Advancing ESG Objectives with ESG-Linked Derivatives

by
Pieter Willem Jansen van Rensburg

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Supervisor: Dr. Mesias Alfeus

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P.W. Jansen van Rensburg	March 2024
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ABSTRACT

Environmental, social, and governance (ESG) concerns require the active involvement of the financial sector in advancing ESG compliance. The global derivative market holds significant importance. Leveraging derivatives, exchanges, and clearinghouses offers a pathway for the financial sector to promote ESG objectives. This research assignment examines the particular challenges associated with utilizing derivatives to promote ESG compliance. It explores ESG-linked derivatives, utilizing Monte Carlo simulation, associated with Key Performance Indicators (KPIs) and priced based on the attainment of specific Sustainability Performance Targets (SPTs). These specific ESG-linked derivatives are tailored for this purpose - advancing ESG objectives. ESG-linked derivatives represent an emerging field, demanding further in-depth exploration.

Key words:

Environmental, social and governance (ESG), Sustainable Finance, Derivatives, ESG-linked Derivatives, Key Performance Indicators (KPIs), Monte Carlo Simulation, Sustainable Performance Targets (SPTs)

OPSOMMING

Omgewings-, sosiale en bestuursaangeleenthede (ESG) vereis aktiewe betrokkenheid van die finansiële sektor om ESG-nakoming te bevorder. Die globale afgeleidemarkte het aansienlike belangrikheid met betrekking tot ESG. Die benutting van afgeleides en aandelebeurse bied 'n middel vir die finansiële sektor om ESG-doelwitte te bevorder. Hierdie studie ondersoek die spesifieke uitdagings wat verband hou met die gebruik van afgeleides om ESG-nakoming te bevorder. Dit ondersoek 'n ESG-verwante afgeleide instrumente wat gebruik maak van Monte Carlo-simulasie, gekoppel aan sleutel prestasie-aanwysers (KPIs) en geprys op grond van die bevrediging van spesifieke volhoudbaarheids prestasiedoelwitte (SPTs). Hierdie spesifieke ESG-verwante afgeleide instrumente is op maat gemaak vir hierdie doel - die bevordering van ESG-doelwitte. ESG-verwante afgeleide instrumente is 'n opkomende veld wat verdere diepgaande verkenning verg.

Sleutelwoorde:

Omgewings-, sosiale en bestuursaangeleenthede (ESG), Volhoubare Finansies, Afgeleides, ESG-verwante Afgeleides, Sleutelprestasie-aanwysers (KPIs), Monte Carlo-simulasie, Volhoubaarheids Prestasiedoelwitte (SPTs)

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LIST OF ABBREVIATIONS AND/OR ACRONYMS

ATM	At-the-Money
CSR	Corporate Social Responsibility
CDS	Credit Default Swap
ESG	Environmental, Social and Governance
GBM	Geometric Brownian Motion
IRS	Interest Rate Swap
ITM	In-the-Money
KPI	Key Performance Indicator
OTM	Out-of-the-Money
SDE	Stochastic Differential Equation
SDG	Sustainable Development Goal
SLL	Sustainability-linked Loans
SPT	Sustainable Performance Target

CHAPTER 1

INTRODUCTION

The current influence of environmental, social, and corporate governance aspects on the economy is highly significant. These factors are integrated into Environmental, Social, and Governance (ESG) principles, drawing substantial attention today and emerging as a major focus for numerous large corporations. Governments and financial institutions play vital roles in promoting ESG, employing regulations and financial products, respectively, to further these objectives. ESG-linked derivatives have been introduced to propel ESG goals, leveraging the extensive global derivative market. By integrating specific factors, these derivatives incentivise companies to enhance their ESG compliance. However, exploration into ESG-linked derivatives remains limited. Therefore, this research assignment endeavors to present the ESG issue and propose potential strategies for constructing ESG-linked derivatives, aiming to advance ESG objectives.

The following section provide an in-depth understanding of sustainability by linking it to practical global agendas and propose strategies for how it can be advanced.

1.1 SUSTAINABILITY

The increased emphasis on sustainability in recent years reflects a global recognition of the urgent need to address environmental, social, and governance challenges. Key international agreements and initiatives, such as the United Nations' '2030 Agenda for Sustainable Development' and the Paris Agreement, have set a strong foundation for steering global efforts towards sustainability. The 2030 Agenda's 17 Sustainable Development Goals (SDGs) serve as a comprehensive roadmap addressing crucial issues like poverty, inequality, climate change, and environmental degradation (Lee *et al.*, 2016). Similarly, the Paris Agreement's focus on climate change mitigation and adaptation that signifies a collective commitment by nations to combat the adverse impacts of global warming (Agreement, 2015).

Undoubtedly, the responsibility for advancing sustainable practices primarily falls on governments; however, the financial sector plays a pivotal role as a catalyst for change in multiple ways. Decision-makers shaping sustainable strategies must integrate environmental considerations due to escalating public sentiments, emerging regulations, technological advancements, and shifts in the market landscape. While considerable attention is directed towards combating climate change, it's vital not to overlook the conventional aspects of sustainability - those concerning social and governance factors. Therefore, the contemporary concept of sustainability encompasses a holistic view, encompassing environmental, social, and governance considerations, all regarded as equally significant, although some may gain more attention depending on the circumstances (Kalfaoglou, 2021).

For example, the recent pandemic has underscored the pressing need to enhance healthcare systems and address issues affecting people's well-being, thus bolstering the social aspect of sustainability (Kalfaoglou, 2021). This highlights that sustainability efforts need to extend beyond environmental concerns and include societal well-being and resilience, recognising that a sustainable future involves not only a healthy environment but also thriving, healthy communities.

In the financial sector, embracing sustainability goes beyond environmental efforts; it includes ethical governance, social responsibility, and financial stability. Institutions are increasingly acknowledging the importance of integrating these facets into their decision-making processes, recognising that a comprehensive sustainable strategy considers not only the planet's health but also the well-being of communities and ethical business practices. This approach to sustainability ensures a more resilient and responsible financial sector that caters to both environmental concerns and societal needs.

Moreover, sustainability in finance is not merely about reducing negative impacts. It also involves identifying and supporting investment opportunities that promote sustainability, such as renewable energy projects, environmentally friendly infrastructure, or social impact initiatives. Through sustainable finance, investors and financial institutions play a critical role in supporting projects that align with environmental and social goals while ensuring financial viability.

The movement toward sustainability in finance is multifaceted, encompassing a shift in investment practices, risk management strategies, and an increased emphasis on transparency. Ultimately, it aims to balance financial returns with positive societal and environmental impacts, contributing to a more sustainable and resilient global economy. As sustainability continues to gain momentum in the financial sector, there's an evolving recognition that responsible and ethical investment decisions are not only beneficial for the planet and society but can also yield long-term financial stability and growth.

Markets are poised to capitalise on the openings provided by political agendas, aiming to integrate ESG considerations into decision-making processes. While it's widely acknowledged that ESG factors represent the fundamental pillars of sustainability, the absence of a universally agreed-upon definition for these factors complicates their consistent understanding and management.

However, the absence of a standardised definition has not hindered the growing significance of ESG analysis, particularly highlighted during the pandemic. The global crisis shed light on economic, social, and environmental vulnerabilities, which have the potential to perpetuate unequal income distribution and widen the wealth gap. Consequently, post-pandemic recovery initiatives primarily underscore the significance of environmental and social factors, while governance remains consistently in demand.

Amid the evolving landscape, the market's focus on ESG considerations reflects a growing recognition of the interconnectedness between sustainability, economic stability, and social welfare. As such, integrating ESG principles into decision-making processes is not just a trend but a necessity for ensuring a more robust, and sustainable future. This emphasis on ESG factors indicates a paradigm shift in market strategies, highlighting the integral role these considerations play in shaping both financial and societal outcomes (UN, 2021). The following section describes the integration of these ESG principles.

1.2 SUSTAINABLE FINANCE AND ESG

Sustainable finance involves integrating ESG criteria into business or investment decisions, aiming to deliver enduring benefits to shareholders, stakeholders, and society as a whole. The primary goal is to foster economic growth that voluntarily aligns with the commitments outlined in international agreements such as the Paris Agreement, and UN Sustainable Development Goals (Agreement, 2015; Lee *et al.*, 2016). This field is expansive, confine the process of considering ESG factors in decision-making alongside profit motives.

Achieving these sustainable finance objectives necessitates collaboration among corporations across diverse industries, the financial sector, and other stakeholders. According to Kalfaoglou (2021), it involves setting environmental, social and governance goals that span various aspects within an organisation, including business models, strategies, organisational structures, cultures, internal processes, risk management, as well as green financing and investing. The objective is to reduce the environmental impact while amplifying the social contributions of an entity.

The rising public interest in sustainable finance stems from shifting market dynamics, societal expectations, evolving environmental protection policies, technological advancements, and the developing regulations that apply to financial institutions. This approach has evolved into a strategy centered on generating and preserving value by actively managing and reporting on environmental, social, and governance impacts, as well as addressing stakeholder concerns and expectations (Kalfaoglou, 2021).

Sustainable finance represents a paradigm shift in how businesses and financial entities perceive their roles in society. It emphasises not only financial profitability but also the creation of value through responsible and ethical practices that contribute positively to the environment, society, and the economy. This approach aligns business strategies with global sustainability objectives, acknowledging the need for collective efforts to achieve a more equitable, resilient, and environmentally conscious future.

This research assignment seeks to establish a framework for encouraging ESG compliance within the financial sector by exploring the creation of a financial instrument known as ESG-linked derivatives. These derivatives are designed to motivate businesses to make positive contributions to the environment, society, and the economy. The following chapter provides a literature review of ESG and each of the pillars.

1.3 RESEARCH ASSIGNMENT CONTRIBUTION

The aim of this research assignment is to:

- Introduce niche topic of sustainable finance and how ESG factors integrate with it.
- Explore what ESG as a whole mean as well as go into each of the pillars of "ESG".
- Discuss the global derivative market and how it can be used to advance ESG-linked derivatives.
- Discuss the importance of determining and verifying the Key Performance Indicators (KPIs) used in the pricing approach of ESG-linked derivatives.

- Introduce the framework of pricing an ESG-linked derivative that builds on work done by Karia (2022), who looks at how binary options can be used to price ESG-linked derivatives, and Mielnik and Erlandsson (2022) who introduce that a Geometric Brownian Motion can be used to simulate KPIs. However they looked at how it can be used in sustainability-linked bonds considering a coupon step-up instead of ESG-linked derivatives.
- Make use of Monte Carlo simulation, instead of the closed-form solution used by Karia (2022), in order to price the ESG-linked derivative.
- Give a few concluding remarks as well as some study limitations with further research that needs to be done.

1.4 RESEARCH ASSIGNMENT STRUCTURE

- Chapter 1 focuses on introducing the heightened focus on sustainable finance and its relationship with ESG. It sets the groundwork for understanding ESG and its relevance to sustainable finance.
- Chapter 2 extends from Chapter 1, providing a comprehensive review of ESG, delving into its three pillars to explain their meanings and how they integrate into sustainable finance principles.
- Chapter 3 delves into the global derivatives market and its collaborative potential with ESG to create ESG-linked derivatives aimed at advancing ESG goals. It covers the global development of the ESG-linked derivative landscape, including challenges and its progress in emerging markets like South Africa.
- Chapter 4 introduces the significance of Key Performance Indicators (KPIs) in ESG-linked derivatives. It details the foundational principles behind KPIs and offers examples relevant to each ESG pillar, alongside potential challenges in their implementation.
- Chapter 5 elaborates on the framework used in constructing ESG-linked derivatives and its correlation with KPIs. It discusses model specifications, input parameter calibration, and their crucial role in pricing ESG-linked derivatives.
- Chapter 6 specifically details the application of Monte Carlo simulation in pricing ESG-linked

derivatives, employing the model described in Chapter 5. It explores how alterations in input parameters can impact derivative pricing and provides a hypothetical scenario for model utilisation. It also illustrates how the final product appears, with a framework that can be used for hedging.

- Chapter 7 concludes by summarising key insights, noting limitations in ESG derivatives, and outlining potential further research in the field of ESG-linked derivatives.

This chapter focused on the issue of sustainability within the finance sector and its connection to ESG factors. It also discusses the research assignments' contributions and structure. The following chapter will delve into the literature concerning ESG.

CHAPTER 2

LITERATURE REVIEW ON ESG

2.1 ESG FACTORS

Defining ESG principles is relatively straightforward, but the real challenge lies in pinpointing the specific indicators related to these themes and devising ways to measure them. Various authorities have developed differing lists of indicators, depending on their particular focus. However, there exists a general consensus regarding the core elements within each pillar.

Environmental considerations primarily revolve around issues such as climate change, adapting to new environmental norms, mitigating physical disasters, addressing air and water pollution, managing resource depletion, and combatting biodiversity loss (Kalfaoglou, 2021). Social considerations encompass concerns about inequality, inclusivity, labour relationships, investments in human capital and communities, and issues related to human rights. Governance considerations focus on corporate governance practices and managerial structures that ensure the integration of social and environmental factors in decision-making processes. They also involve aspects like employee relations and executive compensation.

