CHAPTER 3

Financial Engineering and ICT in the Past

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3.1 Introduction and Conceptualization

This chapter focuses on the creation, production, subsequent advancement with evolving requirements, and adaptation to the state-of-the-art technologies emerging side by side in the ever-changing world, of financial engineering and information and communication technology (ICT). Financial engineering can influence the day-to-day trends of buying and selling by estimating the associated risks, expected revenues, and the corresponding income after using available computing techniques, thereby allowing the use of investment opportunities and/or purchasing prize shares, stocks or other commodities, etc. These computational techniques may be based on well-defined developed statistical or non-statistical procedures. In financial terms, computing is called computational finance, which is also commonly defined as a cross-disciplinary field based on the mathematics of finance, and numerical methods. With the growth of computer technology and innovation, the programming practices were changed in a way that, by using computer simulations it could save lots of time and do a faster amount of work. With the advent of newer technology, algorithms were developed and designed in order to use machines to create guidelines for decision-making. Such algorithms (one of the many well-defined computational criteria) were quite helpful in generating significant results in

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different trade scenarios after being integrated into newly developed computer programs, stochastic models, or numerical models. ICT's primary purpose was to link the various companies and bridge the gap between buyers and sellers. The financial computation was improved by the rise of modern computers with higher speeds and increased workload capacities.

3.1.1 Financial Engineering

Financial engineering is a revolutionary science that depends on mathematics technology for making an investment, hedging, and trading decisions, as well as promoting risk management of such decisions. While this area deals with the creation of new and value-added financial products, it is also considered to be an omnipresent financial discipline that encompasses the design of innovative financial instruments, acquisition deals and mergers, derivative strategies, and restructuring cooperation, among others (Osuoha 2013). In view of this, various scholars have defined financial engineering differently. Zopounidis and Doumpos (2013) define financial engineering as the advancement and creative use of innovative finance technologies. Financial technologies underpinning this concept include financial processes, financial products, financial strategies, and philosophy of finance. Financial engineering on a macroeconomic level helps to improve the allocation of scarce resources. In comparison, financial engineering produces income for creditors at the microeconomic level by finding better ways to tackle consumer demand (Beder and Marshall 2012).[1,2]

Past studies also conceptualized financial engineering in a diverse array of interconnected ways. For example Marshall and Bansal (1992) and Galitz (1995) think of it as the use of financial instruments and techniques to restructure an existing financial profile to have a more attractive financial product. According to (O'Brien 2001), financial engineering is the application of computer technology, mathematics, scientific method, and financial economics for the optimal use of sourcing and financial asset protection. Borrowing from various definitions and conceptualizations of financial engineering (Eales 2000) suggests that the term can be interpreted as a way of fine-tuning financial processes to suit tax, regulatory, or consumer adjustments. Zopounidis and Doumpos (2013) sum it up as the creation from the outset of financial products to provide consumers with distinct financial layoffs at a given time.[3,4]

3.1.2 Computation and Computational Finance

The standard definition of computation, at least as echoed in most major scholarly works, emerges from early studies in computer science. In these studies, computation is defined as the execution sequence of the Turing machines and their equivalent (Denning and Wegner 2010).[5] Modernist definitions call computation any kind of calculation which includes both statistical and non-statistical procedures and often follows a well-defined model, such as the algorithm (Feynman 2018).[6] Computation analysis is vital in the computer science field. In financial matters, computation is classified as computational finance. Computational finance is generally a branch of applied computer science that addresses varied financial issues. Like financial engineering, different financial scholars have also conceptualized this concept differently in the study of data and algorithms used in finance and in the mathematics of computer programs that realize financial systems or models (Levy 2003).[7] Computational finance is related to financial engineering [and often used interchangeably] as it is also commonly defined as a cross-disciplinary area focusing on mathematics finance, computer simulations, and computational methods for making investing, hedging, and investment decisions. In fact, with the use of various computational techniques, quantitative finance experts can reliably determine the financial danger that specific financial instruments may pose (Arratia 2014). Computational finance is also related to other disciplines, such as quantitative finance (Alexandridis and Zapranis 2014; Bock et al. 2013).[8,9]

