Lisbon School of Economics & Management
Universidade de Lisboa

MASTER

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MASTER'S FINAL WORK

INTERNSHIP REPORT

BRIDGING THEORY AND PRACTICE: STRUCTURED PRODUCT VALUATION AT BANCO ATLÂNTICO EUROPA

EVA ISABEL REIS SILVA

JUNE - 2025

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JUNE - 2025

To my grandparents, for being my guiding stars.

To my parents, for always believing in me.

To my boyfriend, for being there through it all.

To my close family and friends.

GLOSSARY

BAE – Banco Atlântico Europa

BBI – Barclays Bank of Ireland

CMD – Capital Markets Division

CMVM – Comissão do Mercado de Valores Mobiliários

CSA – Comparable Security Approach

EC – European Commission

ECB – European Central Bank

ETF – Exchange Traded Fund

EIOPA – European Insurance and Occupational Pensions Authority

FE – Financial Engineering

GDP – Gross Domestic Product

HICP – Harmonized Index of Consumer Prices

ISIN – International Security Identification Number

JEL – Journal of Economic Literature

KID – Key Information Document

MFW – Master's Final Work

MiFID II – Markets in Financial Instruments Directive II

PRIIP – Packaged Retail and Insurance-based Products

SP – Structured Product

SRI – Summary Risk Indicator

ABSTRACT

This report documents my internship experience in the Capital Markets Division of Banco Atlântico Europa. Motivated by an academic interest in structured products, I developed a case study on a structured note distributed by Atlântico Europa – specifically, a Digital Equity-Linked Note tied to the EURO STOXX 50 Index and Eurozone inflation, issued by Barclays.

The report bridges academic theory with professional practice. It begins with an overview of the host institution and a summary of internship tasks, followed by the case study. The first part presents a qualitative analysis of the product's structure, including its decomposition into simpler components and an assessment of financial risks from a macroeconomic perspective. Regulatory and compliance considerations for the distributor are addressed, along with a literature review.

The second part focuses on quantitative valuation, applying Monte Carlo simulation to estimate fair value under a risk-free rate methodology and a comparable security approach incorporating issuer-specific funding costs. Scenario analysis adds further robustness, including sensitivity to the discount rate, equity volatility, and correlation between the Eurozone Inflation index and the EURO STOXX 50 index, modelled via Cholesky Decomposition.

The results underscore that the discount rate has a stronger impact on the structure's fair value than the EURO STOXX 50 volatility or the asset correlation. The comparable security approach produced a theoretical price (100.04%) more aligned with the selling price (100%) than the risk-free model (100.22%), highlighting the importance of incorporating issuer funding costs into the valuation of this type of structured product.

KEYWORDS: Structured Products; Digital Equity-Linked Note; Monte Carlo Simulation; Fair Value; Scenario Analysis.

JEL CODES: C63, E44, G12, G13.

RESUMO

Este relatório documenta a minha experiência de estágio na Divisão de Mercados de Capitais do Banco Atlântico Europa. Motivada por um interesse académico em produtos estruturados, desenvolvi um estudo de caso sobre uma nota estruturada distribuída pelo Atlântico Europa – especificamente, uma Digital Equity-Linked Note indexada ao Índice EURO STOXX 50 e à inflação da Zona Euro, emitida pelo Barclays.

O relatório estabelece uma ponte entre a teoria académica e a prática profissional. Começa com uma apresentação da instituição de acolhimento e um resumo das tarefas do estágio, seguido do estudo de caso. A primeira parte apresenta uma análise qualitativa da estrutura do produto, incluindo a sua decomposição em componentes mais simples e uma avaliação dos riscos financeiros a partir de uma perspetiva macroeconómica. As considerações regulamentares e de compliance para o distribuidor são abordadas, juntamente com uma revisão da literatura.

A segunda parte centra-se na avaliação quantitativa, aplicando a simulação de Monte Carlo para estimar o valor justo segundo uma metodologia de taxa sem risco e outra baseada em títulos comparáveis, que incorpora os custos de financiamento específicos do emitente. A análise de cenários acrescenta uma maior robustez, incluindo a sensibilidade à taxa de desconto, à volatilidade do índice acionista e à correlação entre o índice de inflação da Zona Euro e o índice EURO STOXX 50, modelada através da Decomposição de Cholesky.

Os resultados evidenciam que a taxa de desconto tem um impacto mais significativo no valor justo da estrutura do que a volatilidade do EURO STOXX 50 ou a correlação entre os ativos. A abordagem com ativo comparável gerou um preço teórico (100.04%) mais alinhado com o preço de venda (100%) do que o modelo de taxa sem risco (100.22%), destacando a importância de incorporar os custos de financiamento do emitente na valorização deste tipo de produto estruturado.

PALAVRAS-CHAVE: Produtos Estruturados; Digital Equity-Linked Note; Simulação de Monte Carlo; Valor Justo; Análise de Cenários.

CÓDIGOS JEL: C63, E44, G12, G13.

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ACKNOWLEDGMENTS

First and foremost, I want to express my deepest gratitude to my parents. This would not have been possible without their unconditional love, support, and patience. This achievement is as much theirs as it is mine. Despite the physical distance, I have felt their encouragement every step of the way. Thanks to my extended family, and especially to my godmother, for the joy and warm welcome every time I came back home. I want to thank my grandparents, whose presence I still feel in many moments. I know you are proud, watching from above.

I am profoundly grateful to my boyfriend for his constant support and for being the calm in the storm. Thank you for believing in me, even when I doubted myself. I also wish to thank his family for providing a second home and a supportive environment.

I am appreciative of my friends. To my childhood friends, thank you for the shared history and enduring bonds that have enriched my life. To the friends I made during my academic journey, thank you for being by my side through it all. Our teamwork, adventures, and countless memories have made these past few years feel like a lifetime of experiences.

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This work would not have been possible without the Capital Markets Team of Banco ATLANTICO Europa. To Bernardo Godinho, my appreciation for his mentorship, flexibility, and for sharing his knowledge with me during these months. A special thank you to João Almeida, who was an amazing colleague and always ready to help with anything I needed for my thesis. ATLANTICO truly stands out because of its people, and I am grateful for the warm welcome and friendships I made.

Lastly, I want to thank ISEG. For years, I dreamed of studying here, and after these two years, I can say it was the best decision I could have made. Thank you to all the professors I had the privilege to learn from, and to all my classmates.

AI DISCLAIMER

This internship report was developed with strict adherence to the academic integrity policies and guidelines set forth by ISEG, Universidade de Lisboa. Unless otherwise cited, the work presented herein results from my own research, analysis, and writing. In the interest of transparency, I provide the following disclosure regarding the use of artificial intelligence (AI) tools in creating this internship report.

I disclose that AI tools were employed during the development of this thesis as follows:

- AI-based research tools assisted in the literature review and data collection.
- AI-powered software was utilized for data analysis and visualization.
- Generative AI tools were consulted for brainstorming and outlining purposes.

However, all final writing, synthesis, and critical analysis are my work. Instances where AI contributions were significant are cited and acknowledged.

I have ensured that the use of AI tools did not compromise the originality and integrity of my work. All sources of information have been appropriately cited in accordance with academic standards. The ethical use of AI in research and writing has been a guiding principle throughout the preparation of this thesis.

I understand the importance of maintaining academic integrity and take full responsibility for the content and originality of this work.

Eva Silva, 13th of June 2025

1. INTRODUCTION

Structured products (SP) are complex financial instruments that provide a return based on the performance of one or more underlying assets. These investments typically comprise a bond component and one or more derivatives, offering investors customized risk-return profiles[1]. Thus, they offer investors a way to benefit from specific market conditions while managing risk according to their preferences.

After extensive academic study, including a year and a half of master's-level coursework in Finance, I realized the need for practical experience to understand the dynamics of the real-world financial landscape. Simultaneously, the courses that most captivated my interest were Derivatives and Financial Engineering (FE). Upon completing an in-depth analysis of a structured product for FE, it became evident that it was the path I wished to pursue for my MFW. Bearing this in mind, I recognized an opportunity to combine the strengths of both academic and professional fields – building a case study on a SP chosen within my internship.

The internship inherent to this report was carried out in Banco ATLANTICO Europa (BAE), within the Capital Markets Division (CMD). BAE is a private bank headquartered in Lisbon that serves foreign customers and companies. The chosen SP is a Digital Equity-Linked Note linked to the EURO STOXX 50 Index and Eurozone inflation.

The contribution of this work is twofold:

1. Bridging Theory and Practice: To date, we have primarily seen analyses of structured products that focus on theoretical approaches, often lacking practical relevance. I focus on integrating theoretical concepts with real-world market dynamics to address this gap. To do this, I develop a case study comparing pricing methodologies, contrasting a commonly adopted academic model (risk-free approach) with a more practical market-based approach (comparable security approach).

2. Macroeconomic Context: Many studies have analysed structured products in isolation, without fully considering the broader economic context. To fill this gap, I investigate how the macroeconomic environment influenced the creation and risk assessment of the SP being analysed.