The ESG risk spectrum encompasses a wide range of factors and risks, intertwining environmental, social, and governance aspects. These risks are integral to the overall ESG landscape and are crucial considerations for businesses and investors aiming to understand the potential impact of these factors on their operations, financial stability, and long-term sustainability. Identifying, assessing, and mitigating these ESG risks are becoming increasingly essential for organisations looking to align their practices with responsible and sustainable strategies. The following subsections examines each of the three pillars of ESG and offer insights into methods how compliance to each of the fundamental pillars can be advanced.

2.1.1 Environment

The 'E' pillar within ESG considerations encompasses climate-related risks and environmental risks. Climate-related risks are linked to or caused by climate change, including extreme weather events, while environmental risks stem from environmental degradation, such as water pollution and the decline of natural ecosystems. Although these risks are interconnected, some forms of environmental degradation, like industrial spills causing water pollution, aren't exclusively tied to climate change.

Both climate and environmental risks manifest in two ways: through physical risk and transition risk. Physical risk involves harm to physical assets or human lives due to weather events induced by climate change, occurring either acutely (like heatwaves and floods) or chronically (e.g., rising sea levels and temperature changes) (KPMG, 2021). Transition risks arise from the shift toward a low-carbon economy, encompassing policy changes, technological shifts affecting energy sources, and changes in market sentiment impacting reputation (KPMG, 2021).

These climate-related risks can have notable impacts on both macro- and micro-economic levels, potentially leading to substantial financial losses due to interconnected ripple effects. However, the implications and financial impacts stemming from climate change can vary based on geographical location, unique climate patterns, developmental stages, and specific activities and value chains of an entity.

The interlinking of physical and transition risk channels may lead to the existence of stranded assets, particularly evident in sectors like oil and gas. Stranded assets refer to investments that may no longer yield returns due to changes in the market and regulatory environment driven by climate policies. This situation might arise from abandoned carbon reserves, obsolete investments in fossil fuels, and uncertainties regarding policy changes, potentially resulting in significant financial consequences for businesses vulnerable to shifts brought about by climate-related factors.

Karia (2022) states that banks can contribute to the environment aspect of ESG in various ways. The first option is by making their goods and services more environmentally friendly, such as by providing financial products that do not harm the environment. Sustainable/green bonds and sustainability-linked loans (SLLs) have expanded significantly over time. Sustainable bond issuance surpassed $900bn in 2023, a 20-fold increase from 2015 (Standard and Poor's, 2023). The second method involves making investments in businesses that have a good impact on the environment or in businesses that aim to change their business practices to be more sustainable.

2.1.2 Social

The concept of social sustainability is fluid and evolves over time and locations, aligning with society's evolving definition of a good life and society. At times, it's considered a distinct pillar apart from environmental and governance sustainability, sometimes associated solely with economic growth. However, it can be viewed as the foundation for other sustainability pillars, crucial for the growth and development of the economy and the environment. Over time, social sustainability has expanded and is now recognised as an independent factor in sustainable development. Yet, integrating the 'S' pillar into corporate frameworks and decision-making processes remains ambiguous. Companies are urged to address general social issues like human rights, labour relations, and broader concerns such as unemployment and education (Gillan *et al.*, 2021)

According to Gillan *et al.* (2021), the responsibility for the 'S' pillar often rests within Corporate Social Responsibility (CSR) policies, where companies voluntarily integrate social and environmental concerns in their operations and stakeholder interactions, extending beyond legal obligations. However, while companies have made significant strides in disclosing their environmental impact and governance standards, there's a dearth of similar disclosure regarding social impact and performance.

The pandemic has significantly influenced ESG considerations, particularly fostering a positive impact on social sustainability. As governments align post-pandemic recovery with green initiatives, the effect on market participants' ESG efforts remains less clear. Nevertheless, the altered norms in living and business have led to a new consensus regarding the role of businesses in society. This shift has magnified the focus on the 'S' pillar, especially concerning labour management, prompting increased interest in the social dimension of sustainable investments due to digitisation and globalisation. The pandemic aftermath is expected to heighten the visibility of the 'S' pillar, inviting closer scrutiny from rating agencies, regulators, and market players.

2.1.3 Governance

According to Kalfaoglou (2021), integration of governance issues within ESG analysis encompasses three key forms: the internal operational and organisational perspective of banks, the governance structures overseeing environmental and social risk frameworks within banks, and the governance of the counterparties to whom banks lend. Bank governance is a multifaceted issue addressed through compliance and ethical perspectives. It spans typical governance concerns like board roles and composition, internal control systems, and broader matters such as anti-money laundering, aligning with existing regulations and compliance standards. New demands have arisen to incorporate ESG factors into bank governance (Siems and Alvarez-Macotela, 2015).

The governance issues of bank borrowers play a pivotal role and, if effectively incorporated, could significantly advance sustainability objectives. Siems and Alvarez-Macotela (2015) advocate for robust structures within companies, extending beyond traditional financial and operational risks to include policies concerning environmental and social issues. The board of directors is tasked with the responsibility of integrating environmental and social factors, crucial for overall corporate governance. Board quality is multifaceted, including diversity both in task-related areas (education, professional background) and non-task related aspects (gender, age, race, nationality), impacting the board's leadership role, particularly in endorsing ESG factors in decision-making.

This integration of ESG factors carries both compliance and strategic dimensions. Compliance involves meeting regulatory requirements, while strategically it aims to shift behaviors from a short-term approach to a long-term approach, fostering a sustainable business model. Aligning with ESG themes requires reshaping practices that favour short-term perspectives, such as focusing on quarterly financial results or short-term performance-based pay, to long-term perspectives. However, adopting a long-term perspective is challenging, as the time horizon for ESG impacts often surpasses typical business planning horizons, presenting methodological hurdles in integrating these risks into strategic planning and risk management frameworks.

The following section examines how ESG risks can influence banks and how it can be mitigated.

2.2 ESG RISKS

In addition to the well-known risks currently faced by banks, ESG issues can have an influence on a bank's operational stability and financial health. In the banking industry, these risks can have an immediate impact on the institution - for example, physical damage from natural disasters to bank properties - as well as have an impact on customers, changing sales opportunities and causing production disruptions that may raise the risk of credit defaults (Kalfaoglou, 2021). ESG risks are distinct from other types of risks in that they fall into two categories: non-financial and financial. Non-financial risks like operational difficulties and reputational harm, which primarily affect the institution itself, are in contrast to financial risks like market swings and credit problems brought on by ESG factors (KPMG, 2021).

Addressing ESG risks demands a comprehensive strategy that goes beyond solely assessing how these risks affect the organisation. According to KPMG (2021), it involves deeply comprehending the complex relationship between the bank and its stakeholders. This goes further than recognising the risks the bank may pose to its stakeholders and the environment through its operations; it involves understanding how these stakeholders, in turn, can influence the bank. The objective of this research assignment is to construct a framework designed for banks to encourage ESG compliance among their stakeholders. This is achieved by proposing the issuance of Sustainability-linked (or ESG-linked) derivatives, serving as a mechanism to align the interests of stakeholders with the bank's sustainability objectives. These derivatives would link financial products to specific ESG outcomes, stimulating stakeholders to partake in and support environmentally and socially responsible practices in line with the bank's sustainability goals.

CHAPTER 3

ESG DERIVATIVES: MARKET TRENDS AND DEVELOPMENTS

3.1 GENERAL OVERVIEW OF DERIVATIVES

For centuries, derivatives have been an integral part of financial markets. Today, these markets hold significant global importance, representing some of the largest financial markets worldwide. Derivatives are financial agreements whose value is derived from an underlying asset or reference entity, which can range from interest rates, credit, equities, and foreign exchange to unconventional entities like weather patterns, carbon emissions, or even other financial derivatives. The dynamic and versatile nature of derivatives allow investors to craft financial contracts with tailored features, offering more than just a focus on achieving risk-adjusted returns. This versatility opens the door for innovative and diverse ways to structure financial products, allowing for customisation to meet specific investment needs and objectives.

Derivatives serve various financial purposes, such as hedging, speculation, and arbitrage (Hull, 2018). Hedging involves managing the risk associated with future price changes in the underlying market variable, while speculation entails making bets on the anticipated price movements of a market variable. Additionally, arbitrage involves taking simultaneous positions in two or more financial instruments to secure a profit. One significant social advantage of derivatives is their ability to hedge risks, even those that might be otherwise challenging or impossible to hedge using traditional methods. This hedging capacity extends to risks that are typically hard to mitigate or insure against, thus providing a valuable mechanism to manage and offset unpredictable risks, thereby enhancing overall financial stability and security (Baker, 2022).

The entire derivative ecosystem, including exchanges, clearinghouses, and over-the-counter (OTC) markets, significantly contributes to advancing ESG objectives. The OTC market offers remarkable flexibility as its contracts are tailored to meet specific counterparties' requirements. However, due to their personalised nature, OTC derivatives generally lack the liquidity and other advantages associated with exchange markets. Exchange markets function as regulated trading platforms, serving as vital infrastructures in capital markets (Lee, 2010). Their principal role is to facilitate trading activities by providing a platform for pre- and post-trade data dissemination and executing buy/sell orders, essentially forming a market. As they deal in standardised products, Pirrong (1995) states that exchanges promote liquidity, enhance trade transparency, consolidate trade prices and volumes, mitigate counterparty risks through clearinghouses, and uphold market regulations. Additionally, derivatives exchanges have the capacity to introduce new products, including ESG-linked derivatives, in response to industry needs or regulatory changes.

Clearinghouses, integral entities within exchange groups or operating independently, play a crucial role in the post-trade aspect of derivatives. They manage the process following a trade, confirming trade details, facilitating payments, and settling contracts. According to Baker (2022), clearing can be described as a process where an intermediary intervenes between two parties in a transaction, assuming the rights and obligations of each party. Clearinghouses step in as central counterparties, assuming the buyer and seller roles through novation. Consequently, they absorb the counterparty credit risk, shifting it away from the original counterparties, who then face the counterparty risk associated with the clearinghouse rather than each other.

Equity, debt, and derivatives markets, which are a part of the global capital markets, are essential for a country's economic development. Along with using financial markets to further sustainability objectives, they are also supporting the expansion and rising demand for sustainable finance. According to estimates, the market for sustainable investments increase by about 30% in the last few years since sustainable investing has been introduced (Harrison, 2021). In fact, corporate and sovereign sustainable bonds already make over 10% of the global debt market (Toole, 2022). Additionally, according to ISDA (2021*b*), a rising number of novel transaction structures are emerging in the financial markets, notably in the derivatives sector, to support sustainability objectives. Similarly, efforts to promote sustainable finance are growing on the parts of financial markets and governments.

The following section examines how ESG and traditional derivatives, that is discussed in this section, can be linked to construct ESG-linked derivatives.

3.2 ESG AND DERIVATIVES

There has been an increase in the focus on sustainable finance and climate change by a number of articles, e.g. Jebe (2019) researched how the goal of sustainability reporting is to enhance company practices in the areas of the ESG and Park (2021) talks about the effects of climate change. The function of derivatives in this changing environment has not been focused on substantially. However, in the last few years the subject came up in several industry papers and suggested by CFTC (2022) that derivatives can be 'part of the solution' in an effort to deal with climate change and sustainable objectives. According to Baker (2022), derivatives will play a pivotal role to make it easier to access finance, to make investments less unpredictable, and to make it possible to hedge transition-related risks.

A variety of stakeholders are increasingly demanding that companies and investments produce not only positive financial returns, but also make positive, non-financial social contributions (Baker, 2022). ESG can support this demand by offering a methodology for evaluating a company's or an investment's performance on specific, socially desirable goals. It relies upon KPIs to measure and monitor various aspects of a company's performance within its three categories (ISDA, 2022*a*). ESG-linked metrics currently wrestle with definitional and measurement uncertainties. An insufficient amount of high-quality, standardised data also poses challenges for ESG-linked markets (ISDA, 2022*a*).

ESG-linked derivatives, similar to traditional derivatives, offer investment (speculation), and arbitrage opportunities. According to Baker (2022), there are six primary categories of ESG-linked derivatives that actively support ESG objectives. They facilitate the redirection of capital toward sustainable investments, assist market participants in hedging risks associated with ESG factors, enhance market transparency, price discovery, and overall market efficiency, and contribute to a long-term investment approach.

The first category encompasses sustainability-linked (or ESG-linked) derivatives. In these instruments, ESG-linked factors are integrated into traditional hedging tools like interest rate swaps (IRS), cross-currency swaps, or forwards. A survey conducted by ISDA (2022*b*) identified that IRSs were the underlying product for the majority of ESG-linked derivatives transactions. These derivatives are highly customisable and leverage various KPIs to set and attain sustainability objectives. According to ISDA (2021*c*), the ESG pricing component within ESG-linked derivatives are directly linked to the compliance of one or both parties with KPIs specified in the transaction. Typically, according to Baker (2022), ESG-linked derivatives have been established between a financial institution and a non-financial institution, primarily applying the ESG performance metrics to the non-financial entity. These instruments are frequently utilised in sectors facing significant ESG-linked pressures, such as energy, construction, agriculture, and transportation (Baker, 2022).

