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Chapter 1: The evolution of modern finance: From legacy systems to data-driven ecosystems

1.1 Introduction

Technological evolution has played an important role in the development of finance for thousands of years. The emergence of Pax Romana and the use of paper money in ancient Chinese civilizations, the efficiency provided by double-entry accounting and its circumvention in the Medici administration, the point-to-point telegraph system that conveyed the first commercial messages, and the advent of securitization to finance the construction of the Atlantic Cable during the British Financial Revolution all played a part in history from the bottom up. Once upon a time, we started creating legacy systems. Over time, these systems were orchestrated and synergized into modern financial markets. The broad principles underlying their behavior, rewards, and flaws are now well understood. Such is not the case for the data-driven ecosystem evolving within a new paradigm based on big data. Data overtakes transaction data as the locus of market value. Data per se, and through their ownership and manipulation, exert strong governance over value-maximizing suits and the associated composition of financial conglomerates (Arner et al., 2016; Gomber et al., 2018; Chen et al., 2019).

This chapter systematizes the known economics about the use of data in finance, as well as some prerequisite technical knowledge. Because data-driven finance was also evolving quite quickly, this may not be a complete survey. Our focus remains on the economic forces that are shaping the data-driven financial markets, products, and the platform industry that caters to them.

1.1.1. Overview of Financial Evolution: Key Concepts and Themes

Modern finance has evolved around a number of fundamental guiding forces and themes, most notably market completeness, price discovery, and information assimilation, the role of intermediaries, regulatory and legal innovations, limits to arbitrage and cost of capital, agency-related frictions, and centralized versus decentralized market organization. In this chapter, we present a synopsis, then characterize how they have evolved over the preceding generations of financial development, while also identifying key mechanisms that have underpinned these themes. Our principal focus here is to articulate and explore the set of underlying principles and mechanisms that have agents evolve from decentralized, localized, discrete, low-dimensional data-generating entities to highly interconnected, massive-scale data-driven market participants associated with near complete information flows, granular data-rich environments characterized by intertemporal complements and connections between assets and products, and enabled by continuous, low-to-zero-cost technology-enabled information flows, communication channels, and high-speed decision-making and execution technologies. In doing so, we also point to evidence of the impact of the ongoing financial data and technology revolution on incomplete, persistent heterogeneities in information access and market intermediation, market quality and dynamics, and market-wide vulnerabilities that have emerged in recent years (Zavolokina et al., 2016; Philippon, 2019).

1.2. Historical Overview of Financial Systems

Early forms of trading and borrowing date back thousands of years B.C.; however, it was not until around the year 3,000 B.C. and the invention of the written word that concrete terms or transactions and the first records of a financial system began to appear. By then, taxations ensued when governments interfered with finances related to structured public spending, including infrastructure, defense, diplomacy, and the establishment of empire states, which marked the significant date of conducting and architecting the first financial systems. Mesopotamia, a historical region situated between the Tigris and Euphrates rivers in present-day Iraq, is considered the cradle of the first geographical empire states. It was here, as well as over 12,000 years B.C. in the Jordan Rift Valley, that some of the first examples of an organized functioning city-state-like society, with specialized craft grouping, social stratification, authoritative administration, and religious conglomeration, were established.

The next financial evolutionary advancements occurred in Ancient Egypt and Rome, where long-distance trade and financing systems based on physical and personalized transactions, recorded on papyrus, facilitated business transactions in the first millennium B.C. It was the Egyptians, in particular, who created the first type of banking and developed various ways to make financial transactions, including the use of

marketable seeds instead of direct exchange. The use of a piece of gold as a trading method, which has a fixed value set by the government, is also an Egyptian contribution. With the arrival of trade and banking in Greece, the emergence of financial production and specialized trade started to become noticed and recognized. With the Greeks, as well as in the Roman and later European empires, the idea of an economic entity completely detached from a person or physical role became common and widely accepted in the trading field.

1.2.1. Early Financial Practices

Early financial practices were concerned with real capital and trade in goods. Merchants and traders who saw opportunities to invest in long voyages or complex projects did not possess enough capital individually to undertake these safely. Temporary partnerships to cover specific events distributed the risks and the gains of each undertaking. Fragmentary records of these partnerships have been discovered, for instance, in Babylon, where a transaction dating from about 2400 BC is the oldest proof of a financial operation. The difference between a wise trader and a simple partner is the benefit that the first one receives for making good, risk-taking decisions. These ventures took place under the umbrella of the Babylonian temples, possessing a legal monopoly for trade within the Mesopotamia area, with the clout to replace, in some transactions, the important lack of long-term trustworthy instruments. Other described financial transactions took place in Mesopotamia in the second millennium BC; both classical and neoclassical economists cited them as an example of money in the ancient economy.

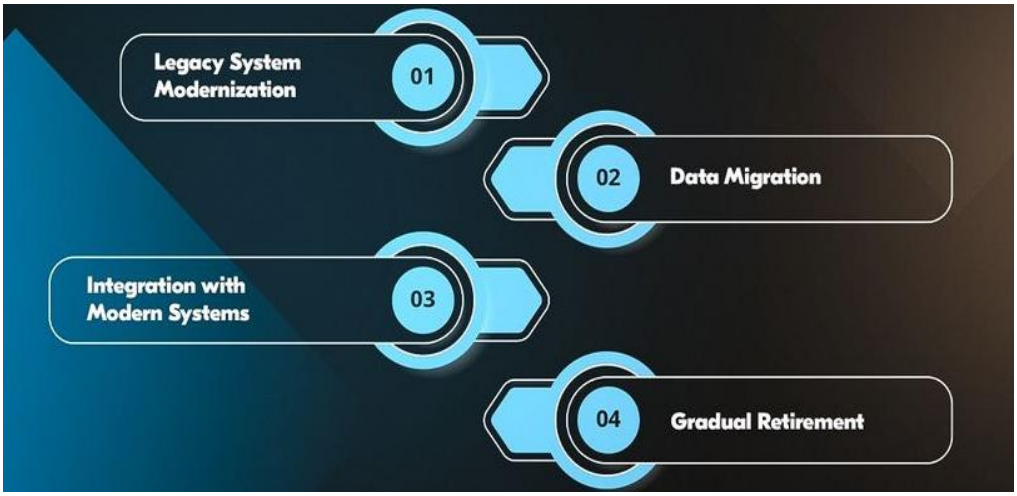

Fig 1 . 1 : Legacy Systems

A small island on the coast of present-day Lebanon was the center of a trade of high-value commodities like tin, silver, and other items of ancient life, primarily with Egypt.

