint arXiv:1607.01341

Miles, W., 2001, "Can narrow banking provide a substitute for depository intermediaries?" Department of Economics, Wichita State University, 30

McMillan, J., 2015, The end of banking: money, credit, and the digital revolution, BookBaby

Nakamoto, S., 2008, Bitcoin: a peer-to-peer electronic cash system

NarrowBanking, www.narrowbanking.org

Norman, B., R. Shaw, and G. Speight, 2011, "The history of interbank settlement arrangements: exploring central banks' role in the payment system," Bank of England Working Paper No. 412

Pennacchi, G., 2012, "Narrow banking," Annual Review of Financial Economics 4:1, 141-159

Phillips, R. J., 1996, "The `Chicago Plan' and new deal banking reform," in Stability in the financial system, Palgrave Macmillan

Phillips, R. J., and A. Roselli, 2011, "How to avoid the next taxpayer bailout of the financial system: the narrow banking proposal," in Financial market regulation, Springer

Powell, J., 2017, "Innovation, technology, and the payments system," Speech: blockchain: the future of finance and capital markets

Roberds, W., and F. R. Velde, 2014, Early public banks

Rogoff, K., 2016, The curse of cash, Princeton

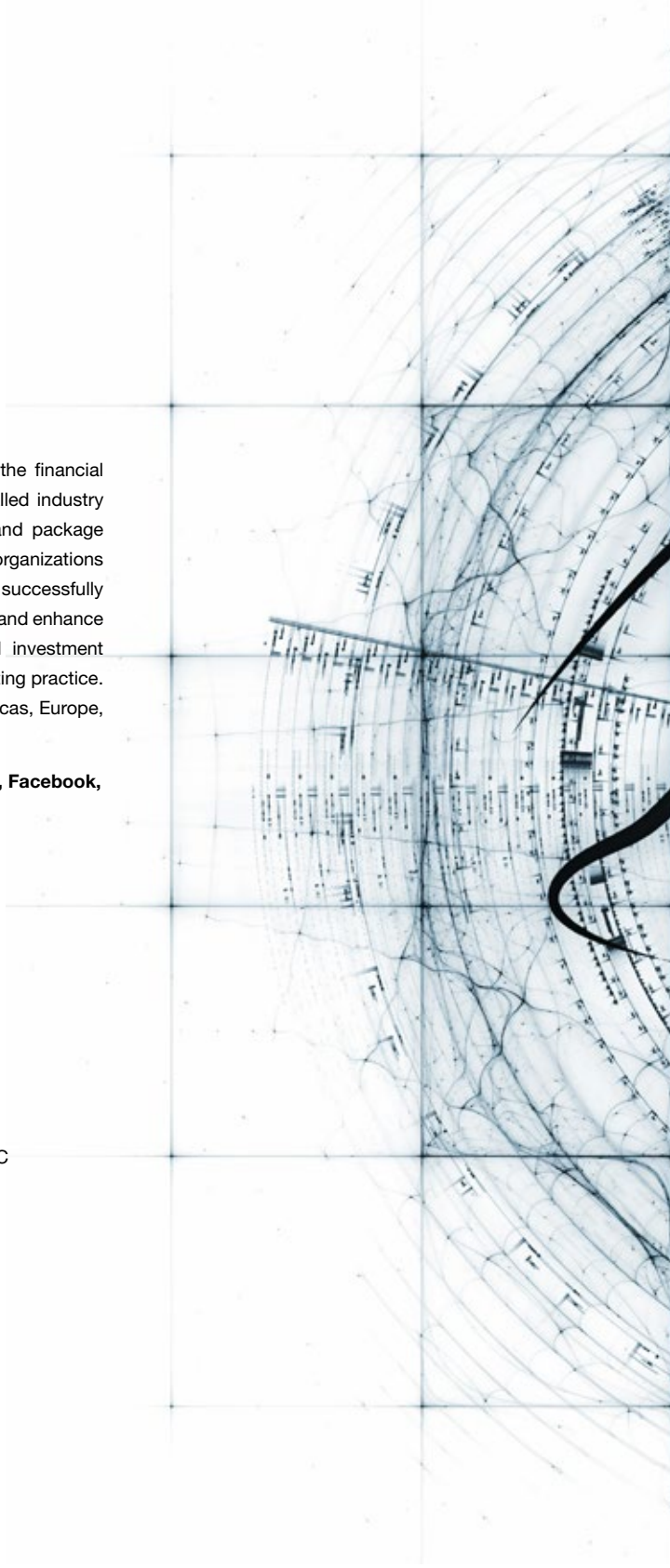
Schwartz, D., N. Youngs, and A. Britto, 2014, "The Ripple protocol consensus algorithm," Ripple Labs Inc white paper, 5

Scorer, S., 2017, "Central bank digital currency: DLT or not DLT? That is the question." BankUnderground http://bit.ly/2FiUV3n

Soddy, F., 1926, Wealth, virtual wealth, and debt, 2nd American Edition, 1933, E.P. Dutton

Soddy, F., 1933), Money versus man, Dutton

Tobin, J., 1986, "Financial innovation and deregulation in perspective," Cowles Foundation for Research in Economics, Yale University



ABOUT CAPCO

Capco is a global technology and management consultancy dedicated to the financial services industry. Our professionals combine innovative thinking with unrivalled industry knowledge to offer our clients consulting expertise, complex technology and package integration, transformation delivery, and managed services, to move their organizations forward. Through our collaborative and efficient approach, we help our clients successfully innovate, increase revenue, manage risk and regulatory change, reduce costs, and enhance controls. We specialize primarily in banking, capital markets, wealth and investment management, and finance, risk & compliance. We also have an energy consulting practice. We serve our clients from offices in leading financial centers across the Americas, Europe, and Asia Pacific.

To learn more, visit our web site at **www.capco.com, or follow us on Twitter, Facebook, YouTube, LinkedIn and Xing.**

WORLDWIDE OFFICES

Bangalore
Bangkok
Bratislava
Brussels
Charlotte
Chicago
Dallas
Dusseldorf
Edinburgh
Frankfurt
Geneva
Hong Kong
Houston
Kuala Lumpur
London
New York
Orlando
Paris
Pune
São Paulo
Singapore
Stockholm
Toronto
Vienna
Warsaw
Washington, DC
Zurich

CAPCO.COM

CAPCO