Tailored KPIs closely monitor a party's adherence to the ESG-linked derivative ESG objectives, aiming to either discourage environmentally detrimental behaviour or encourage beneficial actions (ISDA, 2021*c*). These KPIs often align with global ESG frameworks, ensuring compliance or achieving a specific ESG rating certified by a third party. Failing to meet the contractually stipulated ESG targets entails consequences, typically resulting in an increase or decrease in payment, a contribution to a charitable organisation, adjustments in fees or margins, or other financial alterations (Baker, 2022). In essence, the market's credibility and liquidity hinge on the clarity and verifiability of the KPIs stipulated within these contracts. Significant research is necessary concerning KPIs, as they serve as a crucial metric in ESG-linked derivative. This research assignment aims to delve into the foundational principles of KPIs and explore their role in determining the pricing of ESG-linked derivative.

The other categories encompass ESG-linked credit default swaps (CDSs), ESG-linked exchange-traded derivatives, derivatives on emission allowances (or offsets), derivatives related to renewable energy and fields, and catastrophe- and weather-related derivatives. While these categories are not covered in this research assignment, further research can delve into these specific derivative types (Baker, 2022).

As previously highlighted, exchanges and clearinghouses are uniquely positioned to advance ESG-linked objectives by facilitating the determination of KPIs and fostering ESG objectives in general. Among their most pivotal potential contributions are their capability to mitigate price risk, foster price discovery, and enhance transparency, thereby improving the efficiency of the underlying derivative markets. According to Baker (2022), the derivative ecosystem's benefits encompass the creation and listing of novel ESG-linked products, which are utilised for hedging, investment, and arbitrage. Furthermore, they aid in data generation, integrity, and analytics, promote standardisation and governance, and support market coordination. The development of these new products can be in response to market demand for ESG-linked derivatives or to comply with regulatory developments.

This section examined how ESG-linked derivatives are structured, however the following section examines the challenges that may arise from constructing this ESG-linked derivatives.

3.3 CHALLENGES OF ESG-LINKED DERIVATIVES

Derivative markets, especially exchanges, have historically emphasised transparency in data throughout the trading process, particularly concerning pricing and trading volumes ISDA (2021*a*). Data holds a fundamental position in market operations. Exchanges have consistently gathered and presented data on trade prices, volumes, timing, and other transaction specifics (Kumar, 2022). They control data access, its content, timing, and cost. As platforms that compile information, exchanges have the potential to enhance market visibility regarding the attributes of ESG-linked derivatives. However, this proves to be a challenge in ESG markets due to the scarcity of high-quality, standardised data. All sustainable investments, including ESG-linked derivatives, heavily rely on data. While there has been a notable rise in ESG data providers, the field lacks standardised ESG metrics and methodologies. Exchanges can contribute significantly by utilising their data capabilities to address this challenge. Regulations can address this challenge by establishing standardised ESG frameworks that institutions must follow. This implementation would enable the collection of more diverse ESG metrics across various sectors and industries (Nystedt, 2004).

3.3.1 Standardisation

ISDA (2022*b*) states that standardisation is an important aspect of any financial market, including the ESG-linked derivatives market. In this section, we will discuss the importance of standardisation in the ESG-linked derivatives market, its benefits, and the challenges it faces.

standardisation refers to the development and implementation of uniform guidelines, rules, and procedures for financial products. In the context of ESG-linked derivatives, standardisation involves the establishment of common definitions, methodologies, and reporting requirements for ESG-linked data and metrics. This can help to increase transparency, reduce operational risk, and promote market growth.

One of the main benefits of standardisation is increased transparency. standardisation can help to ensure that ESG data is comparable across different financial products and issuers, making it easier for investors to assess the environmental and social impact of these products. This can help to increase investor confidence and promote the development of the ESG-linked derivatives market (Baker, 2022).

Baker (2022) states that another benefit of standardisation is the reduction of operational risk. standardisation can help to simplify the process of developing and issuing ESG-linked derivatives, making it easier for issuers and investors to understand and manage the associated risks. This can help to reduce the cost and complexity of ESG-linked derivatives transactions, making them more accessible to a wider range of investors.

Finally, standardisation can help to promote market growth. By establishing common definitions and reporting requirements for ESG data and metrics, standardisation can help to create a more efficient and effective market for ESG-linked derivatives. This can attract more issuers and investors to the market, leading to increased liquidity and more diversified investment opportunities (ISDA, 2022*b*).

Despite these benefits, standardisation in the ESG-linked derivatives market faces several challenges. One of the main challenges is the lack of consensus on ESG-linked definitions, metrics, and methodologies. There is currently no widely accepted set of standards for ESG data and metrics, which can make it difficult for investors to compare and assess the environmental and social impact of different financial products.

Another challenge is the lack of regulatory oversight in the ESG-linked derivatives market. Unlike other financial markets, such as the stock and bond markets, there is currently no regulatory body that oversees the development and issuance of ESG-linked derivatives. This can make it difficult to establish and enforce standardisation requirements (ISDA, 2021*a*).

Finally, there is a lack of industry-wide collaboration and coordination in the ESG-linked derivatives market. Many issuers and investors are still developing their own ESG-linked metrics and methodologies, which can lead to confusion and inconsistencies in the market. To overcome these challenges, greater collaboration and coordination among issuers, investors, and regulators is needed to establish and enforce common standards for ESG data and metrics.

3.3.2 Regulatory Framework

The regulatory framework for ESG-linked derivatives is a work in progress, exhibiting differing levels of regulation in various regions and jurisdictions. Generally, ESG-linked derivatives abide by the same regulatory standards as other financial derivatives but require additional consideration for ESG risk factors. ISDA (2021*a*) released a publication outlining the regulatory environment in distinct jurisdictions, focusing on the EU and US with regards to ESG-linked derivatives. It's important to note that this research assignment doesn't delve into the specific regulatory frameworks for ESG reporting within institutions, but rather focuses on categorising an ESG-linked derivative within the broader derivative form.

In the European Union, the ESMA (2022) has issued guidelines on disclosure requirements for ESG-linked products, including derivatives. These guidelines require the disclosure of information on the ESG characteristics of the underlying assets, as well as information on how ESG factors are integrated into the investment process.

The regulatory environment in South Africa has been modified by regulatory agencies to incorporate ESG requirements in the financial industry in response to the increased interest in sustainable finance. National Treasury (2021) revised its technical document Financing a Sustainable Economy, which was initially published in May 2020, and reissued it in October 2021. In order to enable the transition to a low-carbon and climate-resilient economy, including net-zero carbon emissions by 2050, the paper provides the groundwork for long-term investment in sustainable economic assets, activities, and initiatives.

Some authorities are contemplating enacting obligatory reporting requirements for ESG elements in addition to existing recommendations and subcommittees. For instance, FCA (2021) is thinking of requiring some issuers and asset managers to provide information on the climate-related issues on an obligatory basis.

There are still opportunities for development and gaps despite the fact that these legislation and standards offer a foundation for ESG-linked derivatives. For instance, the absence of a universal standard for ESG reporting might make it challenging to evaluate ESG traits among various issuers and assets.

Overall, as ESG factors grow more significant for investors and the financial markets as a whole, the legal environment for ESG-linked derivatives and reporting is expected to keep changing.

The following section examines the risks that can evolve from introducing ESG-linked derivatives in the financial system.

3.4 RISKS OF ESG-LINKED DERIVATIVES

Financial innovations that aim to bring positive social impact can inadvertently introduce risks, heightening the fragility of the financial system. Presently, ESG-linked derivatives represent an emerging and specialised market, reminiscent of the early stages of the Credit Default Swap (CDS) market. Over time, the CDS market evolved into a significant platform for credit risk transfer. ISDA (2022*a*) observes a growing interest in ESG-linked derivatives, predicting that heightened collaboration among market participants, standardised market documentation, and enhanced portfolio efficiencies in ESG-linked derivatives could expedite this market's expansion. Although the ESG-linked derivatives market currently operates on a bespoke basis, following a trajectory similar to that of the CDS market, it might encourage counterparties to develop KPI frameworks, enhancing efficiencies across various instruments and products.

Derivatives, especially those traded OTC, serve as a substantial revenue source for dealer banks but also pose systemic risks to the global financial system. While the ESG-linked derivatives market, at its present size, might not present a significant systemic risk, its expansion may potentially result in such implications. It is undeniable that derivatives, including ESG-linked ones, play a role in risk management via hedging while simultaneously introducing substantial leverage in the financial system, leading to market instability. The fast-paced growth of sustainable finance contributes to the significant leverage in the financial system. For example, a projection by Ahark (2021) anticipates a substantial rise from the current \$2.2 trillion ESG debt market to \$11 trillion by 2025, with derivatives acting as a catalyst for this growth. ESG-linked derivatives can serve as a vital mechanism to promote ESG objectives. However, similar to derivatives in general, they also introduce risks that, if left unregulated, could undermine their intended positive societal impact.

Systemic risk, as defined by Baker (2022), is the threat that the failure of a financial institution or market activity could trigger a chain reaction of collapses across the financial system, significantly impacting financial markets and the economy. Derivatives, especially OTC contracts, are a notable source of this risk. An increase in speculation levels with ESG derivatives could heighten the systemic risk these derivatives already contribute to the financial system. Even if institutions hedge climate risk, they contribute to the overall risk in the financial system. If both parties in a derivative contract - whether ESG-linked or "vanilla" - are speculators, it generates financial system risk. In these cases, even if the contract is ESG-linked, the outcome may purely result in a financial return for the winning party. Strong margin requirements are vital in mitigating excessive speculation levels in derivatives markets.

KPIs are instrumental in the development of ESG-linked derivatives. The forthcoming chapter is dedicated to emphasising the essentiality of identifying and validating these KPIs, pivotal in the construction process of ESG-linked derivatives.

3.4.1 ESG-linked Derivatives in South Africa

In South Africa, sustainability bonds and ESG-linked loans have been more popular, according to a report by KPMG (2022). A rising dedication ESG values is reflected in these financial products. Even while South African corporations have adopted ESG practices in significant numbers, the market for ESG-linked derivatives remains relatively underdeveloped.

While a growing number of South African organisations are incorporating ESG efforts into their strategy, there is still much unexplored potential for ESG-linked derivatives. This market sector is a more recent frontier that South Africa has not yet thoroughly investigated or made use of. Growing this industry may open up new avenues for investment and innovation, supporting the country's larger sustainability goals and showcasing a thorough dedication to ESG objectives in the financial system.

This section provided a broad overview of derivatives and their connection to ESG. It also discussed the challenges and risks associated with ESG-linked derivatives. The next chapter delves into the KPIs used in constructing ESG-linked derivatives, along with examples and challenges related to these KPIs.

CHAPTER 4

KEY PERFORMANCE INDICATORS

4.1 KPI PRINCIPLES

KPIs are a critical tool for measuring the environmental, social and governance impact on financial products, including ESG-linked derivatives. KPIs allow investors to evaluate the sustainability performance of companies and portfolios, and make informed investment decisions based on their sustainability objectives.

Several examples are mentioned below, but ISDA (2021*c*) proposes five overarching principles that counterparties should adhere to in order to ensure the credibility of KPIs. According to (ISDA, 2021*c*), KPIs should be:

Specific - Counterparties needs to ensure that KPIs are well-defined and tailored to address specific aspects of ESG performance. This means identifying precise metrics that align with your organisation's goals and ESG priorities. For example, instead of a vague sustainability metric, specify a KPI like "Reducing GHG emissions by 15% by 2025."

Measureable - KPIs that is used should be quantifiable, allowing for the collection of numerical data to track progress over time. Establish clear measurement criteria and metrics to gauge ESG performance effectively. For instance, use metrics like "Tons of waste recycled per quarter" or "Percentage increase in renewable energy usage."

Verifiable - Ensure that the data used to calculate KPIs can be verified through credible sources. This involves maintaining robust data collection and reporting processes. Third-party verification can enhance the credibility of the reported KPIs, making them more trustworthy for stakeholders.

Transparent - KPI calculation methodologies and data sources should be made transparent and easily accessible to stakeholders. Transparency builds trust and allows interested parties to understand how KPIs are determined. Publish detailed information on how the KPIs are calculated and any relevant assumptions made.

Suitable - KPIs that are relevant to your organisation's ESG goals and that align with your industry and context must be considered. Avoid using generic or metrics that is not relevant to your industry. Instead, choose KPIs that reflect your organisation's unique sustainability challenges and opportunities. Tailor the KPIs to be suitable for your specific business operations and objectives.

In practice, adhering to these principles ensures that your organisation's ESG performance metrics are well-defined, measurable, verifiable, transparent, and closely aligned with your sustainability goals, making them effective tools for tracking and improving sustainability outcomes.

ISDA (2021*c*) states that KPIs are also used to evaluate the effectiveness of ESG-linked derivatives in achieving their sustainability objectives. By measuring the impact of ESG-linked derivatives, investors can assess whether these products are contributing to the transition to a more sustainable economy. This information can be used to make informed investment decisions and to engage with companies and issuers to improve their sustainability performance.