In terms of structure, this report begins with an exposition of the internship context in Chapter 2, focusing on BAE and the CMD. Subsequently, the responsibilities and tasks

[1] More information can be consulted at: https://www.structuredretailproducts.com

undertaken throughout my internship are described, including the tools and methodologies employed. All of this constitutes the first part of this report.

The second part comprises the case study about the structured product distributed by ATLANTICO. In Chapter 3, the product is analysed from a theoretical perspective, including its definition, payoff structure, underlying assets, and issuer. Subsequently, the main financial risks considering the macroeconomic context are presented. This section also incorporates compliance and regulatory considerations (MiFID II, PRIIPs Regulation), and a literature review to contextualize the valuation methodologies (Black-Scholes, Monte Carlo Simulation).

The study then conducts a fair price estimation in Chapter 4, which is compared with the selling price at the time of issuance. The analysis utilizes historical data for both Eurozone Inflation and the EURO STOXX 50 indices. Implied volatility data is also used in the case of EURO STOXX 50 within the Comparable Security Approach (CSA). Additionally, it includes distributions, probability and scenario analysis. The case study concludes with a critical discussion of the results obtained.

Chapter 5 presents the conclusions of this report, outlining the key learnings acquired during the internship, regarding both hard and soft skills. The main findings of the case study are also highlighted.

2. INTERNSHIP IN ATLANTICO EUROPA

This chapter presents an internship framework. It begins with an overview of BAE, its main products and services, client focus, organizational structure, and core values. It also highlights its history alongside some relevant milestones and introduces the CMD. After this, the responsibilities and tasks I had during the internship period are presented.

2.1. Overview of ATLANTICO Europa

Banco Atlântico Europa, S.A. (hereafter referred to as ATLANTICO Europa, ATLANTICO, BAE, or the Bank) is a European Union-based bank established in 2009. The Bank operates under the supervision and regulation of the Bank of Portugal and the CMVM.

ATLANTICO primarily focuses on international private clients with connections to Portugal, offering a comprehensive range of financial products and services. These include core banking, payment solutions, savings products, and financing options. ATLANTICO aspires to be the preferred bank for facilitating international trade, focusing on trade flows between

Portugal and Angola. Besides, it has established banking relationships with financial institutions headquartered all around the world, ensuring a global reach.

BAE is physically present in two strategic locations: Portugal (headquarters) and Namibia (Windhoek). As of 2024, ATLANTICO Europa serves 33,856 clients from 116 countries, according to the 2024 annual report. Around 85% of the clients are non-residents in Portugal.

In terms of competitive positioning, ATLANTICO differentiates itself in the international market by focusing on supporting foreign investment in Portugal and facilitating trade flows between Portugal and its economic partners. Furthermore, BAE offers multilingual support, competitive savings rates, and access to specialized products such as loans, mortgages and structured products. Simultaneously, with its headquarters in Lisbon, the Bank is well-positioned to serve as a bridge between Europe and Africa. This positioning sets it apart from traditional Portuguese banks and allows it to compete in a niche of the international and national banking markets.

Specifically, ATLANTICO's target clientele is segmented into three distinct categories: Affluent, Corporate and Institutional, and Premium.

The Affluent segment serves individuals and families with diverse needs, expectations, and levels of autonomy. It operates through an integrated multi-channel model that prioritizes digital interaction, supported by a multi-format customer support service and a physical branch at the Bank's headquarters.

The Corporate and Institutional Banking segments focus on supporting businesses in their international trade flows and structuring operations. This segment is serviced through the Correspondent Banking, International Commerce, and Trade Finance units.

The Premium segment is designed for selected individuals and high net-worth clients, offering personalized asset management through a dedicated relationship manager. This model emphasizes trust, responsiveness, and tailored investment solutions to meet client's needs. According to the latest Sustainability Report released in 2024, this segment represents around 10% of the Bank's clientele.

The assets under supervision of these three segments are nearly 600 million euros, invested in a broad range of financial instruments. The whole figure (on and off balance) is nearly 1 billion euros, according to the 2024 annual report. In terms of organization, the Bank is structured into several departments across three main areas: Business, Control, and Support. The Business Areas consist of Premium and Affluent Banking, Corporate Banking, Institutional

Banking, Financial Markets, and Capital Markets. The Control Areas include the Risk, Compliance, and Internal Audit departments. Lastly, the Support Areas cover Operations, Financial Planning, Technology and Development, Human Capital, Marketing, Legal, Security, ESG, and Logistics.

ATLANTICO Europa's core values encompass rigor, innovation, operational security, and confidentiality. Moreover, the Bank fosters a culture of diversity predicated on merit, novelty, efficiency, and financial robustness while striving to establish itself as a sustainable financial entity within the market ecosystem.

2.2. Institutional Milestones and Innovation

In 2006, Banco Privado Atlântico was founded in Angola, marking the inception of the "ATLANTICO" brand. The brand expanded its presence to Portugal in 2009 by establishing BAE. In 2012, the Bank inaugurated its headquarters on Avenida da Liberdade, Lisbon. Concurrently, the first ATLANTICO Centre, dedicated to providing customer service, was launched at the same location. 2014 marked the Bank's debut in the capital markets with its first Commercial Paper issuance.

In 2015, the Bank inaugurated its first international branch in Windhoek, Namibia. Furthermore, ATLANTICO Europa was recognized by Exame magazine as one of the top 100 companies to work for in Portugal – a distinction that would be repeated later for three consecutive years (2022, 2023, and 2024), underscoring the institution's commitment to employee satisfaction and organizational excellence.

In 2016, BAE implemented several technological advancements, including the launch of the MY ATLANTICO application. During this year, ATLANTICO was recognized with the award for the fastest-growing small and medium-sized bank in Portugal by the Exame Magazine. The following year, 2017, marked a significant milestone in the Portuguese banking sector, as ATLANTICO became the first bank in the country to offer remote account opening services via video call, thereby reducing customers' need to visit physical branches. In 2018, the Bank inaugurated ATLANTICO Go, a customer service space that replaced the previous centre.

In 2019, the Bank strengthened its commitment to Environmental, Social, and Governance (ESG) practices as part of its strategic framework. This led to adopting the United Nations' Sustainable Development Goals (SDGs) and creating a dedicated ESG department within the Bank's structure. This commitment is demonstrated through various initiatives, including

promoting workforce diversity, organizing social responsibility campaigns (such as blood donation campaigns and corporate volunteering), and implementing eco-efficiency measures. Still in 2019, BAE received two prestigious awards: the Best Trade Finance Bank in Portugal (by the Global Banking and Finance Review) and the award for Structured Products with the best performance (by Structured Retail Products).

ATLANTICO Europa continues to expand its brand presence and maintain its commitment to serving a diverse, international clientele. By focusing on technological innovation, specialized services, and strategic geographical positioning, the Bank aims to solidify its position as a key facilitator of international trade and investment.

2.3. The Role of the Capital Markets Division

This section provides an overview of the CMD, its market coverage, main functions, and operational units.

2.3.1. Overview

The CMD's primary mission is delivering tailored investment solutions for private, corporate, and institutional clients. These solutions comprise alternative investments, risk hedging solutions, financial advisory, and portfolio construction. The CMD also supports the Bank's financial instrument offering through optimization, implementation, monitoring and reporting services. In addition to client-focused services, the CMD manages internal projects, regulatory processes, and partnerships. Besides, the Division produces general research and regularly conducts training sessions on financial markets for the sales teams.

2.3.2. Market Coverage

The CMD operates across diverse investment universes, including equities, bonds, investment funds, and structured products. It facilitates access to major European and U.S. stock exchanges for equity and ETF investments, provides advisory services for bond selection in fixed income, and serves a global client base in investment funds through partnerships with top asset managers such as BlackRock, Schroders, and PIMCO.

2.3.3. Functions and Operational Units

The four core operational units of the CMD are investment advisory services (Advisory Desk), reception and transmission of orders (Execution Desk), product structuring (Structuring Desk), and management of commercial paper programs (Commercial Paper Desk).

The Advisory Desk is responsible for comprehensive investment consulting and asset management activities. Its functions encompass analysing and selecting investment products, managing the Investment Pool of recommended funds and ETFs, and designing both standardized (conservative, moderate, dynamic) and tailored client portfolios.

The Execution Desk is responsible for receiving, processing and transmitting client orders, as well as managing order processing-related projects. After being received, client orders are routed to the appropriate market, broker, or executing intermediary. The desk also coordinates transaction settlements with the Operations Department and executing/custodial entities, while also managing the capital markets pricing structure.

The Structuring Desk aims to develop structured products, with or without capital protection. The desk analyses assets (securities, indices, etc.) with compelling risk/return profiles in the current macroeconomic context, identifying potential underlying assets and simulating their pricing dynamics. This desk coordinates pricing and hedging for each structure with the Financial Markets Department, managing in-house issuance and external entity collaborations. The unit is also responsible for creating prospectuses and related legal and commercial documentation, coordinating regulatory submissions and approvals, and processing structured product orders in collaboration with the Execution Desk.