What is often mistaken is that all of these areas are subfields of financial engineering, and what differentiates computational engineering from other fields is that it is an area of computer science that deals with data and algorithms that emerge in financial simulation or modeling (Chen 2012).[10] On the other hand, the use of mathematical models and extensive data collections for evaluating financial markets and stocks is quantitative finance [also recognized as empirical finance and financial mathematics] (Härdle et al. 2017).[11] Risk management, as it extends to portfolio management, is an example of its application; it is also used in the pricing of derivative securities, such as options. The fields to which computational finance is applicable are roughly categorized either on the sales side or on the acquisition side (LeBaron 2006). Sell-side encompasses the trading operations of investment banks that create and market a wide range of financial products, such as futures, options and interest rate swaps, floors, and caps. In some instances, investment banks would only balance purchase orders. In most situations, they would sell what they produced and purchase-related products to pay off the sales. Conversely, the buy-side is to invest money by buying bonds, stocks, or other complicated products marketed on the sell-side. Some of the modeling and simulation applications used in computational finance include deterministic models, stochastic models, and numerical valuation techniques, among others, as outlined below and described by (Oosterlee and Grzelak 2019).[12]

3.2 Evolution of Financial Engineering and Computation

3.2.1 Evolution of Financial Engineering

For centuries, certain financial functions and markets have been around. There's evidence, for example, that the Romans may have developed the checking system as early as 350 BC (Hopkins 1980).[13] In the 1750s, the first financial institutions had already learned how to take deposits, make investments, make loans, and provide protection. From the early 1700s to the 1970s, over two centuries, the growth of finance was constant and was carried out at a reasonable rate (Beder and Marshall 2012). However, the deregulation of interest rates, commodity prices, and currencies have created the need to manage risks. As such, between 1970 and 1997, financial experts were forced to find means of distinguishing the past and the future of financial institutions. The period was marked by four forces working in tandem to accelerate the adapt: technology, risk intermediation, deregulation, and globalization (Beder and Marshall 2012). Despite the need to manage risks, finance companies have begun to change their way of doing business rapidly since the early 1970s. Banks, government entities, dealers, brokers, central banks, funds, and insurance companies were confronted with new challenges and risks (Beder and Marshall 2012). As noted by (Udoka and Roland 2012), currencies and interest rates have been deregulated, leading to significant new volatility. Specialists started to seek technological help to solve these new risks and challenges.[14] As noted by (Beder and Marshall 2012), financial experts began to explore mathematical tools to address the problems, including risk measures, technical measures, and derivatives.[15]

By the 1980s, technology provided a critical field for addressing specific financial issues and established a risk identification and management platform. It is around this time that the world experienced advances in telecom, the first personal computers, and advances in financial hardware and software (Beder and Marshall 2012). As pointed out by (Ajupov et al. 2014), the word “financial engineering” first emerged in literature in the late 1980s, following heavy reliance on computer technology to conduct various financial functions. By that time, financial technology was expanding the demand for derivatives and the emergence of multiple types of innovative financial products. According to (Ajupov et al. 2014), US markets affected significant conversion of the derivatives market of the time, explaining the emergence and establishment of the concept of financial technology and the substantial number of scholarly work on the concept in the country.[16] Correspondingly, (Beder and Marshall 2012) note that globalization was the second force that characterized the late 1980s and early 1990s, where technology-enabled email, as well as satellite communications, were used. As a result, the flow of information in financial institutions was cheap and basically instantaneous, whereas cross-border transfers were done in seconds to a few days.