The following sections aims to provide a few examples that can be used as KPI in order to construct a ESG-linked derivative.

4.2 KPI EXAMPLES

KPIs serve as prevalent tools for assessing a broad spectrum of ESG factors. The selection of particular ESG KPIs often hinges on the industry, the scale of the company, and the distinct sustainability objectives in place. Nevertheless, examples of distinct ESG KPIs tailored for each of these core factors are elaborated upon in Tables 4.1, 4.2 and 4.3. It is important to note that while this isn't an exhaustive compilation, it offers a comprehensive overview of potential metrics within each category.

Table 4.1: Environmental KPIs

KPI	**Examples of Metrics**
Greenhouse Gas (GHG) emissions	Total emissions, emissions intensity, and reduction targets
Energy consumption	Total energy usage, renewable energy usage, and energy efficiency improvements
Water usage	Total water consumption, water efficiency measures, and water recycling/reuse initiatives
Waste management	Total waste generation, recycling rates, waste reduction initiatives, and hazardous waste handling

Table 4.2: Social KPIs

KPI	Examples of Metrics
Employee diversity and inclusion	Workforce diversity metrics, gender and racial diversity, and representation in leadership positions
Customer satisfaction and product safety	Customer feedback, and product quality and safety records
Community engagement	Community investment, social impact projects, and partnerships with local organisations
Employee satisfaction and well-being	Retention rates, health and safety incidents, and employee training and development programs

Table 4.3: Governance KPIs

KPI	Examples of Metrics
Board diversity	Composition of the board of directors in terms of gender, race, and expertise
Executive compensation	Alignment of executive pay with ESG performance and long-term sustainable goals
Risk management	Processes to identify and mitigate risks related to ESG factors, including climate change, data privacy, and supply chain risks

To effectively implement the aforementioned KPIs, it is crucial to ensure their alignment with the five overarching principles of KPIs as discussed in Section 4.1. KPIs serve as the primary component of ESG-linked derivatives, emphasising the need for meticulous selection, measurement, and validation of the appropriate KPIs for use in these financial instruments. There are a few challenges associated with the KPIs, the next section aims to highlight these challenges and how it can be resolved.

4.3 CHALLENGES OF KPIS

However, there are some challenges associated with the use of KPIs in ESG-linked derivatives. One challenge, according to Berg *et al.* (2022), is the divergence of ESG ratings and the lack of standardisation and consistency in the application of KPIs across different sectors and industries. This can make it difficult for investors to compare the sustainability performance of different companies and products.

Another challenge is the reliability and accuracy of the data used to calculate KPIs (Karia, 2022). In many cases, ESG data is self-reported by companies and issuers, which can lead to inconsistencies and inaccuracies. In addition, the lack of mandatory reporting requirements for ESG data can make it difficult to obtain complete and reliable data.

(ISDA, 2022*a*) states that sufficient disclosure and verification of KPIs is fundamental to the efficacy of ESG-linked derivatives. Disclosure is the process of providing information relating to the performance of a relevant entity against a KPI. Verification is the process of using that disclosed information to check whether that entity has satisfied the relevant ESG target. There are some key points to focus on when agreeing disclosure requirements (ISDA, 2021*c*).

(ISDA, 2022*a*) proposes that when handling the disclosing of KPIs information in transactions, several key considerations should be taken into account. Firstly, there must be a clearly defined process for sharing KPI data within counterparties' documentation. Secondly, it is vital to establish explicit deadlines and timeframes to ensure that counterparties have adequate time to verify the information before any payment adjustments occur. The use of staged disclosure obligations can be beneficial, especially in cases of short-term transactions that may mature before the initial disclosure.

Thirdly, ISDA (2022*a*) states that practical factors such as legal and regulatory obligations, third-party interpretation, and the need to clarify how KPI data was compiled, including assumptions and inputs, are critical during the disclosure process. Counterparties may also incorporate notification mechanisms and legal remedies in case of incorrect information. Fourthly, counterparties have the option to seek assurances through representations, warranties, and undertakings, particularly when using third-party data, necessitating the inclusion of clear disclaimers and warnings.

Lastly, in situations where deficiencies in KPI disclosure are identified during verification, the relevant counterparty should possess the right to request additional or corrected data, which may involve third-party verifiers or the establishment of a representative committee. Consequences for non-disclosure, including potential economic penalties or termination rights, should also be documented.

(ISDA, 2022*a*) proposes that when establishing verification requirements, it's crucial to address practical considerations, particularly for KPIs that may necessitate on-site or similar verification, potentially encountering practical obstacles. Contracts should include fallback provisions for cases where verification is challenging due to a lack of reference points or information. Additionally, standardised outputs in the verification process offer operational efficiency and streamline back-end processes, making it easier to manage life-cycle events. As institutions adopt their own standardisation practices, it's expected to lead to more widespread standardisation in the market.

This standardisation facilitates the assessment of products offered by different parties and promotes interoperability between counterparties. When selecting a verifying entity, counterparties should decide whether to use a third-party verifier to mitigate disputes and reputational risks. Disclosing potential conflicts of interest for third-party verifiers is essential. Some KPIs may require government or government agency involvement, making the ability of the verifying entity to interact with such entities a crucial consideration (ISDA, 2022*a*).

Overall, ESG considerations are reshaping the way companies measure and manage their performance. The integration of ESG-related KPIs enables companies to demonstrate their commitment to sustainability, stakeholder engagement, and long-term value creation. It helps them align their strategies with emerging trends, expectations, and regulatory frameworks, fostering responsible and sustainable business practices.

In summary, KPIs are a critical tool for measuring the environmental, social and governance impact of financial products, including ESG-linked derivatives. While there are some challenges associated with the use of KPIs, they are essential for enabling investors to make informed investment decisions and for promoting the transition to a more sustainable economy through ESG-linked derivatives.

The next chapter introduces the model that is used in constructing ESG-linked derivatives, as well as the assumptions underlying the model.

CHAPTER 5

PRICING AND VALUATION OF ESG-LINKED DERIVATIVES

5.1 MODEL SPECIFICATIONS

5.1.1 Model Overview

This research assignment discusses ESG-linked derivatives, which consist of two main elements: the base product and the KPI option (Karia, 2022). The base product can include various financial instruments like bonds, mortgages, credit rate swaps, and interest rate swaps, each with an associated interest rate or spread provided by the bank (Baker, 2022). Alongside the base product, the KPI option is integrated, impacting the interest rate or spread offered by the bank.

To determine the pricing of this product, both the base product and the KPI option must be valued and combined to establish the value of the ESG-linked financial product.

To illustrate how the valuation of an ESG-linked derivative works, consider an interest rate swap (IRS) as the base product. Suppose Company XYZ acquires an IRS with an ESG component, making fixed payments and receiving floating payments linked to the Secured Overnight Financing Rate (SOFR) at future times $0 < t_1 < \cdots < t_n$ on a notional amount, N. However, if a predefined Sustainability Performance Target (SPT) is met at a specified date $t_\tau < t_n$, Company XYZ receives a discount on the fixed payments made between time t_τ and t_n. This discount can be a few basis points of the notional amount (N), is calculated as $Q = bps \cdot N$ and it applies to each of the fixed payments that is made between time t_τ and t_n.

The SPT is established as a condition based on one or several KPIs compared to a defined baseline, denoted as D. In the context of this model, it's assumed that the SPT is associated with a single metric known as KPI_t and that the SPT is met if $KPI_t > D \cdot KPI_0$ with $D > 1$ for a KPI that needs to increase and $KPI_t < D \cdot KPI_0$ with $D < 1$ for a KPI that needs to be reduced. For instance, if KPI_t refers to carbon emissions and the conditionality would be on a 30% emissions reduction by the measurement date τ, D is set to 0.7.

It is important to note that when the KPI needs to be increased, a call option is utilised, and when a KPI needs reduction, a put option is utilised. The SPT is structured in a manner that the option is only exercised when the SPT is achieved, aligning with market conventions. Furthermore, the option is of European knock-in style, which means that once it is triggered at time t_τ, it remains active, even if the company continues to perform in line with or better than the SPT after t_τ.

Since the SPT is contingent on improving the KPI between t_0 and t_τ, meaning that in the case where an KPI needs to be increased, KPI_0 will be below $D \cdot KPI_0$ $(D > 1)$, and in the case where the KPI needs to be reduced, KPI_0 will be above $D \cdot KPI_0$ $(D < 1)$. As a result, both the call and put option is out-of-the-money (OTM) at the time the ESG-linked derivative is issued.

Consider a scenario where Company XYZ is required to achieve a SPT related to reducing carbon emissions from KPI_0, at the time the IRS is issued, to the level of $D \cdot KPI_0$ with $D < 1$. Company XYZ is thus long an OTM European put option observed at time t_τ, that has a maturity of t_n and strike price of $D \cdot KPI_0$. If the put is ITM at the observed time, t_τ, meaning that the SPT is met, Company XYZ will receive a discount on the fixed payments on the IRS between t_τ and the IRS's maturity t_n.

Therefore, Company XYZ is effectively buying a "traditional" IRS $\left(IRS_0^1\right)$ and a put option $\left(IRS_0^2\right)$ called if the SPT is met. Thus:

$$IRS_0 = IRS_0^1 + IRS_0^2, \tag{5.1}$$

where IRS_0^1 refers to the price of a vanilla IRS where Company XYZ pays a fixed rate and receive a floating rate at predetermined intervals. In this research assignment, the significance lies in the second term of Equation (5.1), which can be computed as follows:

$$IRS_0^2 = \mathbb{E}\left[\sum_{t=\tau}^{n} 1_{\{KPI_\tau \leq \mathrm{D} \cdot KPI_0\}} \times Q_t\right]. \tag{5.2}$$

Assuming that Q_t and KPI_t are independent, IRS_0^2 can be written in the following form:

$$IRS_0^2 = \mathbb{E}\left[1_{\{KPI_\tau \leq D \cdot KPI_0\}}\right] \cdot \mathbb{E}\left[\sum_{t=\tau}^{n} Q_t\right]. \tag{5.3}$$

The equation simply specifies that the value of the option is the probability that the SPT will be met multiplied by the discounted value of the discount on the fixed payment if the option is triggered, which is similar to a binary option as outlined by Hull (2018).

For the purpose of this research assignment, the dynamics of interest rates are not specified and assume they are deterministic. Therefore, the discount factor can be expressed as $B(0,t) = e^{-r_t t}$, with r_t being the risk-free interest rate at time t. Equation (5.3) can be reduced to a simpler expression. The pricing is done under a risk-neutral framework, thus the expected value of the future cash flows is just the discounted cash flows to time 0 using the risk-free rate, using the discount factor, $B(0,t)$:

$$IRS_0^2 = \mathbb{E}\left[1_{[KPI_\tau \leq D \cdot KPI_0\}}\right] \cdot \sum_{t=\tau}^{n} \frac{Q_t}{B(0,t)}. \tag{5.4}$$

Breaking down the IRS pricing so far, it can be seen that at the core of the pricing is a measure of the probability that the SPT will trigger, $\mathbb{E}\left[1_{(KPI_\tau \leq D \times KPI_0]}\right]$.

Specifically define the dynamics of the hypothetical process driving whether the sustainability condition will be met or not, i.e. how to specify KPI_t in order to evaluate $\mathbb{E}\left[1_{(KPI_\tau \leq KPI_0\}}\right]$?

5.1.2 Geometric Brownian Motion (GBM)

This section aims to define a process for KPI_t in order to evaluate the above mentioned probability.

Firstly, fix a filtered probability space $(\Omega, \mathcal{F}, \mathbb{P})$ equipped with an information filtration $\{\mathcal{F}_t : t \in [0,\infty)\}$, that specifies for each time t the set $\mathcal{F}_t$ of events that are observable at that time. The filtration given by $\{\mathcal{F}_t : t \in [0,\infty)\}$, is rich enough to provide all sources of certainty. Here, the set Ω contains the possible states of the world and $\mathcal{F}$ consists of the subsets of Ω, called "events," to which a probability can be assigned. The probability measure $\mathbb{P} : \mathcal{F} \to \mathbb{R}$ assigns a probability $\mathbb{P}(A)$ to each event A.

Suppose that the stochastic process $\boldsymbol{KPI} = \{KPI_t : t \in [0,\infty)\}$ satisfies the stochastic differential equation (SDE) under the risk-neutral pricing framework:

$$\frac{dKPI_t}{KPI_t} = \delta dt + \sigma dW_t. \tag{5.5}$$

According to the general theory of SDEs, this particular problem yields a unique solution, a GBM with appropriate parameters and can be written as (Orlandi, 2023):

$$KPI_t = KPI_0 \exp\left[\left(\delta - \frac{\sigma^2}{2}\right)t + \sigma W_t\right], \quad t \in [0, \infty). \tag{5.6}$$

where W_t is the Wiener process $\sim N(0,1)$, generated by the filtration defined above, and δ (the "drift") is the general trend that the company needs to catch up to in terms of its sustainability target (Mielnik and Erlandsson, 2022). This parameter essentially guides on what the company needs to outperform on, in order to get a discount on their fixed leg payments. Note that the drift (δ) is different from the risk-free rate (r), in the sense that the drift is the trend that the KPI of the company should catch up to in order to meet a sustainability target, whereas the risk-free rate is used to discount the cash flows to time 0. More specific measures are discussed below.