The city of Ugarit received oil and clothing in return, and the governor of the city financed its overseas trading activities involving regular risks but high payoffs. The records of these trade activities date back to 1335 BC, mainly on cuneiform tablets similar to the tablets discovered in Mesopotamia. These reports deal with a hazard class representing the geographical risks of trading, apparently based on a tariff system, indicating a financial strategy deriving from technical and administrative risk management of the business. Eventually, the island's profits turned it into one of the most luxurious centers in the eastern basin of the Mediterranean, influencing, as an entrepreneurial center, the neighboring territories. This percentage comes from the creation of the first examples of unified security assets whose success and wide distribution should have been strictly linked to the monks' ability in managing and mitigating trading risks.

1.2.2. The Rise of Banking Institutions

The period from the fifth to the 15th century, during which banking practices in Italy and then other communities were developing, was largely driven by the religious prohibition on the act of usury. There was a demand for financial solutions, though the use of a bank, though not often called so, allowed the disputable transfer of the title of a property to a trusted friend who, from the moment that he could claim other interests belonging to the same property, less the ones related to personal profit; with these characteristics, he could legally return what should have been an usurious interest. The modern appearance of banking institutions started with the notion of negotiable instruments, with the possibility of banking institutions to issue and circulate their own notes recognized as valuable deposits within the bank and the possibility to be cashed by anyone, giving birth to the concept of money creation, a key pillar of modern banking. The rise of the transformative powers of banking institutions started at the end of the 16th century, during the age of the Renaissance. The first condition for the increase of the transformative role of banks is the economic environment characterized by some structural characteristics which are the intertwined existence of consumer, commercial, and productive macro-segments for which loans are requested, the introduction of negotiable instruments, that is, the instruments that with today's knowledge we could call securities, but that at that time represented equity investments in a company, the necessity to avoid a direct investment in commercial companies during the development phase of international trade, the need to have an instrument furnished by a trusted intermediary that could facilitate operations such as trade transactions, and the possibility to have at disposal a trustworthy counterpart who could accept and guarantee payment obligations and could recognize temporary funds.

1.2.3. The Development of Stock Markets

As early as the 12th century, stock markets began forming in centers such as Bruges, Frankfurt, and Verona. Italian city-states such as Venice, Florence, and Genoa became leading financial centers in the 13th century. An important early market was the Merceria dei Cambi in Florence, established in the 13th century, which was followed by similar markets in Bologna and Naples. The central building of the stock exchange in Paris serves as the financial center of Paris and of trading in the shares of French companies. It forms the Paris Bourse, now part of Euronext together with Amsterdam, Lisbon, and Brussels. In 1397, seven Venetian merchants caught running a state bank could tell the court in their defense that they had already spent the shares in a matter of days to meet the demands of those whose money had been deposited with them. In 1602, the Dutch East India Company issued the first shares that were made tradable on the Amsterdam Stock Exchange, an invention that enhanced the ability of joint-stock companies to attract capital from investors as they now easily could dispose of their shares.

The start of stock trading in Germany was followed quickly by the founding of stock exchanges in Frankfurt am Main in 1585 and Hamburg in 1558. Both of these stock exchanges existed as intermediaries for stock trading, and this phenomenon was soon also contradicted in Asia by the founding of the smaller, yet still opportune, Hong Kong Stock Exchange. The notion of capital flows being an inherently plausible explanation for the rise and ebb of stock markets in European history is further confirmed. The role of financial markets as a result of external growth and the implementation of new techniques is not only empirically supported by historical data, but it also is a rather central trend during the growth periods from the 5th up to the 6th century. The end of stock market trading in an area is more commonly caused by historical forces, such as warfare or political instability, than by purely economic downturns, and the closure of trading in a certain area does not have to coincide with a downturn.

1.3. Legacy Financial Systems

Unquestionably, there were financial systems in the past, but what does 'legacy' mean? And how does that differ from or get in the way of becoming modern financial systems? Indeed, some would argue that many current financial systems are pretty modern now, with sophisticated pricing mechanisms and new bells and whistles coming off the assembly line continuously. Or are we describing dinosaurs, unable to cope with the seismic shifts of today's new technologies and burgeoning demand for new financial services? Typically, a 'legacy' is defined as something that is handed down from an ancestor or predecessor and is complicated by most modern definitions that add 'computer' to the term with associated implications of backward compatibility and adaptability to new uses. Unfortunately, the word is not a compliment in this context and

constitutes the first clue as to why finance is different from so many other industries, where roots are prized, and everything new can be found growing from old stock.

The answer is that these financial systems are legacy only in the sense that they are handed down from earlier in our history, typically of the 1970s and 1980s, and are the failing descendants of ever-more ingenious efforts to deal with the challenges of their time. They are designed, deployed, and operated to test their mettle against the specific problems they were chosen to address and for which they were built. Times have changed. The problems are familiar, but the context and scale are greatly enlarged with direct and immediate relevance for the way that states must operate in their own best interests. The financial systems that were straw in the 20th century are now expected to spin gold in the 21st. They are not up to the task; they are smothered with layers of highly complex infrastructure, redundancy, and regulation and, as a result, provide poor returns on investment with limited transparency, resilience, or efficiency. This is the sense in which I refer to 'legacy' financial systems.