The rise of banks’ mainframe computers, as well as advanced data and record-keeping systems, also defined the 1980s in financial engineering. The related outcome, as noted by (Helleiner 1995), was that capital market activities began to move beyond borders, and traders began to anticipate one market event in response to another. By the 1990s, the Internet and e-commerce had exemplified most business models, and the end of the millennium resulted in the creation of online stock brokerage sites targeting retail investors[17] while replacing phone-based retail stock brokering models (Looney et al. 2004; Tiessen et al. 2001).[18,19] The massive growth in financial engineering started in 1998 (Miller 1998). The era between 1998 and 2006 mostly ended the notion of "mono-line" in financial institutions and banks, insurers, and fund managers started integrating companies across the world. This period was characterized by low-interest rates, low-risk premiums, and tremendous profitability and huge growth in firm sizes (Lustig and Verdelhan 2007).[20] As stated by (Drezner 2008), BRICs and sovereign wealth seeking emerged as major players on the global capital markets, propelled by technology and globalization. Since 2007 onward, the field of financial technology, most notably Fintech, has been epitomized by innovative technology pivoting key areas such as e-banking solutions, core banking applications, advisory services, information processing, payment and transaction, monitoring and analysis, data storage and management, IT management and support services, among others (Chishti and Barberis 2016).[21]

3.2.2 Origin of Computation and Rise of Modern Computers

Edsger Dijkstra made the first case of distinguishing between algorithms and computation in 1970 (Denning and Wegner 2010) and defined algorithms as a static description when computations were defined as a dynamic state-sequence evoked by an algorithm from equipment. Almost 2000 years after the discovery of psychology, physics, and mathematics, after clearing the measurement description, the field of computer science, with which computation and computational principles became centered, appeared. Since then, computing has evolved to biological and interactive modes from Turing machines to object-oriented programming over the Internet. Computer scientists such as Gödel have accepted Turing machines as the foundation of computation models (Eberbach et al. 2004). Computing was seen as pure mathematics, having been used only to work on mathematical problems. But it was found in the 1960s that Turing machines could be used to solve all types of computable problems outside mathematics (Eberbach et al. 2004). As described previously, these revolutionary developments lead to the evolution of modern computing and computation.[22]

3.3 Algorithms

In computer science and mathematics, an algorithm is a finite sequence of distinct and computer-implementable instructions, normally used in performing computation or class of problems. Lyuu (2001) defines this as precise procedures that can be turned into computer programs. Algorithms such as Euclids used in specifying the greatest common divisor can be said to be computable, while those that do not admit algorithms are uncomfortable.[23] Historically, alEuclids have played a critical role in computational finance, and the evolution in financial technology has transformed financial activities from human-driven to algorithm-driven (Chinthalapati and Tsang 2019). Algorithms have not only been employed in traditional financial dealings such as portfolio optimization, risk analysis, trading, and forecasting; they have also been applied in novel areas such as data sampling.[24]

3.3.1 Analysis of Algorithms

Donald Knuth coined the concept of algorithm analysis as a computer science term for calculating the complexity function of arbitrary large inputs into the computation. In other terms, algorithm research has generally been used to evaluate the difficulty of algorithms, including the amount of storage, time, and other resources needed to run them (Knuth 1985). For statistical accounting, algorithm research has often been done to identify worst-case, best-case, average-case, and amortized case scenarios.

In order to solve a financial problem by computation, it is vital to consider time and space complexity since a particular program may run on a machine where memory space is insufficient or vice versa (Knuth 1985). These evaluations have traditionally been used to provide insight into the reasonable directions for the quest for efficient computational finance algorithms.[25]

3.3.2 Software Implementation

Throughout programming, software implementation is the process of transforming algorithms into computer programs for a specific computer program (Lyuu 2001). Programming, design, coding, module testing, and debugging are all vital components of software implementation. There have been numerous implementation activities for a specification or standard. For example, software development tools include programming language implementations such as SQL, Java, Python, and C++ [programming languages are used in computer programming to implement algorithms]. On the other side, web browsers include implementations of the requirements of the WWW Consortium (Tanenbaum and Woodhull 2008). In technological finance, thus, the implementation of software involves the implementation of an algorithm or functional specification, such as software components, programs, or any other computer system, by computer programming and delivery.[26]

3.4 Information and Communications Technology (ICT)

Information and Communication Technology (Technologies) or ICT (ICT) is the technology and components that allow computing. Although there is no generally accepted concept of ICT in literature, it is taken to mean all tools, systems, applications, and networking components that combine to allow people and institutions, such as businesses and governments, to communicate in the digital world (Webb and Cox 2004). As an expanded concept of information technology, ICT emphasizes the role of unified communications and the assimilation in telecommunications (wireless signals and telephone lines) machines and appropriate software, their computing and audiovisual devices to allow all users to access, distribute, display, and manipulate information.[27] Since the 1970s, information technology has evolved with the emergence of four generations of computers.