The parameter σ provides the volatility metric of this stochastic process (Mielnik and Erlandsson, 2022). In this framework, it can be seen that this reflects two dimensions: Firstly, the magnitude of the stochastic variables affecting the company in terms of normal random events (e.g. changes in demand, etc); and secondly the capacity for the company to influence the evolution of the sustainability factor themselves (Mielnik and Erlandsson, 2022). This number can also be interpreted as a measure of the confidence that Company XYZ has means to actually meet the SPT.

The SDE in Equation (5.5) allows for Monte Carlo simulation. Monte Carlo simulation enable the alteration of drift and volatility parameters, providing insight into their influence on the option's price. Such modifications offer a comprehensive understanding of how changes in these parameters affect the option's valuation in various scenarios. Section 6 conducts a thorough Monte Carlo study to examine the impact of the drift and volatility parameters, alongside other factors, on the price of the option.

Example: Imagine Company XYZ engages in an ESG-linked derivative involving an interest rate swap. In this arrangement, the fixed interest payment is tied to an ESG objective, which, in this case, is a commitment by Company XYZ to reduce its thermal coal production by 50% within five years. Now, the counterparty entering into this agreement with Company XYZ holds the belief that meeting such a condition is highly improbable. Achieving this goal would necessitate a fundamental transformation of Company XYZ's current business model, making it unlikely that they will receive the discounted interest payment. From the counterparty's perspective, the optionality in this scenario becomes exceptionally valuable because of the low probability of Company XYZ meeting the KPI.

To take this a step further, Company XYZ might be able to negotiate a more favorable deal, obtaining a higher discount and a lower cost of capital, by setting an ambitious target. This depends on the counterparty's perception of the volatility and probability factors in relation to the ESG target. It's important to note that these factors may be viewed differently depending on whether you are the counterparty or Company XYZ.

Using Monte Carlo simulation, the estimation of $\mathbb{E}\left[1_{[KPI_\tau \leq D \cdot KPI_0\}}\right]$ where $D = 0.5$ involves simulating the thermal coal production KPI at the time of the IRS issuance (KPI_0) through the differential equation specified in Equation (5.5). The simulation spans the agreed-upon five-year period. The probability that Company XYZ will meet the SPT ($0.5 \cdot KPI_0$) equates to the average instances where the simulated KPI, after five years, aligns with the SPT ($KPI_5 \leq 0.5 \cdot KPI_0$). Since the KPI needs to be reduced, it can be viewed as a put option. Subsequently, the option's price can be represented as:

$$IRS_0^2 = \mathbb{E}\left[1_{[KPI_5 \leq 0.5 \cdot KPI_0\}}\right] \cdot \sum_{t=5}^{n} \frac{Q_t}{B(0,t)}. \tag{5.7}$$

The next section aims to derive a closed form solution of the simulation method that is used in the pricing of the ESG-linked derivative.

5.1.3 Closed-form Solution

The preceding section introduced a method for modeling KPI_t, suitable for simulation purposes. This section expands upon that by aiming to develop a closed-form solution for estimating the probability of meeting a SPT.

Referring to Equation (5.6), the mean and standard deviation of the logarithm of the KPI are clearly defined within a geometric Brownian motion process, easily ascertainable using the GBM equation. Hence, by applying the natural logarithm to both sides of Equation (5.6),the following is obtained:

$$\ln(KPI_t) = \ln(KPI_0) + \left(\delta - \frac{\sigma^2}{2}\right)t + \sigma W_t, \quad t \in [0, \infty). \tag{5.8}$$

From Equation (5.8) and the fact that $W_t \sim N(0,1)$, it can be derived that:

$$\ln(KPI_t) \sim \Phi\left(\left(\delta - \frac{\sigma^2}{2}\right), \sigma^2 t\right). \tag{5.9}$$

Thus,

$$\frac{\ln(KPI_t) - \ln(KPI_0) - (\delta - \frac{1}{2}\sigma^2)t}{\sigma\sqrt{t}}, \tag{5.10}$$

is a standard normal variable with expected value of zero and standard deviation of one. Utilizing standardization as shown in Equation (5.10), a closed-form solution for $\mathbb{E}\left[1_{(KPI_t \leq KPI_0\}}\right]$ can be derived, which essentially estimates $\mathbb{P}(KPI_t \leq D \cdot KPI_0)$ or in simpler terms, the probability that a SPT will be met.

From Equations (5.9) & (5.10), it can be derived that:

$$\begin{aligned}
\mathbb{P}(KPI_t \leq D \cdot KPI_0) &= \Phi\left(\frac{\ln(D \cdot KPI_0) - \ln(KPI_0) - (\delta - \frac{1}{2}\sigma^2)t}{\sigma\sqrt{t}}\right) \\
&= \Phi\left(\frac{\ln\left(\frac{D \cdot KPI_0}{KPI_0}\right) - (\delta - \frac{1}{2}\sigma^2)t}{\sigma\sqrt{t}}\right) \\
&= \Phi\left(-\frac{\ln\left(\frac{KPI_0}{D \cdot KPI_0}\right) - (\delta - \frac{1}{2}\sigma^2)t}{\sigma\sqrt{t}}\right) \\
&= \Phi\left(-d_2\right),
\end{aligned} \tag{5.11}$$

with:

- Φ the cumulative Gaussian distribution function,
- $d_2 = d_1 - \sigma\sqrt{t}\ ,\ d_1 = \frac{\ln\left(\frac{KPI_t}{D \cdot KPI_0}\right) + \left(\delta + \frac{\sigma^2}{2}\right) \cdot t}{\sigma\sqrt{t}}$,
- $D \cdot KPI_0$ being the option's strike price.

Estimating the probability that the SPT will be met can be reduced to the closed form of the Black-Scholes formula for a binary put option. This involves using the cumulative distribution function, denoted as $\Phi()$, of the standard normal distribution at the value $-d_2$ for put options. Similarly, for call options, the probability is calculated at d_2, which can be derived in a manner analogous to $-d_2$. The closed-form solution for pricing the option, denoted as IRS_0^2, can thus be expressed as:

$$IRS_0^2 = \Phi\left(-d_2\right) \cdot \sum_{t=\tau}^{n} \frac{Q_t}{B(0,t)}. \tag{5.12}$$

Equation (5.12) is equivalent to Equation (5.7), where equation (5.7) is using Monte Carlo simulation in order to estimate the probability of the KPI meeting the SPT, whereas Equation (5.12) uses the closed form solution as proposed by Hull (2018).

In the realm of option pricing, let's consider Company XYZ. They are essentially purchasing a European put option, but with a unique twist — it is a binary option. This means the outcome isn't tied to the direct price of the underlying asset, but rather, it's determined by a separate stochastic process. On the other side of this transaction, we have the counterparty, acting as the seller of this call option. They receive the premium that Company XYZ pays for the option.

The key factors that influence the option's value include the KPI, drift, volatility, and the specific call dates. These variables collectively determine whether the option is in-the-money or out-of-the-money at the time of issuance. This classification has a direct impact on the pricing of the option and its associated IRS.

This section aimed to develop the closed for solution of the simulation model that is used in constructing ESG-linked derivatives. The following section examines how the input parameters, drift (δ) and volatility (σ), are calibrated.

5.2 CALIBRATION OF DRIFT (δ) AND VOLATILITY (σ)

In the preceding section, it is discussed how the value of the embedded option within an IRS hinges on the calibration of two critical factors: the drift and volatility of the KPI. The most straightforward approach to calibrate these option parameters involves delving into the historical data of the KPI, thereby deducing its behavior over time.

To simplify, in order to predict the probability of the KPI reaching a specific SPT, the historical patterns of the underlying KPI must be understood. Earlier in this research assignment, the principles that counterparties should adhere to in order to ensure the credibility of KPIs, are discussed.

For the purpose of this methodology, an IRS with KPIs that fulfil the conditions and principles discussed is termed a Priceable Discount IRS (PD-IRS). This essentially means that a probability distribution for the probability of a discount occurring can be estimated. Conversely, IRSs where such estimations are challenging or impossible are labeled as Non-Priceable Discount IRS (NPD-IRS).

Mielnik and Erlandsson (2022) state that it is essential to note that this distinction doesn't reflect the non-financial impact's quality in either category. An NPD-IRS might have a more substantial non-financial impact and thus hold implicit value for investors seeking such attributes. However, this research assignment emphasises that an NPD-IRS must be priced differently from a PD-IRS. The advantage of the PD-IRS lies in its partial pricing under the methodology presented here, potentially resulting in a lower uncertainty premium, ceteris paribus, in comparison to the NPD-IRS.

In the context of this research assignment's consideration of a Priceable Discount Interest Rate Swap (PD-IRS) and assuming a law-of-motion as of Equation (5.5), the focus now shifts to the process of calibrating the drift and volatility parameters.

Drift - δ

According to Mielnik and Erlandsson (2022), the drift parameter can be thought of as a measure of an acceptable trend, akin to the minimum rate of improvement in a KPI that aligns with a robust benchmark. To illustrate, in the context of carbon emissions, it can represent a macro-level goal, such as the annual reduction in absolute emissions needed to meet the targets of the Paris Agreement (Agreement, 2015).

For instance, according to IPCC (2022), to keep global warming below 2 degrees Celsius, emissions must decrease by 25% from 2010 levels by 2030, which translates to, according to Mielnik and Erlandsson (2022), a reduction of approximately 2.84% per annum. In the more stringent 1.5 degrees Celsius scenario, the required decline is steeper at 45%, equivalent to an annual reduction of about 5.80%. In this context, the drift parameter sets the rate for achieving these emission reduction goals in line with the Paris Agreement.

The extent of emissions reduction needed to meet climate goals varies across different sectors and industries. However, until specific reduction benchmarks become widely accessible at a portfolio level, a broader, overarching emissions target can serve as a guide for investors seeking to align their diverse investments with the goals set out in the Paris Agreement.

Mielnik and Erlandsson (2022) suggest that there are additional, more detailed methods to adjust for drift. These methods involve analysing the specific characteristics of issuances, such as:

- Historical data.
- Science-based targets.
- Issuer's own declared sustainability targets.
- Climate scenarios.
- Regulatory requirements.

This underscores the necessity for additional investigation into relevant drift terms. However, concentrating on a single drift term offers the advantage of making it comparable across various ESG-linked financial products. This allows investors to establish initial benchmarks for ambition levels within these comparisons.

Volatility - σ

To factor in the issuer's ability to control its KPI (e.g. carbon emissions), Mielnik and Erlandsson (2022) propose expressing volatility in the following manner:

$$\sigma = \sigma_i \cdot \beta, \tag{5.13}$$

where:

- σ_i is the KPI's historical volatility (σ_i), calculated from historical data.
- β quantifies the extent to which a company or entity can exert control over its KPI.

Calibrating the β parameter can be a challenging task, according to Mielnik and Erlandsson (2022), primarily because it relies on how the counterparties perceive Company XYZ's sustainability profile.

When there is not a strong consensus on these perceptions, it is advisable to set $\beta = 1$ as a straightforward approach.

When considering adjustments to the β parameter, it's essential to account for how Company XYZ is perceived in terms of its commitment to improving its carbon emissions profile. If Company XYZ is seen as unlikely to make significant improvements, potentially lacking a credible transition plan or strong management support, the β value would be less than 1. On the other hand, if Company XYZ demonstrates a firm commitment to transitioning to a low-carbon production process, the β value would exceed 1.

This relates to the previous discussion about the disparities between how counterparties view the probability of achieving the SPT compared to Company XYZ's own beliefs. These differences are reflected in the varying β values. Assuming that the counterparty holds a belief denoted as β, and Company XYZ has its own β^*, with β being less than β^*, it becomes clear that the counterparty's volatility assumption will be lower than that of Company XYZ. This results in a scenario where Company XYZ can benefit from a higher discount on its fixed payment.

The following section investigates how the model transforms when it integrates two KPIs instead of the single KPI used thus far

5.3 MULTIPLE KPIS

Until now, the pricing of ESG-linked derivatives has primarily revolved around a single KPI. However, it's worth noting that an IRS can be influenced by multiple KPIs. For example, an IRS could incorporate two KPIs related to carbon emissions and the percentage of women on the board, respectively.

While the inclusion of multiple KPIs may convey the issuer's strong commitment to sustainability practices throughout the organisation, it introduces a significant challenge in terms of pricing complexity. Moreover, this complexity highlights the importance of distinguishing between Priceable Discount (PD) and Non-Priceable Discount (NPD) IRSs.

In essence, the incorporation of several KPIs in ESG-linked derivatives pricing underscores the evolving landscape of sustainable finance and the intricacies that come with it, particularly in differentiating between derivatives that can be easily priced and those that are more complex.