1.3.1. Characteristics of Legacy Systems

The evolution of our financial infrastructure over the past 600 years resulted in a phenomenal improvement in the availability, variety, and economic performance of financial assets and services. However, this evolution also resulted in an intricate web of strongly interconnected infrastructural components that operate under rules that are equally intricate and virtually impossible to modify, as any modification requires excessive resources and effort. A result of this richly interconnected web of business processes, supported by complex data structures and systems that underpin these processes, is the prevalent difficulty in creating transparency in the infrastructure. Making fundamental, or even small, changes in the infrastructure is essentially impossible as that would break too many existing processes and introduce too many consistency problems. An even more limiting characteristic is the essentially batch nature that results from this rich interconnectedness. The financial services industry is unable to provide business data in real time because it would require all underlying infrastructure processes to be real-time as well. Unfortunately, legacy systems have no concept of real time. Companies are forced to make do with real-time windows into their batch world. A simpler description of the lack of real time is the constant need for reconciliation. Finally, the large number of intermediaries in the financial services industry leads to the situation where moving money remains difficult and expensive. Banking services are unequal and unaffordable. Decades of regulation and compliance have made it the industry’s worst nightmare to provide service to the financially excluded, preferring to focus on the customer again and again to protect one from harming oneself when one performs any action that any reasonable person could think

is perfectly harmless. In the past 600 years, the financial services industry has undergone a number of fundamental transformations: from the basic foundation in the form of double-entry based accounting, ledgers, and written contracts of the first 400 years, through the large-scale securitization of loans and treaties in the form of bonds in the 16th and 17th centuries, to the invention of actively tradable equity and insurance in the 18th and 19th centuries, and the development of bank-based issuance of actively tradable obligations and liabilities we are experiencing in its final form today. However, we are now confronted with a disconnected, batch-oriented, anachronistic infrastructure that is obscenely expensive to maintain and very hard to adapt to new realities. For four centuries we have lived in the Information Age that literally changed how we live and think; however, the financial services infrastructure of the past four centuries is essentially the infrastructure of the Statute of Anne, which introduced the concept of copyright for the first time, and the Statute of Anne's famous cousin, the South Sea Company Act, which created a stock that was actively traded for more than £1,000 back in 1720. We are in the paradoxical situation that at the start of the Data Age, the financial services industry is a disconnected, batch-export driven, data-oblivious industry littered with regulation and compliance that stymie innovation and maintain the status quo.

1.3.2. Challenges Faced by Legacy Systems

Legacy systems in finance struggle with fragmented data, causing manual reconciliations, data privacy, and security. Legacy back office systems, serving as cost centers for financial institutions, struggle to support sophisticated operational functions. They were designed to cope with a daytime-based transactional load typically. Often, month-end batch processes, Q&A support, and other offline activities take secondary importance to support the 24/7 business week demands. Integration with other systems is typically performed via manual steps that cause human error and produce untimely results. In this offline step, a dedicated team may perform many time-consuming manual reconciliations based on file transfers and data mappings, compare numbers and percentages, perform calculations, and verify that the data differences between the receiving Q&A system reconciles to the sending system. On occasion, data files may be misplaced or lost, resulting in tens, if not hundreds, of email exchanges or phone calls to troubleshoot these issues. In addition to these existing problems, financial institutions need to transact and validate trades in a more timely manner to achieve operational excellence.

While some financial institutions have been able to cope with both these existing problems and also gain an advantage in acquiring the best trades, technology has not been able to help fix the actual cause of the issues that plague the reconciliation process. Inefficient message processing and messaging formats that do not support new

information types and standards introduced by industry partners with international systems are causing sensitive and notion data bans to arrive in disparate formats, making it difficult to determine that equivalent terms have the relation, aggregation, or hedge the risk of an associated main trade. Functions often resident in proprietary client-server software systems that may reside in the financial services organization or at an intermediary's office serve only to add additional points of operational risk, breakage, and delay. Political limitations set forth by both the various domestic and international settlement guidelines prevent the change that is necessary to allow everyone to operate on similar platforms and take full advantage of the powerful technology infrastructure that runs the financial services operation.

1.3.3. Case Studies of Legacy Systems in Finance

Not all legacy systems in finance mean algorithmically driven systems from the 1970s and 1980s. At present, the inherent structure of financial systems at banks, regulators, exchanges, and trading venues is to a certain degree under public pressure to rapidly upgrade their data collection and computing technologies. These systems have been plagued by manual work, lack of available data sets on market conditions, and increasing scale of levels relevant for the speedup in decision-making and supervision. In what follows, we outline three examples of legacy systems in finance, provide an overview of issues associated, and suggest relevant modern solutions. Our purpose is not to dismiss a legacy approach to finance, but crucially, to highlight that machine learning and big data problems found in finance will likely be a focus in the future. As for the case of Internet firms and customer relationship management firms, a shift to such systems can lead to further productivity growth. One can expect that an active search for legacy interaction with modern machine learning methods will be a productive outcome that many firms involved in finance will seek to address or to gain from.

1.4. The Advent of Technology in Finance

Technological innovation has been a fixture in the financial industry for centuries. From the introduction of the Banker's Clearing House in 1775, which helped facilitate the exchange of checks among 52 major banks in London, to the creation of the first automated teller machine in 1967, financial technology has rapidly evolved to create faster, more efficient, and productive experiences for all participants in the financial ecosystem. Post-World War II saw the rise of mainframe technology in business accounting and large-scale mainframe computers. The advent and success of such a rudimentary precursor to computing allowed various applications back into finance, including statistical and financial analysis, portfolio theory, and the pricing of options

and other financial tools that are precursors to the concept of automated financial analysis and insight creation. The early 1970s also saw the emergence of two tools we take for granted today in finance: the Bloomberg Terminal and the Nasdaq share trading platform.

Rapidly advancing technology has allowed us to make inroads in five primary categories: Trading and execution, Data management, Risk analysis, Regulatory reporting, Client interaction and ready access to information.

It is interesting to note that with each jump in processing power and each new technology, new business models or 'disruptors' have emerged and changed the competitive dynamic in the marketplace, and nowhere has this been more pronounced than the immediate feedback loop or signal of a mispricing in financial assets, which in one extreme can lead to massive dislocation and breakdowns in the financial ecosystem.