The Commercial Paper Desk supports the commercial paper business and operations, specifically interfacing with Corporate Banking for origination, the Financial Institutions Department (FID) for placement, and the Operations Department for settlement processes. The desk's primary responsibilities include preparing auctions, registering proposals, and determining auction outcomes in collaboration with the FID. Furthermore, the desk is responsible for requesting ISINs, system registration of issues, and comprehensive internal and external reporting.

2.4. Internship Responsibilities and Tasks

2.4.1. Overview of Assigned Role

The internship at the CMD of ATLANTICO Europa lasted two and a half months, starting on January 13, and ending on March 28, 2025. The primary goal was to gain insights into how things are done daily in capital markets. During the internship, I participated in various CMD operations, focusing on investment fund analysis and order placement, commercial paper processing, and market research. My responsibilities further included data analysis, preparation of weekly presentations on market updates, and exposure to real-time trading environments.

2.4.2. Key Activities and Responsibilities

2.4.2.1. Introduction and Integration

The beginning of the internship was marked by an overview of the Bank, its culture, values, and operations. This initial phase focused on establishing necessary access credentials and ensuring platform connectivity. Concurrently, I was introduced to the essential tools used throughout the internship.

2.4.2.2. Internal Processes and Operations

Afterwards, I was introduced to the main asset classes with which the CMD operates. In the first few weeks, I had closer contact with investment funds. I conducted data updates for the Bank's Investment Pool, refining key investment fund metrics such as duration, yield, and management fees. This required retrieving data from Bloomberg and assessing fund fact sheets. Indeed, investment funds play a significant role in the advisory services of the CMD since they enable investors to achieve diversification while providing liquidity, potential tax benefits, and professional management.

Subsequently, I became familiar with the internal processes for executing client orders across various securities, namely stocks, bonds, mutual funds, and ETFs. I was responsible for placing mutual fund orders on the intermediary trading platform and registering trade outcomes in the Bank's internal portal after their execution. Furthermore, I became involved in registering and parameterizing new securities within internal platforms, which was crucial for enabling subsequent order placements and trading activities.

Besides that, I was entrusted with the commercial paper issuance processing for the Bank's corporate clients. This role encompassed the entire lifecycle of commercial paper operations, including sending invitations to potential investors, conducting auctions, managing the reimbursement of previous emissions, and providing position updates to investors with existing holdings upon request.

Moreover, during my internship, I supported the preparation of customized Excel spreadsheets to calculate clients' portfolio profitability, using financial formulas and comprehensive analysis techniques. My responsibilities further included maintaining organized records of venture capital funds' subscriptions. These funds are particularly significant due to the Bank's international clientele, many of whom are non-residents in Portugal seeking Golden Visa eligibility. I also supported monthly securities' quotation validations and managed the

distribution of execution and confirmation notices to clients through an automated system. These tasks enhanced my understanding of banking operations.

2.4.2.3. Projects and Meetings

My responsibilities expanded to supporting the compilation of shortlists for various investment instruments, with securities from the Bank's Investment Pool. They were then aggregated into a PowerPoint presentation and sent to the relationship manager, who delivered it to the client. Specifically, when the client was considering several fixed-income opportunities, I supported the development of simulations for indicative bond pricing using Bloomberg data. This enabled the comparison of different bonds, providing clients with a transparent view of total investment costs, including accrued interest, brokerage fees, and taxes.

Besides, I supported the management of corporate actions, which involved reviewing the official documents sent by publicly traded companies, simplifying the information, and communicating it effectively to the relevant client managers. These diverse events included dividend reinvestment plans, stock splits, early bond redemptions, exchange offers, and other similar activities. This role required attention to detail and translating complex financial information into clear and concise communications.

Another project I was involved with was the preparation of weekly training materials for the private banking sales team, featuring relevant market news, performance analyses, macroeconomic indicators, and investment solutions for clients. These presentations incorporated real-time market data extracted from Bloomberg. This approach ensured that the sales team was equipped with the most current and accurate information, enhancing their ability to provide informed advice to their clients.

It is also worth noting that I participated in various meetings that enhanced my understanding of the Bank's operations and strategic initiatives. I attended discussions with the Operations Department to address custodian matters. Weekly meetings within the CMD helped us manage our pipeline of activities and maintain organizational efficiency. I was also included in discussions with third parties, namely intermediaries and potential business partners.

2.4.2.4. Events

During my internship, I attended several events organized by prominent asset managers, including BlackRock, Nomura, Millenium BCP, and Citywire. These events offered valuable networking opportunities and a glimpse into the professional investment world. I took notes on

interesting investment prospects, some of which were subsequently analysed and incorporated into the Bank's Investment Pool, demonstrating the practical value of my contributions.

I also participated in internal initiatives, including the Bank's Annual Executive Meeting, an event where the preliminary results for 2024 were presented, along with corporate objectives for 2025. I took part in a corporate volunteering initiative at the Casa dos Animais de Lisboa, a government-owned institution dedicated to rescuing and caring for stray animals. This experience, part of the "ATLANTICO for US" program, brought me self-fulfilment since I contributed to the animals' well-being.

2.4.3. Tools and Methodologies Used

I used a variety of tools to enhance my productivity and analytical capabilities so that I could perform the tasks described above. The Bloomberg Terminal was crucial for validating quotes, screening funds for returns and volatility, selecting bonds, and obtaining updated market data for the weekly training sessions. This experience significantly improved my proficiency in using Bloomberg formulas. Excel played a fundamental role in maintaining records and automating processes through macros, which reduced operational errors.

I also leveraged internal and external resources for various tasks. I employed Microsoft Teams daily to conduct meetings and communicate with colleagues, facilitating collaboration across departments. I regularly consulted Twitter and reputable financial publications such as the Financial Times to stay informed on recent financial news. This diverse toolkit improved my efficiency and deepened my understanding of financial markets and data analysis.

3. CASE STUDY: DIGITAL EQUITY AND EUROZONE INFLATION-LINKED NOTE

This chapter analyses the structured product selected for the case study, covering its features, underlying assets, and issuer. It also includes a macroeconomic risk assessment, regulatory context (MiFID II and PRIIPs), and a literature review that will pave the way for the practical part of the study, presented in Chapter 4.

3.1. Definition and Payoff Structure

As mentioned, the product under analysis is a Digital Equity-Linked Note linked to the EURO STOXX 50 Index and Eurozone Inflation (measured by the Eurostat HICP Ex-Tobacco Index)[2]. This product was issued by Barclays Bank Ireland PLC (BBI) under the ISIN XS2470048583 on February 27, 2023, and matures 3 years after, on February 27, 2026. The

[2] The product's KID can be consulted at ATLANTICO's website: Key Information Document

product's notional amount is EUR 1000. However, ATLANTICO's teams decided to set the minimum investable amount at EUR 10,000. The minimum threshold was increased by the distributor to avoid much granularity, since the selling process of structured products is quite complex due to regulatory requirements. The issue price is 100% of the product's notional amount, meaning the product was issued at par. The product's currency is the same as the underlying currency – Euro.

This product has embedded capital protection of the whole amount invested (100%), given that no early redemption or termination of the security occurs. As such, investors will get at least the value of their investment at maturity. In terms of payoff structure, this structured note comprises two distinct return components:

- Floating Interest Payments: Annually, the product pays coupons linked to the Eurostat Eurozone HICP Ex-Tobacco Index. These payments are contingent on positive year-on-year inflation variation, calculated as the percentage change in the index relative to its value one year before.

- Equity-Linked Coupon: At maturity, an additional coupon of 0.10% of the notional amount is paid if the EURO STOXX 50 Index closes at or above its initial level (established as 4209.15 points). If the index declines below this threshold, no bonus coupon is distributed.

3.1.1. Product Decomposition

Decomposing structured products into more straightforward financial instruments is a crucial process that enhances understanding, valuation accuracy, and risk management. By breaking down complex products into their constituent parts, such as bonds, standard options (calls and puts), and even exotic options, one can apply established pricing models to each component, leading to more precise valuations.

This approach also improves transparency and performance attribution, allowing us to understand which components drive returns or losses. Additionally, decomposition facilitates risk assessment by identifying and quantifying various risk factors, such as market, credit, and liquidity risks. This benefits both issuers and investors by offering a clearer product picture.

Indeed, the structured note under analysis can be decomposed into more straightforward financial instruments, namely:

- A zero-coupon bond with a notional amount of EUR 1000, designed to secure 100% of this value at maturity.

- A series of three call options (one for each year of the product's life) on the year-on-year variation of the Eurozone Inflation index, with strike price equal to zero. This component represents the product's inflation-linked feature, offering protection against it.

- A digital option (binary call option) on the EURO STOXX 50 index, with the strike level established at 4209.15 points. This component introduces equity market exposure.

The following two subsections explore each return component of the product in depth.