If an IRS is dependent on two KPIs, with KPI^1 focused on reducing carbon emissions and KPI^2 related to increasing the percentage of women on the board, then Equation (5.2) becomes:

$$IRS_0^2 = \mathbb{E}\left[\sum_{t=\tau}^{n} 1_{\{KPI_\tau^1 \leq \text{D}\cdot KPI_0^1\}} \cdot 1_{\{KPI_\tau^2 \geq \text{W}\cdot KPI_0^2\}} \times Q_t\right]. \tag{5.14}$$

To determine the value of IRS_0^2, it's necessary to either model the correlation between KPI^1 and KPI^2 or assume they have an independent relationship. Regarding independence, research conducted by Cek and Eyupoglu (2020) suggests that, even if KPIs belong to different ESG categories, there tends to be a significant correlation between them. Their study focused on ESG factors within S&P companies and found that the average correlation between E and S factors are 0.79, between E and G factors are 0.64, and between S and G factors are 0.63. In the case where correlation exists, it needs to be explicitly incorporated into the model. This is relatively straightforward in a bivariate case if you have enough data, but, according to Mielnik and Erlandsson (2022), it becomes more complex when dealing with three or more KPIs that may not have easily measurable or high-quality data. In general, due to data availability challenges, defining the dynamics of a single time-series in the ESG context is already difficult, let alone considering the interdependence between multiple time-series, making it challenging to define such instruments as PD-IRSs.

An alternative approach, as proposed by Mielnik and Erlandsson (2022), is an IRS that offers multiple discounts, each tied to a different KPI. This approach eliminates the necessity to model the correlation between various KPIs.

The following chapter utilises the model proposed in this chapter, to assess the performance of pricing ESG-linked derivatives, and to examine how changes in input parameters can impact their pricing.

CHAPTER 6

ANALYSES AND RESULTS

6.1 MODEL PARAMETERS

This section utilises Monte Carlo simulation to estimate the option that supplements the "base" product in pricing the ESG-linked derivative (as detailed in Section 5.1). The model employs various parameters to understand the effect of each on the option's price. The parameters used within this model include:

Table 6.1: Model parameters

Parameters
KPI_0
KPI_{goal} or SPT
Risk-Free Rate (rfr)
Drift (δ)
Volatility (σ)
Time to maturity of the underlying option (T)
Observations per year (obs)
Time to maturity of the underlying contract, e.g. IRS (mat_underlying)
Basis points (bps)
Notional amount of the underlying contract (N)
Number of simulations

KPI_0 represents the initial value of the KPI tied to the ESG-linked derivative at the contract's issuance. This value forms the basis for the Monte Carlo simulation. On the other hand, KPI_{goal}, or SPT, defines the Sustainable Performance Target. Achieving this target triggers a discount on the contract. Setting an appropriate SPT requires careful consideration, as too low a target may not significantly impact ESG factors, while an overly high target could be unattainable for the option buyer. The risk-free rate is applied to discount cash flows back to time 0 for option pricing. The drift and volatility parameters, as well as their calibration are detailed in Section 5.2.

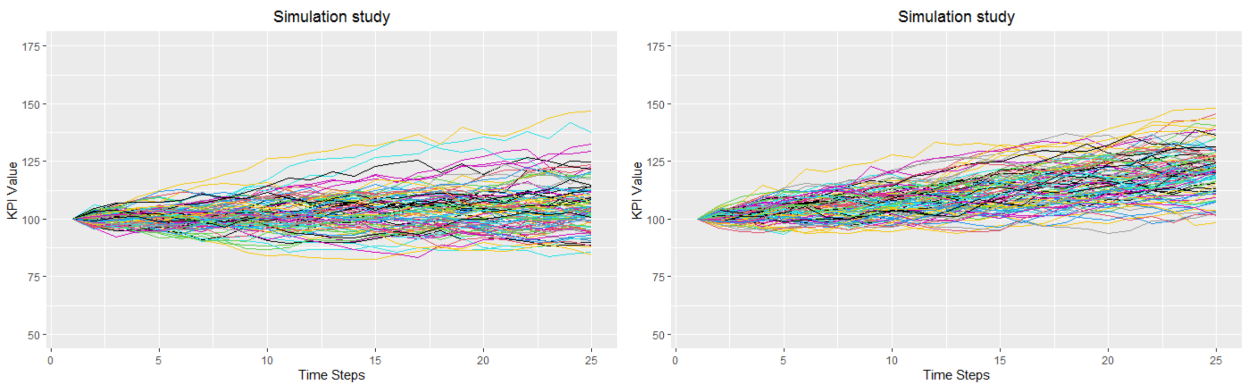
The time to maturity of the underlying option specifies when the SPT must be achieved. This duration may differ from the maturity of the underlying contract, potentially resulting in a shorter time span for the option than the contract. This difference affects the period following the achievement of the SPT, during which the contract receives the discount. The number of observations per year determines the frequency of receiving the discount and influences the time steps in the Monte Carlo simulation. Upon reaching the SPT at the option's maturity, an amount calculated by multiplying the basis points by the notional amount of the underlying contract is received at each observation for the remainder of the contract.

In this research assignment, the chosen number of simulations is 20,000, in the case where the option price is calculated. This selection was made to enhance accuracy in the Monte Carlo simulation, even though it can significantly increase computational expenses. However, the greater accuracy in results justifies this computational cost.

The following section conducts a simulation study to visualise the potential paths of the underlying KPI.

6.2 SIMULATION STUDY

As an illustrative tool, a simulation study is conducted to observe how the KPI evolve over time, where the process underlying the KPI is described as a geometric Brownian motion as defined in Equation (5.5). This approach is employed to examine the impact of the drift and volatility parameters on the path of the KPI. Understanding this influence is crucial since the pricing of the option is highly dependent on the KPI's path. It's essential to emphasise that the calibration of the drift and volatility parameters, detailed in Section 5.2, significantly impacts the option's pricing.



(a) Simulation with $\delta = 0.05$ (b) Simulation with $\delta = 0.2$

Figure 6.1: 100 Simulated paths with $KPI_0 = 100$, $\sigma = 0.1$, and 24 time steps

In Figure 6.1 above, a simulation study, of 100 simulated paths[1], is conducted to observe the influence of the model's drift on the KPI's path over the option's duration. The figures (6.1a and 6.1b) display two separate simulations, both having $KPI_0 = 100$ and assuming a KPI volatility of $\sigma = 0.1$. Both options have a maturity of 2 years with 12 observations per year, summing up to 24 time steps. The main distinction between the sub-figures is that $\delta = 0.05$ in Figure 6.1a and $\delta = 0.2$ in Figure 6.1b. The impact of altering the drift parameter is evident, showing an increased upward trend in the KPI for Figure 6.1b in comparison to Figure 6.1a.

The analysis from Figure 6.1 suggests that careful consideration is necessary in the selection and calibration of the drift parameter. The drift parameter significantly shapes the path of the underlying KPI, which can notably affect the option's price. Refer to Section 5.1 for details on calibrating the drift parameter.

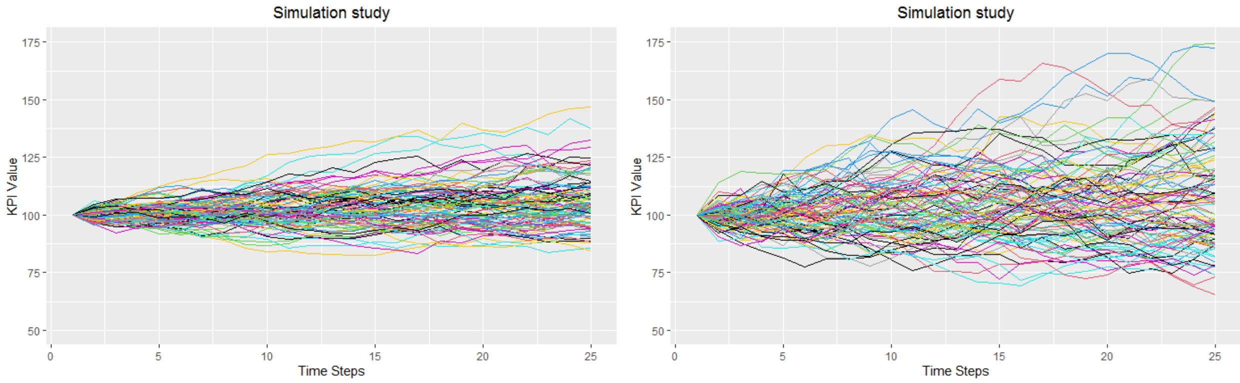
Figure 6.2 demonstrates how adjustments in the volatility parameter impact the path of the KPI. Comparable aspects such as KPI_0, maturity, and the frequency of observations per year are assumed in similarity to those in Figure 6.1. In this instance, the drift is held constant at $\delta = 0.05$, while two different volatility values, $\sigma = 0.1$ and $\sigma = 0.2$, are applied in the simulation studies illustrated in Figures 6.2a and 6.2b, respectively. It is evident from Figure 6.2b that modifying the volatility parameter leads to a significant variation in the KPI's final range, spanning approximately from a low of 60 to a high of 175. This variation substantially influences the volatility of the option's pricing. Subsequently, this section will explore the impact of changing volatility on the option's pricing. Thus, the volatility parameter must be carefully calibrated, as elaborated in Section 5.2.

The following sections examines how the simulation study, that is done in this section, is used in order to price the option.

6.3 PRICING OF THE OPTION

This section delves into the significance of the path of the KPI, specifically in the context of the simulation study that is integral to pricing the option. Section 5.1 explored the underlying dynamics of the model, emphasising the theoretical aspects. In contrast, this particular section focuses on the practical application of the model and how the KPI value influences the value of the option.

[1] 100 Simulations is used for illustrative purposes, whereas 20000 is used in the calculations.



(a) Simulation with $\sigma = 0.1$ (b) Simulation with $\sigma = 0.2$

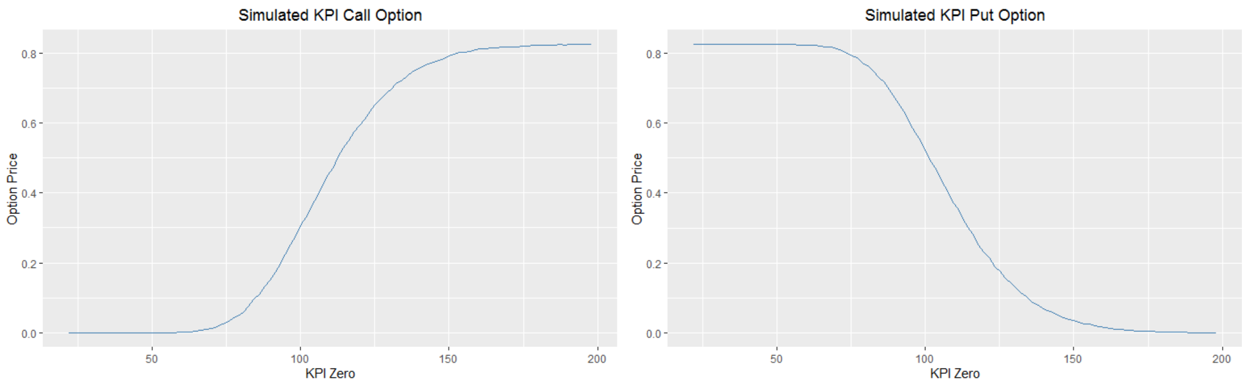
Figure 6.2: 100 Simulated paths with $KPI_0 = 100$, $\delta = 0.05$, and 24 time steps

$$IRS_0^2 = \mathbb{E}\left[1_{[KPI_\tau \geq D \cdot KPI_0\}}\right] \cdot \sum_{t=\tau}^{n} \frac{Q_t}{B(0,t)}, \tag{6.1}$$

$$IRS_0^2 = \mathbb{E}\left[1_{[KPI_\tau \leq D \cdot KPI_0\}}\right] \cdot \sum_{t=\tau}^{n} \frac{Q_t}{B(0,t)}. \tag{6.2}$$

The visualisation in Figure 6.3 delineates the paths of KPI call and put options as the KPI value increase. As discussed in Section 5.1, call options are deployed when an increase in the KPI value is necessary to meet an SPT, while put options are used to decrease the KPI value. Employing 20,000 simulated KPI paths, Equations (6.1) and (6.2) are used to estimate the price of call and put options, respectively. Both equations necessitate Monte Carlo simulation to assess the probability of the KPI meeting a specific SPT. The distinction between the call and put options lies in the estimation of the probability concerning the KPI values' relation to the SPT: the call option considers the probability of the KPI being higher than the SPT ($D \cdot KPI_0$), while the put option examines the opposite. In both cases, the probability is multiplied by the summation of all discounted payoffs to time 0. These formulae are fundamental in generating Figures 6.3a and 6.3b.

Observing Figure 6.3a reveals that the call option price increases as the KPI value increases. Starting at a value of zero when the KPI value is at deep out-the-money levels. Initially, the rate at which the price increase accelerates as the KPI values approach the at-the-money levels, represented by the SPT, similar to the strike price set at 110 in this scenario. Subsequently, as the KPI value becomes more in-the-money, signifying a greater favorable range, the rate at which the option price increase decelerates. Consequently, the option price tends to converge toward its maximum payoff - established by the predetermined basis points multiplied by the notional amount. This outcome aligns with expectations, considering that as the KPI value rises significantly while the SPT remains constant, the probability of reaching the SPT approaches near-certainty (probability converges to 1).