1.4.1. Introduction of Computers

The introduction of computers in the finance industry has significantly changed the way investment management is conducted. As the costs of computation progressively decreased, people have been able to generate and process an increasing amount of data. Computers permit abstract models to be run that are not solvable by pen and paper due to their length and complexity, and have also permitted entirely new models to be developed. As a consequence, a wealth of new investment strategies utilizing information that was either too expensive or too slow to process before has been able to develop. More fundamentally, the type of information used for investment decisions has also shifted. The first generation of quantitative models relied on a labor-intensive process of data entry from paper copies of the fundamental financial reports. Communications with brokers went by mail or phone.

Rapid computing has, in essence, provided us with two things: models that help us reflect information manipulation that lies beyond human learning or evolution, and models that have been informed with a genuinely more diverse and larger set of information. Neither of these developments could have been achieved without rapid progress in efficiency, power, and speed. As a consequence, over the past decades, we have observed a significant increase in model complexity, and a move from information sets that mostly contain a few balance sheet figures and some trading statistics on a daily or weekly frequency to much larger and varied data sets, often containing unstructured information.

1.4.2. Impact of the Internet on Finance

Finance has always benefited from advances in information technology. The development of the printing press enabled wider dissemination of financial information. The telegraph allowed faster communication of market prices. Radio and TV broadcasting accelerated the distribution of financial information. The advent of the Internet significantly changed the financial industry's landscape. It affected the relationship of finance with other services, individuals using finance, investors, corporate finance, the approach to risk, and finance's regulation and control. Particularly, it is transforming modern finance into data-driven ecosystems where finance is intertwined with information technology and an investment's value will increasingly be driven by the investment in technology. This reality is raising new theoretical and practical finance problems that need to be solved. Therefore, advanced technology could be the solution to advanced finance problems. In the long run, the largest trend in finance is the transformation of modern finance into a software system.

Thanks to the Internet, modern finance is becoming increasingly intertwined with technology. It currently operates in ecosystems generally dominated by companies whose core competency is information technology and software systems. Because of this increased monopoly power, these ecosystems can practice higher pricing and suppress the income of those who have contributed to such investments. This reality is causing several problems in the existing financial models. Currently, this power is contributing to creating a few highly visible financial hubs in decreasingly democratic states. Therefore, although the modern Internet-driven financial ecosystem is more competitive, it is also more fragile. It can be disrupted more easily by those who have the power to disrupt it.

1.4.3. Emergence of Fintech Companies

Over the years, quite a few fintech companies have emerged, which are game changers in the areas in which they operate. These companies have developed deep knowledge on how to create super successful fintech ventures, whereas traditional banks, first-hand observers who have seen the impact of technology, still have not been able to exploit its power. There is a lot that startups can teach, not only in terms of insights and use cases, but probably a lot would depend on the innovation deeply embedded in their DNA. The methods blended with technology have helped companies scale up at a pace that was unimaginable probably a decade ago. As these companies start making revenue, it is interesting to observe how the market reacts. Rather than trying to take over the market through cooperation and synergy, many corporate finance companies are attempting to develop similar tech capabilities. The customer base, transaction data, investment, and

technology are an untapped gold mine that has been lying dormant in bank vaults for decades now.

These consumer-facing companies have a competitive edge by diving into this pool of data, picking up the right pieces of information, analyzing them for valuable insights, and benefiting from this in the correct place at the correct time. It would not be wrong to state that banks, being the oldest fintechs, have long relied on machinery and workforce rather than on technology to drive the financial industry into the next generation. Some of these companies are like a deer in the headlights, totally caught off guard when these fintechs literally come and snatch the work that they have been doing with unmatched efficiency and prominence. These companies that know how to couple technology with finance may drive banks out of the market. For developers, relevant programming languages are more important than developing those fancy presentations with grandiose figures and calculations. Along with necessary integrations, technical judgment stands on a coefficient order (priority, relevance). Digging through the brain and algorithm, turning it into a self-sustainable product helps companies a great deal.

1.5. Data-Driven Ecosystems

We believe that the next frontier in modern finance will be the ecosystem level – a completely new vision of finance that has never been possible before with traditional, people-driven organizations. The advantages will be both overwhelming economic gains and lower volatility and systemic risks. To get a glimpse into the future of financial ecosystems, look at the current state leaders of the Trillion Dollar Club. They are very different, but all of them live, learn, evolve, and grow phenomenally in their own ecosystems, with unique and data-rich platforms at the center.

In many ways, we've seen finance ecosystems before, but so far it has just evolved into a quite different complex and not very transparent story. To switch to a different and more promising path, we'll have to achieve progress or breakthroughs when evolving the future ecosystems, rather than just letting them emerge. This is where artificial intelligence and data mining will play a major role. On the other hand, it benefits from the adaptation and "taming" of the exciting developments in quantum computing that promise mind-boggling new levels of computing power.

1.5.1. Definition and Characteristics

A financial ecosystem is an economic community supported by a foundation of interacting organizations and individuals. The organisms live, work, and thrive within the support system and maintain a dynamic equilibrium within the environment. A

financial ecosystem is composed of the "social organization" of the financial industry, including governing rules, public institutions, soft institutions, educational entities, professional associations, and companies, and an "economic organization" which is formed by market mechanisms, establishment, intermediation, integration, and risk management. Security, liquidity, profit, access, and cost are critical assessment factors for these two different organizational dimensions of a financial ecosystem.

The aggregate economic landscape and corporate profiles are not only a direct reflection of the development of the financial ecosystem but also the object of its optimizations. Core financial functions and payout rules are reliable features of a financial ecosystem. Market transaction activities such as trading, price discovery, and investment decisions are conducted through financial instruments, regulated by market rules, and recognized by traders. Securities exchanges, trading systems, OTC platforms, and regulatory compliance organizations are essential components—financial intermediaries that reduce information asymmetry and transaction costs, provide states of risk sharing, offer insurance and credit spread functions, and supervise credit intermediation mechanisms. The settlement and clearing systems effectively manage the payments and receipts of funds and securities and ensure the safety and integrity of financial markets. Information, feedback, management, and data services have a significant impact on the decisions of financial institutions, managers, financial regulators, and academic investors.