3.1.2. Floating Interest Linked to Eurozone Inflation

As stated, the annual floating interest payment is based on the inflation index, which corresponds to the Eurozone HICP Ex-Tobacco Index taken directly from Eurostat. The Floating Interest Amount (FIA) per security, for each interest payment date, is calculated as follows:

$$(1)\ Rate\ of\ Interest = Max\left(0, \frac{Inflation\ Index\ (t)}{Inflation\ Index\ (t-1)} - 1\right) \times 100\% .$$

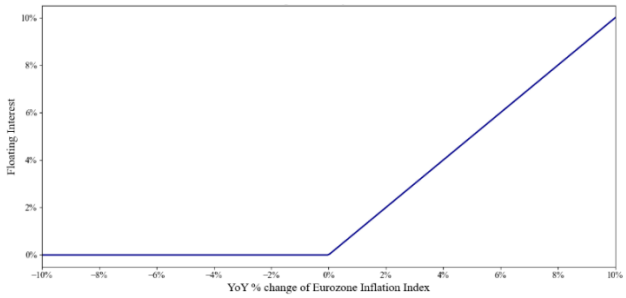
$$(2)\ FIA = Rate\ of\ Interest \times 1000 \times Day\ Count\ Fraction .$$

Table 1. *Relevant dates for Floating Interest.*

Interest Payment Date	Inflation Index (t)	Inflation Index (t – 1)
27 February 2024	November 2023	November 2022
27 February 2025	November 2024	November 2023
27 February 2026	November 2025	November 2024

Source: product's term sheet. Author's elaboration.

Figure 1. *Floating Interest payoff structure.*



Source: Author's elaboration.

The Inflation Index (t) corresponds to the index 3 months before the current Interest Payment Date. In contrast, the Inflation Index (t – 1) corresponds to the same index 15 months before the current Interest Payment Date. Indeed, this means that the time window between these values is 1 year (12 months), so in fact this formula measures the year-on-year change of the index. The Day Count Fraction employed is $30/360$. The relevant dates regarding this

interest component are presented in Table 1. Figure 1 illustrates the Floating Interest payoff structure for each year of the product's life.

3.1.3. Equity-Linked Coupon

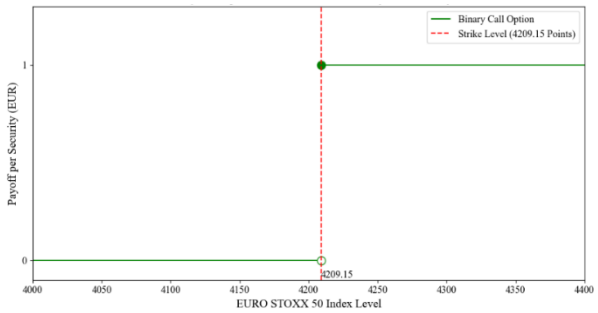
The product's bonus coupon is tied to the EURO STOXX 50 Index. In practical terms, this corresponds to a binary call option (or digital option) on the index since there are only two possible payoffs at maturity.

When maturity is reached, if the final reference level is **at or above** the initial reference level (4209.15 points), a coupon of 0.10% of the notional amount is paid (EUR 1), and no coupon is paid otherwise. The initial reference level corresponds to the index's closing level on the initial valuation date, which is February 8, 2023. Likewise, the final reference level corresponds to the index's closing level on the final valuation date, which is February 9, 2026. Therefore, this component can be mathematically represented as:

$$(3)\ Coupon_{\,Maturity} = \begin{cases} 0\%;\ Und_M < 4209.15 \\ 0.10\%; Und_M \geq 4209.15 \end{cases},$$

where Und_M corresponds to the EURO STOXX 50 Index level on the final valuation date. Figure 2 graphically represents this payoff structure, with the red dashed line corresponding to the strike level of 4209.15 index points.

Figure 2. *Equity-Linked Coupon payoff structure.*



Source: Author's elaboration.

When combining both components (Floating Interest and Equity Coupon), this corresponds to a Cash Flow (CF) at maturity of:

$$(4)\ CF_{Maturity} = \begin{cases} 1001 + FIA; Und_M \geq 4209.15 \\ 1000 + FIA;\ Und_M < 4209.15 \end{cases}.$$

It is important to note that the values discussed refer to each security, with a notional amount of EUR 1,000. The return components are structurally unrelated, linked to different underlying indicators – Eurozone inflation and the EURO STOXX 50 Index. As a result, the FIA is

included in both scenarios regardless of the performance of the equity index, since it depends solely on the year-on-year variation in Eurozone inflation.

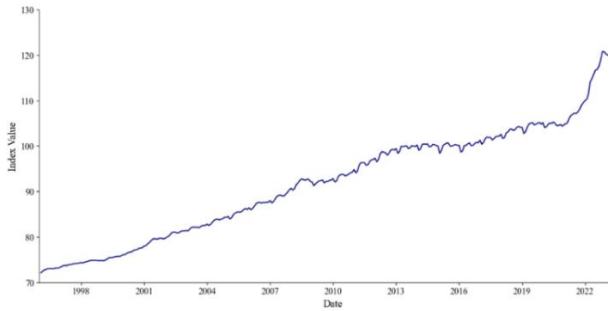
3.2. The Underlying Assets

3.2.1. Eurostat Eurozone HICP Ex-Tobacco Index

The Eurostat Eurozone HICP Ex-Tobacco Index is a variant of the Harmonized Index of Consumer Prices (HICP). It measures inflation in the Eurozone by tracking price changes for a representative basket of consumer goods and services (food, housing, transportation, education, among others) and excluding tobacco-related items. According to the Eurostat official website, the HICP for the Euro Area serves as the primary inflation indicator for the European Central Bank (ECB). Thus, it is the key macroeconomic indicator of price stability and monetary policy. The ECB defines price stability as a year-on-year HICP increase below 2%, aiming to maintain inflation close to this target over the medium term.

The selection of this index as the underlying inflation measure for the structured product was strategic and well-founded. It serves as an optimal proxy for Eurozone inflation due to its robust methodology and widespread acceptance. The index is calculated and published monthly. Structured products linked to the HICP Index provide clients with inflation hedging while exposing issuers (in this case, Barclays) to Eurozone inflation risks. Figure 3 shows the index historical data from its creation in 1996 until January 2023, right before the structured note was issued. There is an upward trend, especially from 2021 onwards, reaching an all-time high in October 2022.

Figure 3. *Eurostat Eurozone HICP Ex-Tobacco Index historical data.*



Source: Eurostat official website. Author's elaboration.

Figure 4 presents the index's year-on-year (YoY) variation over time, representing the annual inflation rate. In 2022, inflation in the Euro Area went over 10%, which is five times the 2% ECB's target.

Figure 4. *Eurostat Eurozone HICP Ex-Tobacco Index YoY percentual change.*

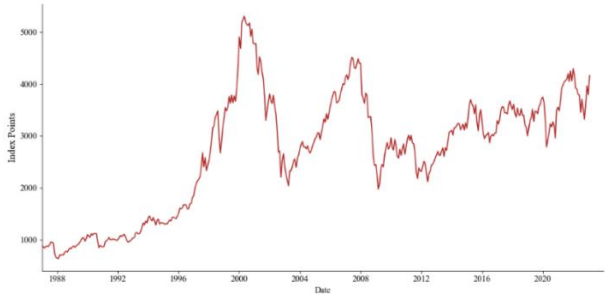
Source: Eurostat official website. Author's elaboration.

3.2.2. EURO STOXX 50 Index

The EURO STOXX 50 Index is the leading blue-chip[3] index for the Eurozone, covering the 50 largest market capitalization companies from Eurozone countries. Although the EURO STOXX 50 Index was officially launched in 1998, historical data is available from as early as 1986, as the index was retroactively calculated for prior years. The index was assigned a base value of 1,000 points as of December 31, 1991, to establish a consistent benchmark.

The index is managed by STOXX Limited, a subsidiary of Deutsche Börse AG. It serves as underlying for a wide range of investment products such as ETFs, futures, options and structured products, being one of the most liquid indices for the Eurozone. There are more than 160,000 structured products linked to the EURO STOXX 50 index (STOXX, 2025). According to the index's fact sheet as of January 2025, the three predominant sectors in its composition were Technology, Industrial Goods and Services, and Banks, with weights of 17.8%, 15.4% and 11.7%, respectively. In terms of countries, the most representative was France (39.2%), followed by Germany (28.5%) and the Netherlands (13.9%).

Figure 5. *EURO STOXX 50 historical data.*



Source: STOXX official website. Author's elaboration.

In Figure 5, the index's monthly historical data is shown from 1986 (inception) until January

[3] The blue-chip designation is used for a stock market index that tracks the performance of blue-chip companies, which are large, well-established, and financially stable corporations with a history of reliable performance.

2023, right before the structured product's issuance date. From its inception, the index has shown significant growth and an overall positive trend. Historical data show periods of both sharp increases and declines, reflecting economic cycles and market events, such as the dot-com bubble at the beginning of the century and the Global Financial Crisis (GFC) in 2007-2009.