(a) Simulated KPI call option path

(b) Simulated KPI put option path

Figure 6.3: Simulated KPI option path with $KPI_0 = 100$, SPT = 110, rfr = 5%, $\delta = 5\%$, $\sigma = 20\%$, T = 2, obs = 12, mat_underlying = 4, bps = 4 and N = 100

Conversely, when observing Figure 6.3b, the put option price decreases as the KPI value increases. Starting at a value equal to the maximum payoff when the KPI value is at deep in-the-money levels. Similarly to the call option, the rate at which the price decrease accelerates as the KPI values approach the at-the-money levels. Subsequently, as the KPI value becomes more out-the-money, signifying a less favorable range, the rate at which the option price increase decelerates. Consequently, the option price tends to converge toward its minimum payoff - which is zero. This outcome also aligns with expectations, considering that as the KPI value rises significantly while the SPT remains constant, the probability of reaching the SPT approaches 0.

This section examined how the pricing of a call and put option is done, the following section investigates the sensitivity of the option pricing with respect to the change of some of the input parameters.

6.4 SENSITIVITY OF OPTION PRICE TO UNDERLYING FACTORS

This section concentrates on explaining the influence of alterations in input parameters on the option price. In the preceding section, the discussion revolved around how the KPI value influences the option price. Firstly, this section delves into examining the precise rate at which the option price changes concerning shifts in the KPI value, referred to as the delta of the option. Moreover, it explores the impact of alterations in the KPI_{goal} (SPT), drift, and volatility parameters on the option price.

6.4.1 Delta of Option

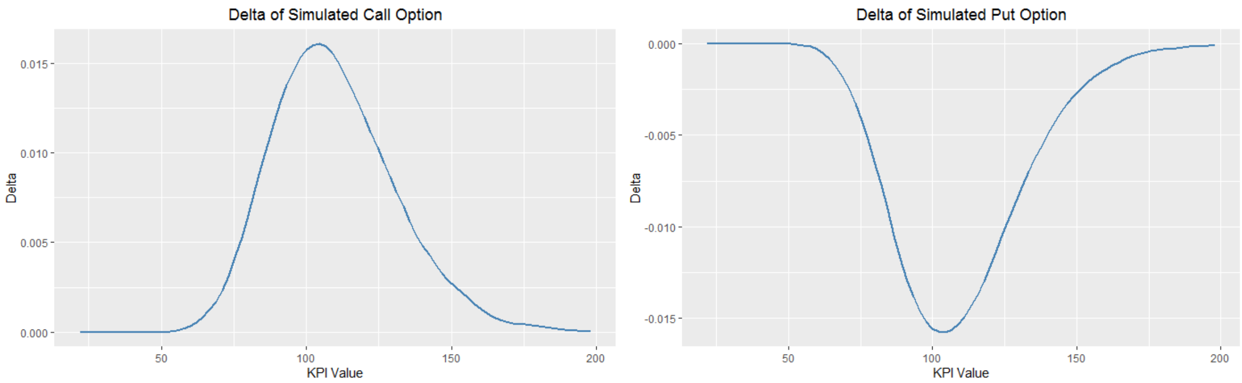
The delta of the call and put options can be seen in Figure 6.4. The delta in financial terms, according to Hull (2018), is the rate of change in the price of the option with respect to the change in the underlying asset. In this case the underlying asset is the KPI used to value the option. Thus the delta in this research assignment is calculated as:

$$\Delta = \frac{\delta V}{\delta KPI} \tag{6.3}$$

where V is the price of the option.

Figure 6.4a serves as the first derivative of Figure 6.3a, essentially depicting the rate of change observed in Figure 6.3a. While the previous section mentioned the rate of change, Figure 6.4a precisely indicates when the rate of change begins to rise and fall, hence marking when the delta of the call option is increasing or decreasing.

In Figure 6.4a, the delta of the call option initiates at zero, reflecting the zero option price at that stage. It gradually rises around the KPI value approximately half of the SPT. The delta attains its peak at the at-the-money levels, where the KPI aligns with the SPT. As the KPI value reaches deep out-of-the-money levels, the delta diminishes back to zero. An observation worth noting is that the delta of the call option exhibits a positive skew, as its right tail is somewhat thicker compared to the left.



(a) Delta of simulated call option

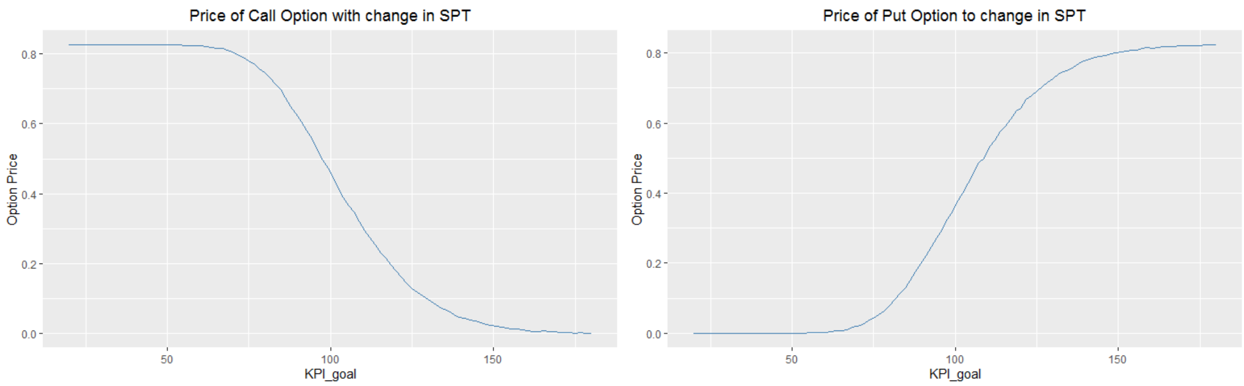
(b) Delta of simulated put option

Figure 6.4: Delta of simulated KPI option

Similarly, Figure 6.4b serves as the first derivative of Figure 6.3b. In Figure 6.4b, the delta of the put option initiates at zero, reflecting the converged maximum option price at that stage. It gradually falls around the KPI value approximately half of the SPT. The delta attains its trough at the at-the-money levels, where the KPI aligns with the SPT. As the KPI value reaches deep out-of-the-money levels, the delta returns back to zero. It is evident from Figure 6.4 that the delta of the put option is simply the negative of the delta of the call option.

6.4.2 Change in SPT

Choosing an appropriate SPT is crucial for financial institutions. If the SPT is set too low, it may not achieve the intended impact, while a very high SPT might be unattainable. In Figure 6.5, the impact the SPT on the option price, with a constant KPI at issuance, is demonstrated. It reveals in Figure 6.5a, that the call option price declines with a higher SPT, while the put option price increases in Figure 6.5b. This aligns with the idea that a higher SPT becomes more challenging for a call option holder to achieve, resulting in a reduced price. Conversely, the situation is reversed for a put option holder.



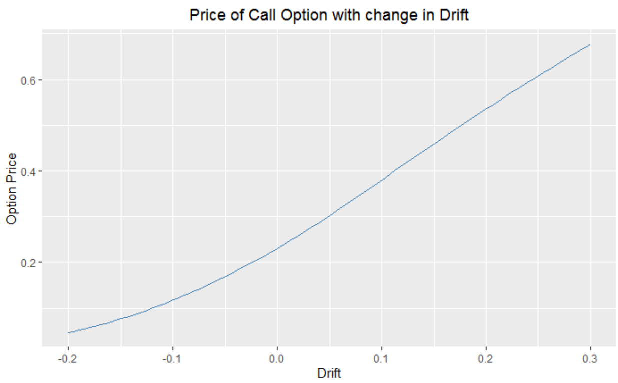
(a) Change in simulated KPI call option price (b) Change in simulated KPI put option price

Figure 6.5: Change in simulated KPI option price with respect to change in the SPT, all other parameters constant

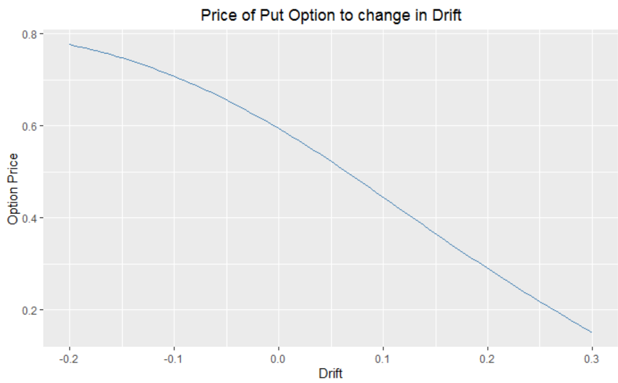
6.4.3 Change in Drift (δ)

As explained in Section 5.2, the drift is a crucial parameter requiring calibration. The impact of drift variations on the option price is demonstrated in Figure 6.6. The drift parameter essentially signifies the acceptable trend necessary for the KPI to reach a specific benchmark. Its values can range between negative and positive.

In Figure 6.6a, a nearly linear positive relationship between the call option price and the drift is evident. As the drift value increases, the call option price rises as well. aligns with the findings from Section 6.1, where the simulation study revealed that a higher drift induces an upward trend in KPIs. Consequently, a higher drift enhances the probability of the KPI reaching the SPT under a call option, resulting in a higher option price.



(a) Change in simulated KPI call option price



(b) Change in simulated KPI put option price

Figure 6.6: Change in simulated KPI option price with respect to change in δ, all other parameters constant

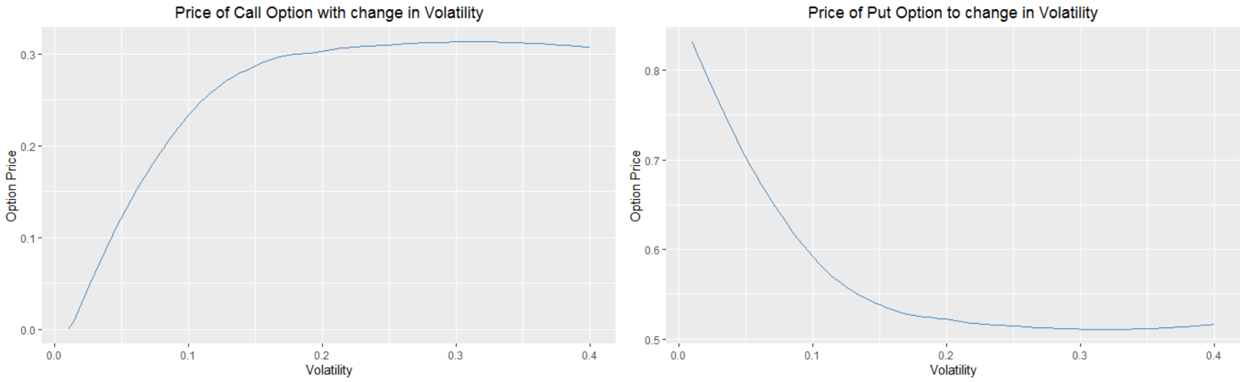
In Figure 6.6b, a nearly linear negative relationship between the put option price and the drift is evident. As the drift value increases, the put option price falls. Similar to above, a higher negative drift would induce an downward trend in KPIs. Consequently, a higher negative drift increases the probability of the KPI reaching the SPT, resulting in a higher option price. A higher positive drift would have an opposite affect.

6.4.4 Change in Volatility (σ)

In Section 5.2, it was discussed that volatility represents the issuer's capacity to manage the KPI. The influence of volatility on the option price can be observed in Figure 6.7. From the simulation study in Section 6.1, it was noted that high volatility results in a substantial variation in the KPI path.

In Figure 6.7a, the graph demonstrates that a low volatility leads to a lower call price, as the KPI's path experiences minimal variation, thereby maintaining the KPI value around its initial level of 100. With an increase in volatility, more simulated paths tend to meet the SPT at the conclusion.

However, when the volatility reaches a certain point, the variation becomes too substantial, potentially leading the KPI to move in a downward trajectory. Consequently, only a few KPIs meet the SPT, resulting in the probability estimation converging to a value below 1. As a result, for higher volatilities, the option price converges to a value below the maximum payoff.



(a) Change in simulated KPI call option price

(b) Change in simulated KPI put option price

Figure 6.7: Change in simulated KPI option price with respect to change in σ, all other parameters constant

In Figure 6.7b, the graph demonstrates that a low volatility leads to a higher put price, since the KPI value starts in-the-money experiences minimal variation, thereby maintaining the KPI value around its initial level of 100. With an increase in volatility, more simulated paths tend to be above the SPT at the conclusion. However, when the volatility reaches a certain point, the variation becomes too substantial. Consequently, only a few KPIs meet the SPT, resulting in the probability estimation converging to a value above 0. As a result, for higher volatilities, the option price converges to a value above the minimum payoff.

The pricing of the option as well as how the pricing of the option is influenced by some underlying factors are discussed so far. The following section aims to provide a real-world example where the specific ESG-linked derivative discussed in this research assignment, can be used in order to solve real-world problems.