1.5.2. Key Technologies Enabling Data-Driven Finance

Recent advances in AI have been driven by the combination of three key factors: algorithmic techniques supporting the representation of input data, the optimization of adjustable parameters during testing, and a range of differentiable activation functions ensuring the reduction of prediction error in a selected loss function. We broadly refer to this machinery as a neural network. Deep learning, a concept often regarded as a subfield of machine learning, is essentially an implementation of these key factors in a multilayer version of a neural network. In finance, many pioneering applications of machine and deep learning techniques have occurred in startups. In academia, researchers have demonstrated the predictive power of news sentiment, as well as of established social media platforms, in identifying market and economic dislocations.

The fundamental disadvantage of traditional asset pricing, comparing the value of the asset with a discounted stream of cash flows, is that this information is expensive to produce in the first place and is itself unobservable, so it must be estimated using models with uncertain parameters. The use of machine learning can help mitigate this as a complement or a substitute for some of these issues by confronting additional and broader data sources with no structural assumptions and having many flexible parameters that deliver superior estimates for the underlying component risks. These

advantages mean that machine learning techniques, particularly in conjunction with large datasets and broad sets of economic observations, can provide more accurate value estimates.

Fig 1 . 2 : Technologies Enabling Data-Driven Finance

1.5.3. Benefits of Data-Driven Approaches

What are the exact benefits of data-driven approaches, which are the core of smart finance? First, data-driven approaches are instrumental in enhancing the performance of economic activities. By increasing the information available to economic agents, such practices improve the decision-making process and achieve better results. With smarter finance, it will be possible to take advantage of more and better economic opportunities, boost the rate of growth of GDP, and raise living standards. Information-induced improvements in decision-making procedures foster more efficient capital allocation as errors and waste in capital assignment and use are reduced. In addition, reducing the dependence of agents on complex mechanisms anchored in legal and physical realms helps to overcome structural rigidities and empowers agents to better manage the need for speed inherent in knowledge-based production processes. Whenever smarter finance is involved, greater transfer and sharing of information in the marketplace is established.

A second reason for welcoming data-driven ecosystems is that they can reduce fragilities and instabilities associated with the legacy components of modern finance. A major source of vulnerabilities concentration is the role of financial institutions, which tends to concentrate resources and risks, and thus pose challenges to effective risk management systems. Such concentrations were previously justified in the name of economies of

scale and scope, which have traditionally led to operational cost reductions. However, newly developed data informatics technologies have now made such diversifications and managerial cost reductions possible without the necessary concentration of resources in the traditional financial service providers. As a result, if properly designed, data mining and data sharing activities can help fragile economies to achieve institutional microfoundations commensurate with the fast and highly volatile dynamics driven by data and knowledge-intensive activities.

1.6. Regulatory Changes and Their Impact

Regulators are also turning their attention to the potential of an evolved ecosystem. This area has until now seen limited focus by regulators, relative to the drivers of technology, investment, and innovation. Substantial policy work and potential regulatory intervention are called for. Much of the financial services industry has traditionally been highly regulated to protect public interests, such as systemic stability, consumer protection, and market integrity. The long history and complexity of regulation in finance have created vestigial elements that are hard to justify and differentiate from evolutionary path dependence.

Advances in technology, changes in commercial models, development of new data sources, and new techniques have resulted in a perception that regulatory objectives are being met incorrectly, inefficiently, and inequitably relative to a changed technological base and competitive landscape. This is likely to require some fundamental discussions of regulatory philosophy and incentivization. A significant degree of introspection will be needed. While the complexity and difficulty of these tasks should not be underestimated, the benefits of creating a coherent, data-aware ecosystem are significant, since there exists a virtuous circle between data and regulatory oversight. This coupled policy and industry work will be needed to enhance public welfare.

1.6.1. Overview of Financial Regulations

The modus operandi for financial regulations is reactive. Whenever there is a failure or fraud, it generally leads to the imposition of new rules and regulations on the markets to prevent any such occurrence in the future. Most regulations are aimed at creating mechanisms to impose transparency on one part of the system or the other. These are generally created as means to support the primary values underlying the market. For example, the requirement to disclose information is a means to ensure fair trading. Maintaining the capital adequacy ratio is a requirement to ensure the solvency of a bank. Similarly, institutions are subjected to governance and conduct norms as a part of building trust.

Regulation is increasingly aimed at bringing the digital ecosystems under its purview through concepts like data protection, digital privacy, and the right to be forgotten. This has implications for the nature of the system being modeled, the entities claiming ownership of the data, and also the party applying data stewardship. The initial focus of these legislations was on business-to-customer transactions. With the introduction of AI, namely knowledge graphs, cognitive computing, robotics, and learning systems to support automation and autonomous action in financial services, it is critical that related technology 'trustworthiness' will need to move from advisory to mandatory.

1.6.2. Adapting to New Technologies

In order to stay relevant and maintain their mission, financial institutions need to adapt to and maximize the benefits of new technologies. Ensuring that their technology infrastructure remains state-of-the-art is critical to developing next-generation products and services, implementing evolving industry standards, and meeting the demands of an increasingly sophisticated and demanding customer base, which has come to expect real-time, secure, and non-stop access to information. This is particularly true for transactional business applications and trading floors, manned today by smart machines making decisions that do not directly require human interaction. Leveraging lessons learned from the field of high-performance computing, financial institutions will have to continuously redesign and upgrade their technical architecture using the latest digital enabling tools. One important trend will be the transformation of large monolithic applications into distributed modular pieces extending outside organizational boundaries. Flexibility will come through standardization, embracing industry security and technological standards, growth in the usage of specialized computing banks for data analytics and artificial intelligence, exploitation of metadata for building agile, reusable high-order-based architectures, and adoption of modern, agile development methodologies. Internal systems will evolve rapidly into a hybrid of cloud/private cloud/tailored models, and full integration will have to be based on secure and validated technologies. As the importance of mastering data becomes a key point of strategic advantage in the emerging digital economy, we believe that internal IT will also evolve and change, following the integration pattern that is now transforming the physical and financial infrastructure of the whole industry.

1.6.3. Future Regulatory Trends

We will finally examine how financial regulation might develop in the light of financial services inclusion in platform strategies. As strategies evolve, favoring a better understanding of consumers and the workforce, compliance with directives becomes de

facto. Large internet retailers might, in light of their pledge to improve consumer experience, risk buying a distressed financial institution to secure a banking license and serve their consumers better, thus addressing the lack of generational saving with the kind of understanding and customer focus they bring to their main business.