3.3. The Issuer

The structured note under analysis was issued by BBI, a wholly owned subsidiary of Barclays Bank PLC that serves clients in the European Economic Area (EEA) following Brexit. While ATLANTICO conceptualized the product, BBI has legal and financial obligations for coupon payments and capital redemption. This arrangement underscores the importance of BBI's creditworthiness in assessing the product's overall risk profile. As of January 2023, BBI held strong credit ratings, with Standard & Poor's assigning a long-term issuer credit rating of A+ and Moody's rating it A1 (Barclays, 2023). This rating reflects BBI's crucial role within the Barclays Group and its status as a core subsidiary. These ratings remain the same as of March 2025, reflecting the institution's stability (Barclays, 2025).

The coupon payment process, observed during my internship in BAE for the February 2025 distribution, follows a multi-step transfer: from BBI to ATLANTICO's custodian, then to ATLANTICO, and finally to the investor. This process illustrates the critical role of the issuer's financial stability in meeting its obligations and the rather complex financial infrastructure supporting this event.

3.4. Risk Assessment and Macroeconomic Environment

Macroeconomic trends play a crucial role in financial product design and investor behaviour, thereby shaping the rationale behind a product's structure, its appeal to investors, and its risk exposure. This section examines the key financial risks influencing the structure under analysis, considering the macroeconomic conditions leading up to its conceptualization and issuance. In this sense, the analysis focuses on how macroeconomic factors – such as economic growth, inflation trends, and equity market performance[4] – influenced the product's perceived and forecasted risks before its issuance in February 2023.

[4] Exchange rates and labour market conditions were also considered. However, given that the underlying asset is denominated in euros, exchange rate fluctuations were not deemed particularly relevant for the fair price calculation, unless the investor's base currency differs from the product's base currency. As for labour market conditions, available indicators (such as the Employment Expectations Indicator peaking in January 2023) pointed to continued labour market tightness in the Eurozone, which aligned with the overall positive macroeconomic outlook at the time of the product's issuance.

3.4.1. Eurozone Economic Growth and Uncertainty

Given that the Digital Equity-Linked Note is tied to Eurozone Inflation and the EURO STOXX 50 Index, its performance is directly influenced by both macroeconomic conditions and equity market trends, which are explored in this subsection.

3.4.1.1. GDP Growth

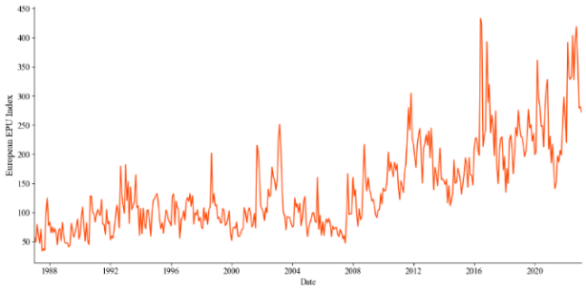
The COVID-19 pandemic led to a historic 6% contraction in the Eurozone economy, surpassing the 4.4% decline experienced during the GFC. In 2021, the region rebounded strongly, with 6.3% GDP growth. Despite 2022 challenges, the Eurozone continued its recovery, posting 3.5% (Eurostat, 2023).

Moreover, according to the European Commission's Winter 2023 Economic Forecast, GDP growth in the Euro Area was projected at 0.9% for 2023 and 1.5% for 2024. These projections, based on the most reliable and recent data available before the product's release, set a positive tone for the Eurozone's resilience and ongoing recovery.

3.4.1.2. Economic Policy Uncertainty Index

The years preceding the structured product's issuance were characterised by heightened uncertainty. The Economic Policy Uncertainty (EPU) Index measures the uncertainty surrounding government policies and their potential economic repercussions. Since the structured note is tied to Eurozone dynamics, analysing the EPU Index's behaviour in this region is pertinent. However, while the official EPU website provides data for Europe as a whole, it does not offer a distinct aggregated index specifically for the Eurozone. In this sense, the European EPU Index was utilized.

***Figure 6**. European EPU Index from 1987 to January 2023.*



Source: EPU official website. Author's elaboration.

This indicator has been showing an upward trend, especially after the GFC (Figure 6). The index reached another major peaks, namely in 2020 and in 2022. In early 2023, even though uncertainty moderated slightly, levels remained elevated. These peaks signal increased market

risk and volatility, which directly influences structured products' fair pricing through several factors, namely volatility premiums, sensitivity to discount rates and investor sentiment.

Interest rates are critical in determining the fair price of structured products, especially those with fixed-income components or capital protection features. When interest rates rise, the present value of future cash flows stemming from the structured product decreases. This occurs because higher interest rates increase the discount rate employed when valuing these cash flows, often through the risk-free rate used in pricing models such as Black-Scholes and Monte Carlo. Conversely, during periods of low interest rates, these products become more attractive as the lower discount rate enhances the present value of embedded derivatives and future cash flows.

Investor sentiment and risk appetite are also key drivers of structured product pricing. In times of heightened policy uncertainty, investors may prioritize capital-protected or conservative structures, such as the one being analysed, over riskier products. This shift in demand influences pricing, as issuers adjust premiums to align with market preferences. Positive sentiment can lead to higher prices for growth-oriented products, while negative sentiment may push prices lower for speculative instruments. Volatility premiums are explored in the next subsection.

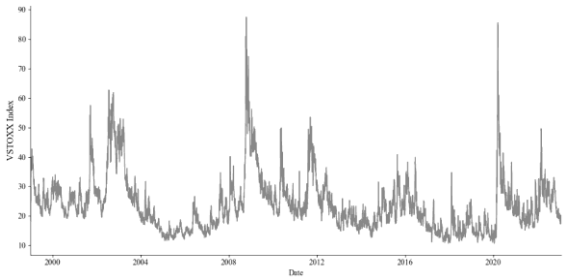
3.4.1.3. Equity Market Conditions

The structured note under analysis incorporates an embedded binary call option on the EURO STOXX 50 Index. Given this equity-linked component, providing a comprehensive framework for analysing equity market conditions is essential.

The index demonstrated notable resilience and outperformance in the years leading up to February 2023. According to STOXX official website, it rose 24.1% in 2021 and, despite broader market challenges in 2022, it declined 8.8%, outperforming many global peers. In early 2023, the EURO STOXX 50 started strongly, gaining 9.9% in January alone. This strong performance and positive sentiment surrounding the EURO STOXX 50 highlighted a shift in investor sentiment. European equities began to attract more attention due to their relative valuation appeal and improving economic outlook. This provided a favourable backdrop for structured products linked to the index, enhancing their appeal to investors.

However, the years leading up to 2023 witnessed significant volatility in both global and European equity markets. Equity market volatility can be measured by the VSTOXX Index, which monitors the 30-day implied volatility of the EURO STOXX 50 from real-time options prices on the index (STOXX, 2025).

Figure 7. *VSTOXX Index from January 1999 to January 2023.*



Source: STOXX official website. Author's elaboration.

This index registered significant spikes in 2008 during the GFC, in 2020 due to the pandemic and in 2022 following geopolitical tensions (Figure 7). By early 2023, VSTOXX had stabilized, but still elevated compared to pre-pandemic references. Volatility impacts the fair pricing of structured products. During periods of heightened volatility, the cost of derivatives increases due to higher implied volatility premiums. Conversely, when VSTOXX stabilizes, as it did in early 2023, implied volatility premiums decrease, reducing the cost of embedded options and potentially improving the product's attractiveness.

3.4.2. Inflation Trends

Structured products are inherently exposed to inflation risk, stemming from uncertainty in future inflation rates and their impact on purchasing power and capital erosion. The floating interest component of the product introduces a unique exposure to this risk, presenting opportunities and challenges depending on the perspective.

From the investors' perspective, on one hand, a rise in Eurozone Inflation directly increases the annual coupon received, as the payout is linked to the year-on-year change in the inflation index. On the other hand, elevated inflation expectations typically prompt central banks such as ECB to raise interest rates. This increases the discount rate applied to the note's future cash flows, lowering its fair price. However, the note's design as an inflation hedge means heightened inflation expectations could increase its fair value to account for uncertainty. For example, during high inflation periods such as 2022, demand for inflation-linked instruments often rises, driving up valuations. Furthermore, in this context, inflation risk is asymmetric and skewed to the upside for the issuer. Higher inflation triggers larger coupon payments, increasing the issuer's liability and potentially amplifying its credit risk.

As stated, inflation in the Eurozone reached unprecedented levels in 2022. Given this context, investors were deeply concerned about inflation and its adverse effects, particularly capital erosion caused by rising prices. This underscored the need for financial instruments that could serve as effective inflation hedges while preserving capital. Simultaneously, periods of

negative inflation, or deflation, are historically rare and typically short, as evidenced by only a few notable occurrences in the last few decades. In the Eurozone, and according to the HICP Ex-Tobacco index data, this happened in 2009, 2015 and 2020. This rarity implies that the probability of sustained deflation is low, making it reasonably probable for investors to receive coupon payments.

Moreover, from the issuer's perspective, forecasts for 2023 and beyond indicated a significant moderation in inflation rates, with headline inflation expected to decline to 5.9% in 2023 and further to 2.4% in 2024 and 2% in 2025, reaching the long-term target (ECB, 2023). This downward expectation significantly reduced the risk associated with issuing an inflation-linked product.