3.4.1 Rise of Modern Computers

In order to understand the processes and effects of globalizing technologies and their functions, such as computers and computing, it is vital to take into account the historical development of this technology and the process of disseminating it in general (Duque et al. 2007). It is widely acknowledged that the evolution of ICT has its basis in the rise of modern computers.[28] The term computing has its roots in the 1920s (Copeland 2006; Parolini 2013). Computer machines in that period referred to any machine that did the human–computer work, that is, any machine that was able to solve mathematical problems with effective methods like a human being.[29] However, in the late 1940s and 1950s, the advent of Electronic Numerical Integrator and Computer (ENIAC) replaced computing machines with simply "computers" but initially with digital or electronic prefixes (Goldstine and Goldstine 1996). In 1951, states Tatnall (2012), the first device to use transistors instead of vacuum tubes, was officially introduced; this computer was referred to as the Universal Automatic Computer (UNIVAC 1).[30]

After two years, IBM (International Business Machine), with its 600 and 700 series, made its mark in the development of computer technologies. By this period, more than 100 programming languages had been developed, and computers had operating and memory systems (Copeland 2006). Storage devices had already been developed, such as disks and DVDs. As noted earlier, the Turing machines built-in 1936 formed the basis and principles underlying the development of modern computers. In 1963 the third generation of computers (the modern computer) began with the invention of integrated circuits. The computing machines became smaller and lighter with this invention but also more efficient, durable, and with a strong memory. At the same time, computers could run numerous and diverse programs (Copeland 2006).[31] The early 1980s saw the introduction of the Microsoft Disk Operating System (MS-Dos), and IBM's development of personal and office computers (Swayne 2003). By the mid-1980s, Apple created its icon-powered GUI for the Macintosh computers (Friedman 1997). Microsoft Corporation created the Microsoft Operating System in the 90s, spearheaded by Bill Gates and Paul Allen. As stated by Hammarlund et al. (2014), the fourth generation came with optimized VLSI circuits and gave rise to 16-bit, 32-bit, 64-bit, and embedded computers, which are still being built into various creations to date.[32] Currently, the most efficient machine (supercomputer) is named Summit, developed by IBM for the Oak Ridge National Laboratory in Tennessee at the United States Department of Energy. The massive computer can reach an unbeatable 1486 petaflops thanks to its 2.41 million cores and can run 200 quadrillions of calculations per second (Liebsch 2020).[33]

3.4.2 Digital Revolution

Digital revolution signifies the change from mechanical and analog electronic technology to digital electronics, beginning in the late 1950s to the late 1970s instigated by the introduction as well as the proliferation of digital machines and record-keeping that is witnessed today. The digital revolution, as stated by Clarke (2012), was the most significant event in information technology and dissemination since Gutenberg's printing press and marked a huge contribution to human interaction. This revolution began in 1947 with the translator's invention, a data transfer machine that fueled digital technology (Hutchins 1997).[34] The early 1950s saw the debut of the first physician pager in New York City, immediately followed by selling the first machine for simple arithmetic and data handling. By late 1960, the ARPANET network had already formed an early Internet successor (Grubesic et al. 2003). In the early 1970s, the first email was sent reading along QWERTYUIOP (McKenzie 1980). Around the same time, the first computer console was developed and saw the game precursor "Pong" launch.[35,36]

The first computer, equivalent to a modern-day laptop, was produced in 1981, according to Grego (2009), with a panel slightly larger than a matchbox. ABBA was the first artist to capture and store songs on a compact disk (CD) in 1982 (Larkin 2011).[37] The first mobile phone was later created in 1984, costing around $4000, with a 10-hour charge that only provided 30 minutes of use (Park 2005).[38] The first fully functional digital camera was developed in the late 1980s, noted Kawahara (1988), which provided up to 10 images to be processed. In 1989, Tim Berners Lee invented the World Wide Web while working at CERN, and 0.05% of the world's population used the Internet by 1990 (Gillies 2000). Following the invention of WWW, CERN created the first web browser and released it for public use.[39] In 1994, the first "smartphone" that supported faxing, emailing, and calls was released (Andrew 2018).[40] With the launch of the first smartphone, the creation of the first modern social media site followed in 1997, bearing the name *Six Degrees* (Watt 2004). This invention was quickly followed by the creation of Bluetooth technology to allow the sharing of digital content from one smartphone to the next.[41]