One key tenet of the directives is the objective to turn ill-informed and disenfranchised consumers into informed professional investors, capable of asking for better investment outcomes and privatized shareholdings throughout the rest of the economy to support generational saving and adequate retirement income distribution. The commission again fails to engage with the market conditions that deter most of the non-bank data monopolies from taking part in this pan-European work. National discount brokerage markets are thin in part because they are eminently replicable by national champions, extending their reach from their national franchise and actively marketing to consumers. Taken from the perspective of the agglomeration of platform capabilities in large data monopolies and forming part of a broader web idiosyncrasy, the buying intent behind mergers and business diversification reasons rhetorically put forward suddenly sounds more plausible.

1.7. Case Studies of Modern Financial Institutions

To illustrate how far modern financial institutions have come in terms of the deployment of technology and, consequently, value creation for their clients, we review two cases in some detail. Both are examples of the second-generation investment process mentioned earlier and based their development on the creation of large proprietary data sets. In both cases, it was initially outsiders, or those within the firm with a background outside of finance, who had their Eureka moment. We note that both examples stand out as good management for the time at which they were established.

Given that this chapter tracks the revolution in technology that has occurred over the last 35 years, these firms point the way ahead. They were the tall trees that reforested investment thinking from essentially European roots over 200 years older. They and many of their competitors have survived and developed, while the high scientific value-added processing managers who had been in the vanguard of processing management have been either cut down by the logical difficulties to further scientific development or visited by the tycoon equivalent of death by a thousand cuts.

1.7.1. Success Stories in Data-Driven Finance

The successes of data-driven finance tend to come from within the modern business realm and related support services because here data and modern computational

capabilities are abundant. We now point out specific examples. As precedence behaviors by accessible for-stake of KDRSs, we discussed mobile phones, credit cards, online broker technologies, search engines, clinical databases, and superstores. From just these examples, it is apparent that most of the major technical and organizational changes called for by data-driven finance are here.

First, for-stake business enterprises urgently demand rich data in rapid feedback loops for decision making. Collecting big clinical data, for example, in a proprietary superstore, although representing a complicated technical innovation challenge involving cutting-edge decision science methodologies, can produce enormous organizational benefits because teams of just-in-time statistical decision analysts can be brought effectively to bear on customer needs. Of all individual industries, credit card companies have shown the longest, most determined, and most dynamic systems commitment to big data analytics with major successes not only in introducing statistical decision science into their internal decision making for rapid response, which can suggest good general business practice, but also selling a wide variety of mostly successful added-value services based on their statistical big data and machine learning decision science experience. Their decades of experimentation, production experience under fire, and accompanying statistical decision science track and test retrospective data provide them with distinctive business process advantages. These advantages appear competitive with other firms in different industries that have comparable, similarly long histories.

1.7.2. Lessons from Failed Implementations

Having discussed both technology and incentive-backed visions of alternative end states of the evolution of a modern trade processing infrastructure, we come to a brief discussion of how technology and incentives interact to influence success. For the infrastructure segment, what distinguishes successful implementations from failures? What lessons should electronic trading system implementation derive from both successful failures and early successes? This is relatively easy to answer for the technology. Except for the newest infant-class technologies, technology shortfalls that lead to failures have been studied in most cases and usually involve topics like system design management, systems integration, and project management. More problematic are the issues of institutional shortfalls that lead to failures.

The institutional issues that have been dissected are numerous. Often cited are difficulties in addressing and reconciling differing goals, requirements, and expectations implicit in system pre-profiling, selection, implementation, and post-implementation; stakeholders who do not or cannot understand the role and importance of IT; stakeholders who do not or cannot define their requirements and concerns about IT and

the organization; and a communication problem among different stakeholders or between management and IT staff. The sense of institutional barriers imposed by legacy systems, as described by stakeholders, suggests other institutional barriers. While the literature is less well developed specifically for large financial systems infrastructures, the time is probably ripe for such a dissection. Needed, then, is not simply research but the collection of experiences with failed and partially successful implementations, as well as successful ones. Success stories too often remain shrouded in trade secrecy. Establishing and applying tests of success is essential.

1.8. The Role of Artificial Intelligence and Machine Learning

We have discussed in some detail the evolution of modern finance from archaic, antiquated systems developed in the past into current offerings. We have also briefly touched upon the current state of the art in the banking sector – with the advent of chatbots and robo-advisors. This evolution is not happening at all levels of granularity and sophistication within organizations that are functional to the proper functioning of fully digital banks. Anti-money laundering or Know Your Customer systems, for example, still rely on traditional statistical methods and, in some cases, simple AI engines. Hence, not only is there a gap between chatbots and the branch level, but there is also a gap within the silos of the banking systems.

With the growing amount of data generated every minute worldwide, and the faster and more powerful algorithms and computing resources we have at our disposal, both banks and regulators need to correctly interpret the vast amount of information at their disposal in order to make decisions. We are slowly advancing into the era of machine learning, where the decision-making process is delegated to a neural network or big data. The big question here is – who will be responsible once things go wrong? Some of the simpler conference scoring models employ deep neural networks that, on occasion, produce fairly bizarre results. Although DNNs are considered superior in dealing with unstructured data, overly parameterized models might suffer from a loss of interpretability, and CDS scoring is based on the minimum amount of information to allow the assignment of risk for bond default. The concern arises when those scores are used in one composite score – how to defend the company or the rating agency if errors are reported from an AI model rather than a more traditional econometric model? On top of this, the learning part relies on existing data that may have negative repercussions in the future: if the model suggests that lending to Sub-Saharan African countries is profitable due to the data employed that does not capture the upcoming escalation of social conflicts in the area, would the AI be in question?