Ultimately, both conditions – investor demand for inflation protection and reduced issuer risk due to expected inflation moderation – provided the foundation for conceptualizing the structured note under analysis. Its design reflects a strategic response to both immediate market concerns and longer-term economic projections.

3.4.3. Credit Risk

As this structured product is issued by BBI, investors are exposed to the risk of default by the issuer during the note's 3-year maturity. Financial instability at Barclays could compromise its ability to meet payment obligations, resulting in delayed or reduced payouts, or even loss of capital in extreme cases. Downgrades in BBI's credit rating may also reduce the product's market value, as higher credit risk leads investors to demand increased yields. However, as mentioned in the issuer's section (*3.3*.), Barclays' strong credit profile mitigates concerns for investors, signalling a low likelihood of default, even under adverse economic conditions. From the issuer's standpoint, lower inflation expectations at the time of issuance reduced the likelihood of large coupon payouts, thereby limiting the issuer's financial liabilities over the product's maturity.

3.4.4. Liquidity Risk

Liquidity risk is prominent for structured products, as they are often designed with limited or no active secondary market. Investors may not find a buyer if they wish to sell the product before maturity, making it difficult or costly to exit early. The KID of the product highlights these circumstances and recommends the investor to hold it until maturity.

3.5. Regulatory and Compliance Considerations

This section delves into the regulatory and compliance considerations that both the structured note under analysis and ATLANTICO as its distributor are subject to. Key regulations include the MiFID II (Markets in Financial Instruments Directive II) and the PRIIPs Regulation (Packaged Retail and Insurance-based Investment Products).

3.5.1. MiFID II

MiFID II is a European Union legislation that came into effect in 2018, covering virtually every asset and profession within the EU's financial industry, including structured finance. This stringent regulatory framework is designed to enhance investor protection and transparency.

According to MiFID II, derivatives, including structured notes, are considered complex products, meaning their distribution involves more detailed requirements. These include classifying clients into three categories (retail, professional, or eligible counterparties), and performing appropriateness and suitability tests to assess the clients' knowledge, experience/expertise and risk tolerance (Art. 25) before selling them structured products. Additionally, distributors must define the product's target market (Art. 16), ensuring its compatibility with the client's risk profile and product's returns (ESMA, 2025).

3.5.2. PRIIPs Regulation

The PRIIPs regulation came into effect in January 2018. A PRIIP is defined as a packaged investment where the return or amount repayable to the investor depends on the performance of the underlying assets (e.g., stocks, bonds, derivatives) or reference values (e.g., market indices, exchange rates). PRIIPs regulation's primary goal is to enhance retail investor protection through standardized disclosures like the KID (European Parliament & Council, 2014, Article 4). The KID is a mandatory document that must be provided by the issuer (Barclays in this case). In addition to the product description, the document must include its risks, returns, and costs, including the case of early redemption, recommended holding period, complaint options, and other relevant information.

Regarding risk disclosure, the KID must include a Summary Risk Indicator (SRI), which reflects market and credit risks. This indicator measures risk from 1 (lowest risk) to 7 (highest risk). Barclays measures the structured note's SRI as 2 out of 7, which is a low-risk class. Under Article 15 of the PRIIPs regulation, available in EIOPA's website, the KID must be reviewed and updated at least annually.

Furthermore, as a Portuguese distributor, BAE is subject to several reporting requirements from the CMVM, in line with both MiFID II and PRIIPs. For instance, all advertising and information related to the offer of complex financial instruments is subject to the CMVM prior approval to be presented to investors.

Despite being two independent regulations, they are closely related and complementary in their objectives, namely regarding product governance, cost transparency and risk disclosure. MiFID II relies on the standardized KID from PRIIPs to define target markets and ensure products are suitable for investors, using the KID's detailed risk, cost, and performance information. Additionally, PRIIPs manufacturers must regularly update KIDs, and any changes prompt reviews mandated by MiFID II to confirm continued suitability. This process creates a loop where updates to the KID trigger reviews under MiFID II, ensuring that products remain suitable for their intended markets. Indeed, distributors like ATLANTICO leverage the KID to fulfil MiFID II's suitability obligations, ensuring regulatory cohesion and compliance.

3.6. Literature Review

This literature review aims to pave the way for the practical part of this case study by exploring the fair pricing methodologies used for options embedded in structured products. Firstly, the standard financial models are discussed, particularly the Black-Scholes framework and Monte Carlo simulation techniques, highlighting their assumptions, suitability, and limitations. Subsequently, the Funding Valuation Adjustment (FVA) and the Comparable Security Approach (CSA) are discussed.

Hull (2014) characterizes the Black-Scholes model, introduced in the early 1970s, as a significant breakthrough in pricing European options. This model has profoundly shaped derivatives' pricing and hedging, remaining foundational for valuing vanilla options today.

Regarding assumptions, the model assumes frictionless and arbitrage-free markets, meaning there are no transaction costs or taxes, and assets are perfectly divisible. It also assumes a constant and known risk-free interest rate and continuous trading. The model further presumes that the underlying asset follows a Geometric Brownian Motion (GBM), implying log-normally distributed returns and constant volatility over the option's life. Additionally, the Black-Scholes model assumes that short selling is allowed, and that investors can borrow and lend unlimited amounts at the risk-free rate (Black & Scholes, 1973). When it comes to plain vanilla call options, several studies have shown that the Black-Scholes Model performs well (Macbeth & Merville, 1979).

However, while the model's assumptions enable a closed-form solution for European-style options, they also limit the model's applicability to more complex or path-dependent products, namely exotic options. For instance, volatility does not remain constant over time, especially for exotic options, nor do risk-free interest rates used to discount cash flows.

Monte Carlo Simulation relies on risk-neutral valuation. It simulates thousands of random price paths for the underlying asset(s) and averages their discounted payoffs to arrive at the option price (Boyle, 1977; Hull, 2014). This method is one of the most widely used for pricing options. Like the Black-Scholes Model, Monte Carlo also assumes the underlying follows a GBM, implying a log-normal distribution of returns and constant volatility.

According to Hull (2014), the key advantage of Monte Carlo Simulation is that it can be used when the payoff depends on the path followed by the underlying variable and only on its final value, underscoring its flexibility. It can also be used when the payoff from the derivative depends on multiple underlying assets, allowing it to accommodate complex payoffs and stochastic processes. The accuracy of the results given by this model increases as more paths are generated.

Nevertheless, Hull (2014) also highlights the drawbacks of this method – it can become computationally time-consuming and expensive, particularly when thousands of simulations are conducted. Additionally, it cannot easily handle situations with early exercise opportunities, besides assuming a risk-neutral world. It is also worth noting that the Monte Carlo Simulation is subject to similar criticisms as the Black-Scholes framework regarding the assumption of constant volatility and a constant risk-free rate over the option's life. Relying on the GBM poses limitations in capturing volatility clustering (periods of high volatility are usually followed by periods of high volatility and the same for periods of low volatility), jumps, and fat tails.

While the classical approaches have shaped the field of option pricing, they face challenges in accommodating the complex, nonlinear, and dynamic nature of modern financial markets. Specifically, assuming future cash flows should be discounted at the risk-free rate relies on an idealized setting with no credit, liquidity, or funding risks. However, this assumption may not account for the material impact of issuer-specific funding costs and creditworthiness on the instrument's fair value.

In this sense, and especially after the GFC, banks began to employ the Funding Value Adjustment (FVA). The purpose of FVA is to change the value of a derivative to what it would be if the bank's average funding cost was used as the risk-free discount rate (Hull, 2014).

Despite widespread use, Hull and White (2012) state that derivatives pricing should not consider funding costs. Their position advocates for using the risk-free rate, following a well-established principle in corporate finance theory – pricing should be kept separate from funding. Hull (2014) also emphasizes that FVA can create arbitrage opportunities between banks with differing funding profiles (e.g., buying options from high-funding-cost banks and selling to low-funding-cost banks). Andersen et al. (2019) also recognize that FVA is embedded in current dealer practices and can reflect funding costs associated with maintaining derivative positions. However, they point out that FVAs can lead to non-credible accounting practices, raising questions about their appropriateness and coherence.

In practice, many financial institutions incorporate funding costs in the valuations of their structured products. One method for estimating these funding costs is the Comparable Security Approach (CSA). This method derives the issuer's funding curve from market instruments such as bonds or credit default swaps issued by the same or similar entities. Typically, these comparable securities are selected aligning with the issuer's credit rating, the structured product's maturity profile, and market liquidity conditions. Thus, the observable yield implicitly incorporates a market-based assessment of the issuer's credit and liquidity premia.

The CSA is more a market convention than a fully formalized academic model, serving as a pragmatic extension of FVA. In practice, adopting the CSA entails discounting cash flows stemming from the structured product at the funding-adjusted rate rather than at the theoretical risk-free rate. This approach is favoured for its operational feasibility, making it popular among market participants.