To improve internet connectivity, Broadband was invented in the United Kingdom in 2000, and Skype was launched to connect people around the world by 2003 (Zennström and Friis 2003).[42] Immediately after Skype was born, Mark Zuckerberg and his schoolmates set up Facebook, instigating the new age of social media. This followed the introduction of YouTube (2005), Facebook (2006), iPhones (2007), 3D printing (2008), and iPads (2010). After the launch of a distributed ledger-based network by Satoshi Nakamoto on January 3, 2009, Bitcoin became a widely accepted digital currency in 2011. Google started testing driverless vehicles in 2012, and Oculus Rift and virtual reality headsets became available to consumers by 2016. Today, virtually everything is digitized, from healthcare to education, and it looks set to continue at an unprecedented pace.

3.5 ICT in Finance

ICT focuses primarily on information exchange, and its development as a science corresponds with developments in IT and computing technology (Hitt and Brynjolfsson 1997). As noted previously, the difficulty of conducting business in the 1960s has caused countless uncertainties and risks in the corporate world. The development of IT devices such as computers in the 1970s provided easy and reasonably priced access to financial institutions for information (Ernst and Kim 2002). As machines were inexpensive and publicly available, financial firms became able to manage and process the data efficiently. At the same time, IT efficiency and pace enabled the creation of financial services that included the issuance of credit cards and electronic screening. According to Teo (2002), after the invention of the Internet, business transactions had moved online, and by 1998 more than $50 billion worth of transactions had been made online.[43,44]

By the twenty-first century, Bughin et al. (2010) reported that routine electronic banking had increased considerably, demanding more computers, networks, and security programs. This has intensified the advocation of global finance, enabling financial transactions to run on a worldwide scale. Financial markets became the first organized, global markets that operated through a network of computers (Knorr Cetina and Bruegger 2002). Crucially, the Internet allowed the uninterrupted access to credit ratings and scores to all businesses, insurance firms, and lenders.[45] With the emergence of social media, new messaging, and interactive platforms were developed, and people became more linked and educated than ever before. Socially driven information technology has allowed financial institutions and companies to reach out to customers of diverse demographics in pursuit of competitive advantage. Today, as stated by Kirmani et al. (2015), new, most effective, up-to-date, common, and flexible ICT technologies underscored by computer-based modulus operandi have overridden nearly all modern industrial processes, through their efficiency, performance, and reliability.[46]

3.6 Conclusion

Financial institutions have been around for centuries. Over time, these structures have experienced radical technological reshaping, step by step, of a cycle that could be divided into different periods. In the first century, from the 1700s to the 1970s, financial infrastructure development was at a comfortable level, yet the globalization of interest rates, commodity prices, and currencies produced a need to manage risks in the early 1970s.

The time from 1970 to 1997 was the second phase that pushed financial experts to find ways to separate the past and future of financial institutions. In this time, four coercing forces, including technology, risk intermediation, deregulation, and globalization, were the bringers of change in the state-of-the-art financial engineering in cooperation with ICT. In brief, economies around boundaries were getting closer and engaging with each other in a way that caused the response of one business to the results of another. As a result of globalization, financial institutions' costs decreased, leading to an exemplary creation of online brokerage deals replacing telephone-driven deals.

The years 1998 and 2006 enabled financial institutions and banks, insurers, and asset managers to merge businesses across the globe. Since 2007, Fintech, the world's most popular financial technology, has been embedded with innovative technologies that address key areas such as banking solutions, core banking solutions, advisory services, information management, payments, and settlement. Financial engineering computation methods evolved due to side-by-side development of the available information communication technology that facilitated the public interest.

Notes

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