1.8.1. AI in Risk Management

Artificial intelligence and alternative data are already changing the landscape of modern risk management, which has traditionally lagged behind other finance areas such as trading in technology adoption. In the first phase of embracing AI, risk practitioners are using the technology to better estimate fundamental investment risk, core to the risk premium paradigm. Using traditional factors such as credit and equity, as well as novel ones like oil volatility and ESG, AI systems are expected to improve traditional factor risk premia. Although most AI-assisted functions officially reduce the demand for risk capital, they indirectly increase the tail risk in the system through tight factor coordination that leaves the economy susceptible to single factor shocks with unknown correlations. The second phase of the AI revolution in finance has the ambition of embracing the complexity of financial systems and markets and applying the technique to the menacing tail risk problems that AI itself creates. Post-modern VaR has multiple self-reinforcing interactions that are weaknesses without AI and flaws with AI. Consequently, the push for AI-driven systemic risk comes hand in hand with a push for decentralized intelligent systems more generally and a class of reinforcement learning models that act as mediators of financial systemic effects and can help adjust incentive problems such as the distinction between apparent and real liquidity without forcing illiquidity on the system at large. Such an approach to AI envisions a technologically advanced, regulatory accommodative world where risk-off is never sudden and catastrophic while still creating scarcity of safety goods that galvanizes animal spirits and drives the economic growth process.

1.8.2. Machine Learning in Trading Algorithms

The revolution in quantitative strategies has been in part possible thanks to the increasing amounts of market data available. In this setting, it is natural to expect state-of-the-art machine learning algorithms to provide an edge just by processing all that information. This line of reasoning may be correct when it comes to increasing predictive power regarding the short-term behavior of financial assets. An estimated reduction in the half-life of financial returns, from around 20 minutes to about 30 seconds, is a testament to that.

Nonetheless, behaving optimally according to these short-term predictions is not an easy feat by itself. To be effective, an algorithm needs to move faster than the competition, and improvements in execution speed are subject to diminishing returns. But there is an even more fundamental stumbling block. By reverting to the mean so quickly, short-term strategies may bear low (or even negative) returns even when making correct predictions. There is, thus, a systematic erosion of prediction quality, more acute for

statistical arbitrage to be so, but also present to some degree among the quantamental and even machine learning driven hedge funds.

The academic literature is aware of these issues and has incorporated knowledge about market quality into model specifications. Conversely, practitioners actively contribute to research by providing computers, human capital, and a large array of interesting campgrounds for trials and diagnosis.

1.8.3. Personalized Financial Services through AI

To succeed, AI initiatives need to go beyond generating predictions and focus on designing personalized products and services for individuals and businesses, leveraging their preferences in a way that adds a great deal of value to machine learning and prediction generation. It involves: (i) offering products that are personalized to individual needs, incorporating intelligent advice, respectful emotional support, and being delivered at a reasonable or better cost for planned spending; (ii) providing a personalized format, where digital technology enables products to be delivered customized and present targeted guidance to users through content, wiring, and interfacing mediums that increase the likelihood of user attention, appreciation, and engagement as they provide support, help, advice, interactive decision-making, and community networking; (iii) market offerings should also deliver an enjoyable, emotionally satisfying experience to the consumer, which provides a level of satisfaction with the process itself and the expected result. It is the key to creating the next generation of financial products, services, and models that individual consumers value rather than a general trend or fad. Various models, including shared-value models, are just a handful of the models for linking incentivizing value.

Intelligent abacus-type models operate best when they focus on building human value. In artificial abacus-type models, emotional support comes from improving a financial institution's or platform provider's digital connection to the user. This connection is created by managing and using personalization to provide very complete and useful targeted guidance to the user for better decision-making concerning a specific financial need, and the ability to select and receive advice and guidance about making products, one transaction and contact at a time. Only then does the connective support create the financial community philanthropic benefit once identified and developed, and these value models serve as a key foundation for the development imbued into spending decisions to create identifiable consumer benefits—those applications that earn profits—that can emerge from AI research. These efforts diversify beyond the profit-making technical discoveries and associated algorithmic advances applied in machine learning enterprises to date. When consumer abilities, activity levels, and the precision and effectiveness of distributed recommendations expand in these predicted areas, financial

market detriments will decline, helping to prevent future financial market crises or drying up much sooner.

1.9. Future Trends in Finance

The finance industry is going through a period of rapid technological change. The evolution of finance is characterized by four key trends: (1) customer interface; (2) finance ecosystem; (3) artificial intelligence; and (4) dematerialization of finance. Each of these trends represents a fundamental change in the way that finance institutions operate and provide services to the economy. In the customer interface phase, finance institutions started providing interfaces to retail customers. Banking services have, for a long time, been delivered by real people to real customers. In the finance ecosystem phase, a dramatic change is happening in terms of the relationships among financial institutions and between them and their customers. In the artificial intelligence phase, there is the beginning of a fundamental change in the way finance is provided as well as the way information is used in the provision of financial services. In this phase, the integration of knowledge in finance and computer science is starting to make it possible to make finance a true science. Finally, there is the phase of the dematerialization of financial products. Many aspects of today's finance are dependent on an intermediate physical process. The dematerialization phase is the phase in which the availability of physical resources is no longer relevant. The dematerialization phase allows financial services to be offered independent of the location of the processor of the digital information. These four phases capture the recent rapid change and, particularly, the new technology is revolutionizing a sector that had historically evolved very slowly.