Nonetheless, this practice remains controversial. On one hand, both FVA and CSA attempt to bridge the gap between theory and real-world market conditions. On the other hand, they challenge the fundamental principle that valuation should be independent of funding, introducing firm-specific funding costs into pricing models. This tension between theoretical rigor and practical realism continues to fuel debate in both academia and the financial industry.

Since the objective of this report is to bridge theory and practice, both the classical risk-free valuation and the CSA will be employed in the practical section, allowing for a comparative discussion of how each approach affects the pricing of the structured product.

4. STRUCTURED PRODUCT VALUATION AND ANALYSIS

This chapter encompasses the practical part of the case study. I explain the methodology in the first subsection, including the data and assumptions. Next, I present a description of the

valuation process and the baseline results. I also compute the probability of a floating interest payment yearly, and a bonus coupon payment at maturity stemming from the digital option on EURO STOXX 50. Then, I conduct a scenario analysis, including changes in key inputs and a Cholesky Decomposition. Finally, the main conclusions drawn from this analysis are presented.

4.1. Model Inputs and Assumptions

4.1.1. The Pricing Model

Amongst the option pricing models in the literature review, the one that presents the best fit for this case study in terms of feasibility, accuracy, and flexibility is the Monte Carlo simulation. As mentioned before, it has the advantage of being suitable when the payoff depends on the path followed by the underlying variable and when it depends only on its final value, which is the case for both call options and digital options. Moreover, it is adequate when there are several underlying variables, which applies since we deal with two underlying indices.

Monte Carlo simulations rely on a set of parameters and random variables to estimate future underlying prices through a stochastic process (GBM), which assumes that asset prices follow a random walk with drift. To compute the simulated underlying asset's prices at maturity (S_T), the inputs needed for this model include the model time step (Δt), the risk-free rate (r) and volatility (σ), assuming a risk-neutral valuation. The ε term is a random sample (or shock) from a normal distribution with mean zero and standard deviation of one. Mathematically, this can be represented as follows:

$$(5)\ \boldsymbol{S_T} = \boldsymbol{S_0} \times \boldsymbol{e}^{\left[\left(r-\frac{\sigma^2}{2}\right)\Delta t+\sigma\varepsilon\sqrt{\Delta t}\right]},\quad (6)\ \Delta\boldsymbol{t} = \frac{\boldsymbol{T}}{\boldsymbol{n}},$$

where $\boldsymbol{S_0}$ is the initial asset price, $\boldsymbol{T}$ is the time to maturity and $\boldsymbol{n}$ is the number of time steps.

The payoff is calculated at maturity after generating all simulations. The simulated payoff is calculated based on the simulated asset price. Each payoff is discounted back to the issuance date using the risk-free rate, representing the present value of future cash flows. The final expected value of the derivative is the average of all discounted payoffs across all simulations. Since the product under analysis comprises more than one financial instrument, its final value will correspond to the sum of its components' fair value.

4.1.2. Inputs and Assumptions

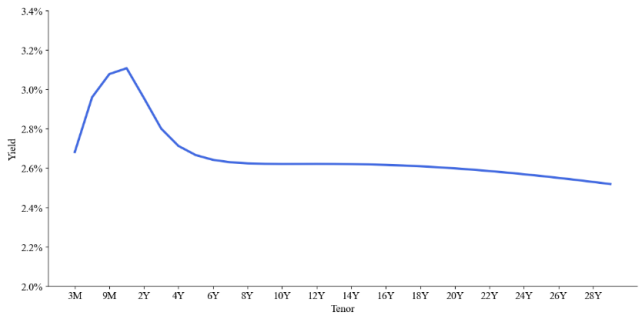
This subsection examines the inputs and assumptions employed throughout the structured note's valuation and provides the rationale behind them. All inputs are assumed to remain constant throughout the life of the structured product. The time window chosen for the model

time step was one year due to the product's annual coupon nature. Since the product has a 3-year maturity, the analysis encompasses three time steps.

The r term, in the risk-neutral approach, was retrieved from the ECB AAA Euro Area Government Yield Curve. This curve comprises euro-denominated central government bonds with AAA ratings by Fitch Ratings. It is constructed using zero-coupon bond yield estimates and is updated every target business day. This curve was selected despite the issuer, BBI, being part of a UK-based banking group, as the product under analysis is denominated in Euros. Moreover, it focuses on the Euro Area, linked to euro-denominated variables. By adopting a euro-area risk-free curve, the analysis aligns the valuation with the currency and economic environment of the product's underlying exposures. Additionally, this approach mitigates currency risk arising from discounting euro-denominated cash flows using a risk-free rate in a different currency. Furthermore, from a hedging perspective, it is reasonable to assume that any hedging undertaken by the issuer would be conducted in euros, further supporting the appropriateness of using a euro risk-free curve.

Based on this rationale, the mid-yield to maturity[5] was retrieved from Bloomberg and the ECB's official website. As of February 27, 2023 (issuance date), the tenor chosen was 3 years. The corresponding yield to maturity was 2.8002%. Figure 8, built from Bloomberg data, displays the yield curve from which this value was obtained.

Figure 8. *ECB AAA Euro Area Government Mid Yield Curve as of February 27, 2023.*



Source: ECB official website, Bloomberg. Author's elaboration.

Regarding the CSA, the methodology followed was slightly more complex. Since the goal was to determine the issuer's funding costs, the first step was to conduct a fixed income search in the Bloomberg Terminal for zero-coupon bonds issued by Barclays. Zero-coupon bonds are often employed in the CSA as they provide a precise measure of the issuer's credit spread without the complexities of coupon payments. However, no results were found for this search

[5] The mid yield to maturity is the average between the bid and ask yields of a bond. It provides a balanced measure of market expectations, minimizing the influence of temporary price fluctuations.

when filtering for the currency (Euro) and maturity date. In response, fixed coupon bonds with similar criteria were searched. These financial instruments are often widely traded, making them more liquid and observable in terms of prices than zero-coupon bonds. When the issuance date filter was added to the previously used filters, the results indicated a single fixed coupon bond.

Relying on a single comparable bond typically introduces limitations, such as reduced representativeness and increased idiosyncratic risk. However, in this case, the selected bond closely matches the structured product across several critical dimensions: issuer, currency, issuance date, and maturity. This high degree of alignment enhances the precision of the yield estimate, as it minimises discrepancies related to credit risk, market conditions, or structural features. Despite this, a sensitivity analysis (e.g., ±100 basis points shift in the bond yield and its effect on the structured product's fair value) is conducted in section *4.3.1.*

The chosen security is a 3-year fixed coupon bond (ISIN XS2470028395), with a coupon rate of 3.27%, issued in February 2023 and maturing in February 2026, similar to the product under analysis. In this context, the yield to maturity is more appropriate than the coupon rate, as the former captures the issuer's total funding costs by accounting for all cash flows and the bond's market price. After searching for the bond historical prices, we arrive at a mid-yield to maturity of 3.6550% as of February 27, 2023. Although the bid yield could be interpreted as the issuer's funding cost, the mid yield was chosen for this analysis due to its neutrality and market convention. It represents a more stable view of what the issuer might expect to pay in the market. Moreover, since the objective is to estimate an average and representative cost of funding, the mid-yield provides a more stable and consistent basis. This case also ensures methodological coherence, as the mid-yield was used in the risk-neutral approach. The ECB AAA yield curve represents mid-yields, reflecting a mid-market consensus rather than bid or ask levels.

Regarding volatility (σ), one figure is required for each market variable – Eurozone Inflation and EURO STOXX 50 Index. Historical volatilities were computed over a 5-year horizon for both variables to maintain consistency and ensure methodological robustness[6]. This

[6] While the 5-year time window was chosen as baseline, market conditions have shifted significantly in recent years, particularly following the post-COVID inflation spikes and the 2022 rate hikes. A comparison was performed between 3-year and 5-year historical volatilities to address potential distortions. The difference was not material for the Eurozone Inflation Index (2.1039% vs. 2.0344% for the 3-year and 5-year time windows, respectively). In turn, for the EURO STOXX 50, the 3-year historical volatility was 24.3914%, almost four percentage points (pp) higher than the 5-year historical volatility (20.7583%). For this reason, section *4.3. Scenario Analysis* considers both a 5pp increase and decrease in EURO STOXX 50 volatility.

time window captures sufficient historical behaviour while excluding outdated regimes that could distort the analysis.

For the Eurozone Inflation index, monthly data were sourced from Bloomberg. Given that the February 2023 index data was unavailable at issuance, the period considered spans from January 2018 to January 2023. Monthly log returns were calculated, from which the variance was derived. The standard deviation was then annualized using the square root of 12, as the index is released monthly. Following this, we obtain an annualized volatility of 2.0344%. The same methodology was applied to the EURO STOXX 50 Index, with the key difference being the use of daily price data. In this case, the time frame spans from February 27, 2018, to February 27, 2023, corresponding exactly to a 5-year window ending on the product's issuance date. Daily log returns were used to calculate the variance, and the resulting standard deviation was annualized using the square root of 252, reflecting the average number of trading days in a year. This results in an annualized volatility of 20.7583%.