6.5 EXAMPLE OF FINAL PRODUCT

To illustrate the appearance of the final product, this section focuses on the pioneering ESG-linked derivative established between ING and SBM Offshore (ISDA, 2021*b*) with a few assumptions made to fit our model. SBM, a global provider of floating production solutions for the offshore energy industry, is the issuer of this derivative, while ING is a Dutch-based global financial institution.

In August 2019, ING facilitated the world's inaugural ESG-linked derivative, specifically crafted to hedge against the interest rate risk of SBM's 1 billion USD five-year floating rate revolving credit facility. Essentially, this derivative comprises an Interest Rate Swap (IRS) as the underlying product, coupled with a KPI option that incorporates the ESG component. Let's consider that the terms of the IRS dictate that SBM is required to make a fixed payment of 5% per annum, payable monthly, in return for the floating rate payment tied to the Secured Overnight Financing Rate (SOFR) provided by ING.

This particular ESG-linked derivative functions by adjusting a positive or negative spread to the fixed rate established during the swap's issuance, contingent upon SBM meeting a specific SPT, evaluated by a third-party entity, Sustainalytics. In this research assignment, a negative spread is solely considered if a particular SPT is achieved.

Let's consider that the established SPT pertains to SBM Offshore's waste management, a significant ESG factor in their operations (SBM, 2021). SBM aims to decrease their waste output over the next three years. The existence of this ESG-linked derivative serves as a substantial incentive for SBM, as it offers a reduction in the fixed payment made to ING throughout the remainder of the IRS if SBM successfully meets the SPT.

Assume SBM currently releases 150 metric tonnes of waste into the sea annually, and they aspire to diminish this by 30% within the next three years. While SBM has already implemented certain measures to reduce waste, they intend to bolster these efforts. The agreement between SBM and ING stipulates that SBM could receive a 5-basis point discount from the fixed payment for the remainder of the IRS contract should they achieve the targeted 30% reduction in waste over the next three years.

The computation for the KPI option, which is applied on top of the Interest Rate Swap (IRS), is now underway. As previously outlined, in order to evaluate the option's price, key determinations need to be made: whether a call or put option is necessary, calibration of the waste management's volatility, and establishing the drift. Given the imperative to reduce SBM's waste output, a put option is essential for pricing this option.

The volatility can be approximated by analysing the historical volatilities pertaining to SBM's waste management. Suppose that reviewing their past annual reports indicates a historical volatility of 13.6%. However, estimating the drift proves challenging based on information within their annual reports. An industry expert, however, suggests that a 4.7% reduction per year is necessary to meet a specific zero waste benchmark in the future. This figure serves as an assumed drift for the computation.

Since all the input parameter are now known as:

Table 6.2: Model Parameters for Final Product

Parameter	**Value**
KPI_0	150
KPI_{goal} or SPT	$0.7 \times 150 = 105$
Risk-Free Rate (rfr)	5%
Drift (δ)	-4.7%
Volatility (σ)	13.6%
Time to maturity of the underlying option	3 Years
Observations per year	12 per year
Time to maturity of the underlying contract, e.g. IRS	5 Years
Basis points (bps)	5 bps
Notional amount of the underlying contract (N)	$ 1 billion
Number of simulations	20000

The calculation of the put option price can be performed using the input parameters outlined in Table 6.2 and employing a Monte Carlo simulation, as discussed in Section 5.1.2. The potential payoff for the put option amounts to 9.808M USD. This sum represents the cumulative value of the discounts that SBM will receive on each of the fixed payments for the remaining two years of the underlying IRS contract, which involves 12 payments per year, discounted back to time 0.

The determined price, using the simulation method described in Equation (5.7), for the put option stands at 3.923M USD. This valuation is a result of the model's consideration that the probability of SBM meeting the SPT, given the calibrated parameters of drift and volatility, is fairly average.

Consequently, SBM incurs the cost for the put option at the commencement of the contract. If SBM successfully reduces their waste by at least 30% within three years, they will receive the payoff between years 3 and 5, corresponding to the maturity of the IRS contract.

The solution obtained in closed form, as expressed in Equation (5.12), can be utilized for comparison with the simulation method to assess its accuracy. The put option price, as determined by the closed form solution, is 4.008 USD. When compared to the simulation method, the difference is only 0.085M USD, indicating a negligible difference relative to the aggregate of the two methodologies. This suggests that the simulation method is satisfactory, affirming the viability of Monte Carlo simulation for pricing ESG-linked derivatives.

6.6 HEDGING

In the preceding section, the ultimate utility of an ESG-linked derivative is explored. It becomes apparent that substantial amounts of capital are at stake, prompting the question, "How can these risks be mitigated and hedged?" This section addresses this pertinent issue by delving into hedging such exposures.

As per Baxter (1998), practitioners in derivative markets emphasize that hedging is pivotal in determining pricing. Failure to hedge a contract can lead to financial losses, regardless of its initial sale price. The success or failure of a transaction hinges greatly on the effectiveness of the hedge employed.

Hedging strategies span a wide array of derivative markets. In its simplest form, hedging involves trading in the underlying asset to offset risk. However, Dupire (1992) has contributed significant insights by devising hedging approaches for derivatives using simpler instruments like forwards and calls.

Conversely, there are instances where hedging may not be feasible, as seen in incomplete markets where no position can be established in the underlying asset. This is evident in our research assignment, where no position can be taken in the underlying asset, namely the KPI, which is used to calculate the option portion of the ESG-linked derivatives as described in Section 5.1.1. Hence, alternative solutions are required to hedge the involved contract.

Recently, there has been considerable exploration into hedging within incomplete markets. The conventional approach involves employing static minimum-variance hedges (Hull, 2018). Basak and Chabakauri (2012) extended this by examining dynamic settings within incomplete markets, aiming to identify hedges that optimize a hedger's preferences or yield the most effective hedge. Their analysis encompasses various criteria, focusing on means and variances of hedging errors, which represent the deviation of the hedge from its target value.

The methodology by Basak and Chabakauri (2012) attempts to address the hedging problem by incorporating the traditional minimum-variance criterion and enhancing it with tractable, dynamically optimal hedges within an incomplete-market framework. This approach holds relevance for this research assignment, as it caters to hedgers seeking to mitigate the risk associated with nontradable assets at future dates. In the context of this research assignment, the KPI, serving as the underlying asset, aligns with this notion of a nontradable asset.

The primary approach to address this challenge involves acquiring a position in a tradable security that exhibits correlation with the nontradable asset, thereby hedging the contract. However, the difficulty lies in identifying a security that displays correlation with the KPI to achieve comprehensive hedging.

As highlighted by Basak and Chabakauri (2012), it's crucial to recognize that complete risk elimination is often unattainable in incomplete markets. Therefore, the objective shifts towards minimizing risk exposure to replicate the target payoff of the contract as accurately as feasible. This implies that while it may not be feasible to eradicate all risks, the focus is on mitigating them to the greatest extent possible, aligning with the desired contract outcomes.

6.6.1 Main Idea

To illustrate the main idea, Basak and Chabakauri (2012) considers a continuous-time, incomplete-market economy with a finite horizon $[0, T]$. Fix a filtered probability space $(\Omega, \mathcal{F}, \{\mathcal{F}_t\}, P)$ on which there are defined two correlated Brownian motions, w and w_X, with correlation ρ, which represents the uncertainty. All stochastic processes are assumed to be well defined and adapted to $\{\mathcal{F}_t, t \in [0, T]\}$, i.e., the augmented filtration generated by w and w_X.

Consider a scenario where the hedger is obliged to retain the nontradable asset, represented by the KPI in this research assignment, with a final value of KPI_T at time T. The nontradable asset serves as the basis for pricing the ESG-linked derivative. The outcome of the ESG-linked derivative's payoff, denoted as X_t is contingent upon the realization of the nontradable state variable, denoted as KPI. The evolution of the nontradable asset adheres to the dynamics outlined in Section 5.1.2:

$$\frac{dKPI_t}{KPI_t} = \delta dt + \sigma dW_t, \tag{6.4}$$

where the drift parameter, denoted as δ, and the volatility parameter, represented by σ, are defined in Section 5.2. To mitigate the risk associated with the nontradable asset, continuous trading in two securities is employed: a riskless bond offering a constant interest rate r, denoting the risk-free rate, and a tradable risky security. Depending on the context, this risky security could signify a stock, a futures contract, or any other derivative security correlated with the nontradable asset.

Consequently, the average and volatility of instantaneous returns on the tradable security may vary based on the price of the nontradable asset, KPI. The dynamics governing the price of the tradable security, denoted as S and proposed by Basak and Chabakauri (2012), can be represented as:

$$\frac{dS_t}{S_t} = \mu\left(KPI_t, S_t, t\right) dt + v\left(KPI_t, S_t, t\right) dW_t, \tag{6.5}$$

where the stochastic mean return, μ, and volatility, v, are deterministic functions of S and KPI and W_t is the Wiener process as described in Section 5.1.2.

Basak and Chabakauri (2012) proposes a hedging policy that should by utilised by the hedger. The hedging policy is described as, θ, where θ_t denotes the amount invested in the security at time t, given initial wealth M_0. The hedger's tradable wealth M then follows the process:

$$dM_t = \left[rW_t + \theta_t\left(\mu_t - r\right)\right] dt + \theta_t v_t dW_t. \tag{6.6}$$

It is impossible to completely offset the fluctuations of the nontradable asset through tradable wealth, rendering the market incomplete. Market completeness is only attainable under specific circumstances, notably when there exists a perfect correlation between the nontradable asset and the returns on the security, expressed as $\rho = \pm 1$. In this scenario, the nontradable asset can be replicated by trading the security, and standard no-arbitrage methods can be employed to identify the optimal hedge portfolio.

Basak and Chabakauri (2012) argue that due to the inherent limitations of incomplete markets in allowing for perfect hedging, the prevailing approach in the literature involves employing certain criteria to establish a hedging policy. This policy is typically defined in terms of the hedging error $X_T - W_T$, which gauges the effectiveness of the hedge.

Basak and Chabakauri (2012) employ the traditional variance-minimizing criterion that can be utilised by the hedger whose problem is:

$$\min_{\theta} \mathrm{var}_t \left[X_T - M_T\right], \tag{6.7}$$

subject to the budget constraint in Equation (6.6) and considering the ESG-linked derivative's payoff denoted as X_T.

Basak and Chabakauri (2012) contend that obtaining variance-minimizing hedges explicitly in dynamic settings, particularly within general stochastic environments, remains a challenge. They address the problem articulated in Equation (6.7) through dynamic programming in their paper, thereby establishing a time-consistent dynamic hedging policy.

It's important to note that this research assignment does not delve into the specifics of solving this problem. Rather, its purpose is to offer a framework illustrating how hedging principles can be applied within the context of ESG-linked derivatives.

CHAPTER 7

CONCLUSION

ESG challenges have gained global recognition, prompting various initiatives to address them. While governments hold responsibility, the financial sector can significantly catalyse these efforts. Public sentiment, emerging regulations, technological advancements, and market shifts encourage both governments and the financial sector to advance ESG principles. While the environmental aspect of ESG receives considerable attention, institutions increasingly acknowledge the importance of integrating social and governance factors in their decision-making processes.

The focus of this research assignment was to establish a framework for promoting ESG compliance within the financial sector by exploring the creation of a financial instrument called ESG-linked derivatives. Although derivatives play a substantial role in the financial market, ESG-linked derivatives are not yet well-developed. Research underscores the significance of ESG-linked derivatives but reveals persistent challenges. The absence standardised ESG data leads to price transparency and comparability issues among products and issuers. Furthermore, the regulatory framework for ESG-linked derivatives remains underdeveloped, demanding considerable attention to bridge existing gaps.

This research assignment discusses an ESG-linked derivative reliant on the KPIs of the issuer. The product comprises a base product, which can encompass various derivatives, and an option determining the issuer's discount if predetermined SPT are met by the KPI. Monte Carlo simulation is employed in pricing the option. The objective of creating ESG-linked derivatives to foster compliance has been achieved.

FURTHER RESEARCH

This research assignment aimed to establish a basic framework using Monte Carlo simulation to price ESG-linked derivatives. The calibration of drift and volatility parameters within the model holds significant importance. However, this research did not involve real-world data for calibrating these parameters. Future research is crucial in exploring how these fundamental parameters can be calibrated using real-world data.

This leads to a critical issue: the absence of standardised ESG data. It is essential to implement regulations that mandate companies to disclose their ESG data. This approach would enable the use of more industry-specific ESG data to calibrate parameters and refine the model. While there have been advancements in regulations and standardisation, further development remains necessary in this relatively new area.

The substantial financial stakes involved in derivatives create considerable risk for issuers, necessitating the implementation of hedging strategies to mitigate these risks. Section 6.6 endeavors to establish a framework for hedging tailored specifically to ESG-linked derivatives, where the underlying asset, referred to as the KPI is nontradable. This presents significant challenges, as conventional hedging methods typically entail taking a position in the underlying asset, which is not feasible in this scenario.

Section 6.6 proposes a framework wherein a tradable asset exhibiting correlation with the nontradable asset can be utilized to hedge ESG-linked derivatives. However, further research is warranted to identify specific securities that demonstrate such correlation and can be effectively employed for hedging purposes in this context.

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