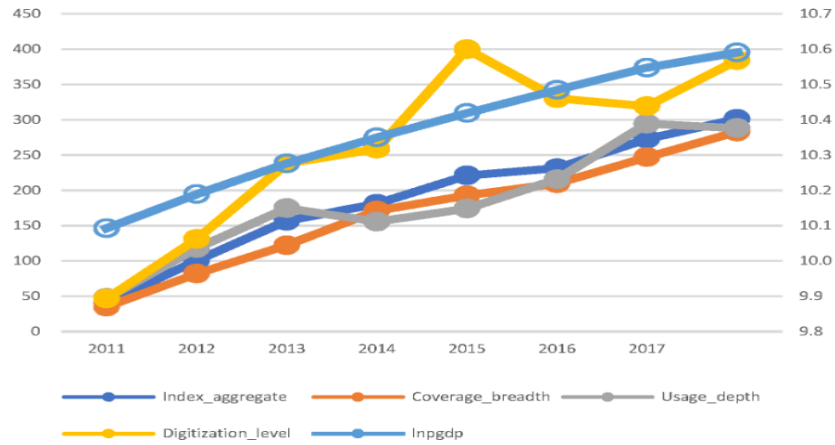

Fig 1 . 3 : Digital Finance and Economic Development

1.9.1. Blockchain and Cryptocurrencies

Blockchain and cryptocurrencies are in the limelight of financial institutions. Although the two phenomena are different, not many practitioners understand them, let alone be able to enunciate. One of the reasons is that the development communities for the two phenomena are separate. Another reason is that the concepts are treated together, which loses focus on both as well. This chapter uniquely discusses blockchain as one main construct of cryptocurrencies and uses this appreciation to underpin various cryptocurrencies. Cryptocurrencies with underpinning assets such as foreign currencies, commodities, stocks, and properties are given an in-depth treatment. The brief policy discussion calls for regulatory consideration.

Originally, blockchain was exclusively designed as a transaction infrastructure for Bitcoin. As transactions queued to be included in the next block, a group of developers adopted Bitcoin's blockchain in 2013 as a safe place to store distributed data, moving away from traditional transactional use. This was one of the first side chain projects, which later developed into traditional blockchain applications. However, a side chain project does not comply with Bitcoin protocols, and the mechanism relies heavily on a consensus model with drawbacks in economic costs, time, unproven reliability, block size, and incentives. Side chains remained a concept with promises of adding parallel blockchains for different purposes and tokens. In a more modern sense, layering assets outside the Bitcoin protocol carries potential risks of Bitcoin being horizontal across all markets.

1.9.2. Open Banking and API Ecosystems

Open banking has been observed as a banking system that offers access to one's finances through application programming interfaces. A significant percentage of global customers are interested in leveraging multi-banking capabilities, financial controller functionalities, and robo-advisors. This novel trend offers vast possibilities to exchange information among banks and with customers. Consequently, open banking is expected to sacrifice banks' ability to capture added back-end integration revenue. A notable percentage of banking professionals are interested in solutions interacting with online digital marketplaces, compliant offer-based APIs, and digital full banking APIs.

The preceding effects underline a great change in power and roles within banking market products. This technology not only challenges the traditional banking business models, but also opens extensive business prospects. Most services today are still based on legacy systems, and only a small percentage of bank professionals are operating on API-driven models. Recently, it has been observed that banks have finally started to appreciate APIs. Remarkably, a significant percentage of respondents categorize integration payments,

consider integration with third-party solution providers, focus on backend legacy modernization, data sharing with third parties, and balance checking and ATM locator services. A total of a large percentage of bankers have already deployed their APIs. This translates to a total of deployments, with a median of deployments, and deployed APIs that are already receiving significant traffic.

1.9.3. Sustainability and Ethical Finance

Sustainability, whether from an economic or environmental perspective, has become a topic of growing interest among companies, financial institutions, and ultimately, the public. There is now increased pressure to incorporate ESG (Environmental, Social, and Governance) factors into portfolio management. It is proposed that ESG be integrated into company metrics and that companies undertake a transition to the Sustainable Development Goals. However, there is much work to be done to make these proposals actionable for companies, investors, and other stakeholders. Large investors are increasingly asking ESG questions or announcing policies that reorient the management of their funds to favor ESG investing.

In the short term, investment strategies will face challenges; however, the longer-term structural change will require an ecosystem rethink. The components of this modern ecosystem are collaboration, graduation of systems, a change in corporate culture, board composition, incentives, and a longer-term orientation. Groups for Climate and Sustainable Finance have set up a Sustainable Finance Working Group. Among target deadlines are the common taxonomy by the end of 2020, evaluating the potential introduction of enablers in the financial regulations by the end of 2020. Taxonomies integrate and centralize the complex nature of ESG investments, linking performance with wider stakeholder outcomes. The financial transactions taxonomy will cover a number of environmental objectives, but no other ESGs.

1.10. Conclusion

In this paper, we have mapped some evolutionary trends of modern finance, including a shift from product to client orientation, a growing reliance on effective allocations of global economic resources, and a move from a focus on beta to differentiating between information and decisions. Our main thesis is that the business model of finance is changing, credit intermediation will be at the forefront, and that the next giant in technological and strategy platforms will emerge from China. The objective was to have an impact and contribute to the current debates in finance and economics, and to present some evolution trends and guidelines for national and international regulators, policy makers, and practitioners, especially those aiming at or in the business of corporate

finance. In our evolution of finance, we have the disappearance of the middle office targeting an enlargement and not only the creation of value for clients through sustainability, the disregard of fake guruism returning scientific validation in order to save the planet and neutralize zombies, and dramatic development of China as the country with the world´s highest GDP. In this paper, legacy systems have changed into a new ecosystem, particularly Artificial Intelligence Fueled Finance in China. The main result of our analysis is that, particularly, that the next giant technological platform and strategy wise in finance will come from China. We draw conclusions, suggestions, and recommendations for theory, practice, and policy implications. Challenging, open, and fascinating questions remain for future research.

1.10.1. Key Takeaways and Implications for the Future of Finance

The speed and impact of the digital revolution created the stark new reality of a growing chasm between technology-driven transformations in the front office and the reliance on legacy infrastructure incapable of keeping pace with the demands of modern financial organizations. The combination of technological advancements is now altering the trajectory of modern finance from deterministic banking to a new world of indeterminate, data-driven decision-making in financial organizations that share insights, risk, ideas, and even processing for execution.

Advancements in technology apply more pressure to the long-established walls of privacy, dispute resolution, proprietary information, governance, risk and compliance, organizational control, decision-making, and the concept of relative competitive advantage. The reaction of post-industrial capitalism to these changes will ultimately define the unique composition of future modern financial organizations. In fact, the most significant impact of this digital revolution does not come from the automation of tasks or the reduction in the total number of employees, but from the sharing of intelligence, decision-making, and processing across organizational boundaries that enable the creation of a new data-driven financial ecosystem. The future of finance is collaborative, automated, transparent, and capable of delivering continuous insights and enhanced integrity while promoting competitive differentiation.

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