In this analysis, I employ historical volatility for both indices following the risk-neutral valuation framework. However, when applying the CSA, I adopt a more market-reflective methodology by using the implied volatility for the EURO STOXX 50, as derived from the VSTOXX index. The VSTOXX value on issuance date was 19.9638% (extracted directly from Bloomberg). This dual approach ensures theoretical consistency and practical relevance, allowing for a comparison between a model-based valuation and a real-market pricing perspective. All inputs are summarized in Table 2.

Table 2. *Model Inputs.*

Variables	Risk-free Approach	CSA
Discount Rate	2.8002%	3.6550%
Eurozone Inflation Volatility	2.0344%	2.0344%
EURO STOXX 50 Volatility	20.7583%	19.9638%

Source: Author's elaboration.

In the baseline analysis, the correlation between the two underlying variables is assumed to be zero. However, to consider the potential interdependence between both indices, Cholesky Decomposition is implemented to simulate correlated stochastic paths. This method of sampling from a multivariate normal distribution is widely used in financial modelling to jointly simulate multiple risk factors and capture their co-movements (Hull, 2014). This technique converts independent standard normal shocks into correlated shocks using a lower-triangular

matrix derived from a given correlation coefficient (ρ). Mathematically, this matrix can be represented as follows:

$$(7)\ L = \begin{bmatrix} 1 & 0 \\ \rho & \sqrt{1-\rho^2} \end{bmatrix},$$

assuming we are simulating two correlated normal variables (2×2 matrix) with correlation coefficient ρ.

To compute the correlation coefficient between the Eurozone Inflation Index and the EURO STOXX 50 Index, historical monthly log returns over the past 5 years (from January 2018 to January 2023) were collected and analysed using Excel[7]. This resulted in a correlation coefficient of -0.1480, indicating a weak and inverse relationship, consistent with recent periods of monetary tightening and inflation shocks that have exerted downward pressure on equity markets. It is also worth noting that this approach was not applied because the product's payoff structure directly links the two underlying variables. Instead, it was introduced to account for their potential macroeconomic interdependence, such as inflation influencing equity performance. In this sense, including correlation in the simulations enhances the robustness of the analysis. This is further detailed in section *4.3. Scenario Analysis*.

4.2. Valuation Methodology: Cash Flow Estimation and Pricing Analysis

This section is divided into two subsections: one presents the results obtained in the risk-free approach, followed by the results of the CSA.

Under both approaches, 100,000 simulation paths were generated per year to model the evolution of the Eurozone Inflation Index and at maturity for the EURO STOXX 50 index, following the GBM. The drift was set equal to the discount rate (risk-free rate or issuer funding costs, depending on the approach), in line with the no-arbitrage assumption of the Black-Scholes model. As stated, no correlation between the two variables is assumed.

Present values for each payoff component were computed by discounting expected cash flows at the suitable discount rate, and then summed to provide an estimate of the structured note's fair value. All the figures and tables in this chapter were obtained from own Python scripts with data retrieved or with data resulting from own calculations.

[7] Data is available upon request.

4.2.1. Risk-Free Approach

4.2.1.1. Fair Value and Component Breakdown

The main results regarding the structured note's fair value and its components following the risk-free approach are presented in the Table 3:

Table 3. *Present Value of Structured Note Components (Risk-Free Approach).*

Component	Present Value (€)	% of Notional
Year 1 Coupon	€28.21	2.82%
Year 2 Coupon	€27.43	2.74%
Year 3 Coupon	€26.63	2.66%
Digital Option	€0.48	0.05%
Zero-Coupon Bond	€919.43	91.94%
Total	€1,002.17	100.22%

Source: Own calculations.

The fair value estimate stands at 100.22% of notional, closely aligning with the selling price of 100%. The results indicate that most of the structured note's value is concentrated in the zero-coupon bond component (91.94%), underscoring the principal-protection feature. The inflation-linked coupons contribute meaningfully to the total value (around 8.22%), though their present value decreases across the three years due to increasing time discounting. In contrast, the digital equity option contributes only 0.05%, reflecting its limited magnitude, binary payoff structure and the moderate probability of ending in the money.

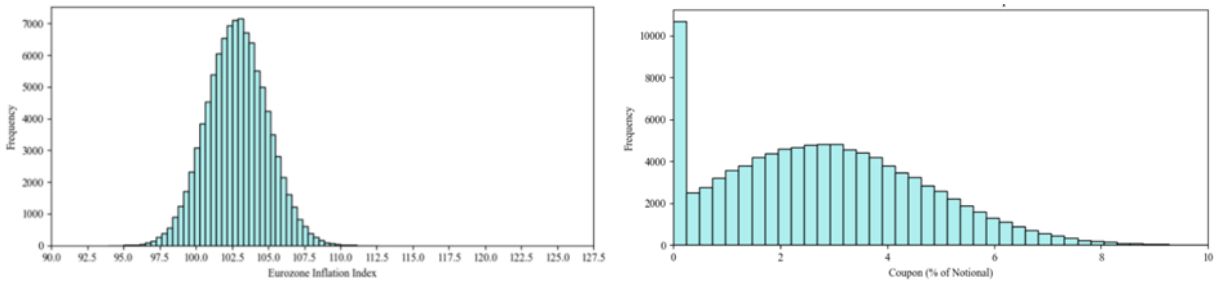
From the issuer's perspective, the results support the product's commercial viability. As mentioned, the total fair value of the structured note under the risk-neutral approach aligns with the selling price of 100% of notional. This alignment between theoretical fair value and issue price implies that the product is priced with minimal arbitrage or over-hedging cost. However, since the fair value estimate is slightly above the selling price, it may also signal that the riskless world assumed is pushing the theoretical value upward, highlighting the difference between idealized model assumptions and real-world market pricing.

4.2.1.2. Distribution and Probability Analysis

This subsection presents the simulated distributions of the Eurozone Inflation Index across each year of the product's life and the EURO STOXX 50 Index at maturity in the risk-free framework. In addition, the distributions of the inflation-linked coupons are shown. Some probabilities are also computed, namely the likelihood of receiving an inflation-linked coupon in each year of the product's life individually and of receiving coupons in all three years.

Finally, the probability of obtaining the bonus coupon at maturity is mentioned[8]. These metrics provide a clearer picture of the likelihood and frequency of the note's various payoff components being triggered, which is useful for both the issuer and the investor.

Figure 9. *Distribution of the Eurozone Inflation index paths and Inflation-linked coupons at Year 1.*



Note: The left distribution displays the Eurozone Inflation index paths, and the right distribution presents the Inflation-linked coupons at Year 1. Source: Own calculations.

The majority of the Eurozone inflation index generated paths are higher than the assumed initial index level of 100, which makes a coupon in Year 1 highly probable (91.45%). The right side of Figure 9 presents coupon distributions in Year 1, with a sharp concentration near 0%. This happens since the first histogram bin includes both exact zero and small positive values. Compared to Year 1, the Eurozone inflation's distribution at Year 2 (left side of Figure 10) reflects an increase in path dispersion, due to cumulative uncertainty.

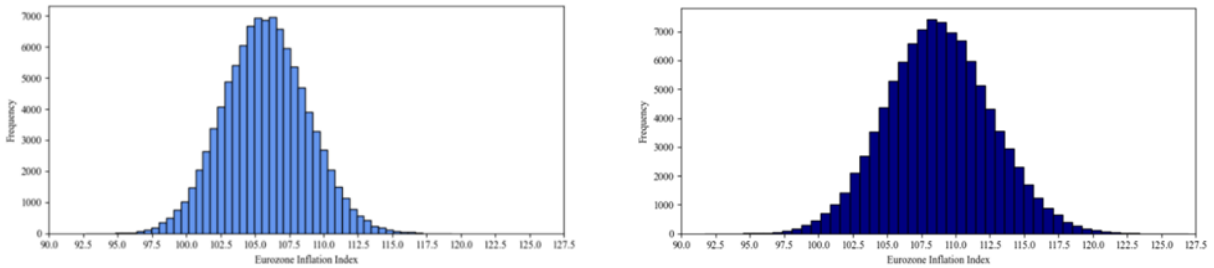
By Year 3, the distribution is even more dispersed (right side of Figure 10), with almost no generated paths near the initial index level of 100. The coupon distributions for Years 2 and 3 are very similar to the one obtained for Year 1[9].The simulated probability of getting a coupon payment from Eurozone inflation in Years 2 and 3 was the same, at 91.44%. Indeed, the likelihood of getting an inflation-linked coupon is roughly the same across all three years of the note's life. This is explained by using the GBM process with constant drift and volatility, combined with the annual reset of the strike level to the previous year's inflation level. The model assumes independent and identically distributed annual shocks, meaning no structural forces would make inflation more or less likely to rise in later years. As a result, the relative year-over-year change in the inflation index follows a consistent distribution.

While the probability of receiving a positive inflation-linked coupon each year is very high, the likelihood of receiving coupons in all three years drops to around 76.50%. This gap is a natural outcome of probability compounding across independent events. Figure 11 presents the EURO STOXX 50 index's simulated paths to maturity. Under the risk-neutral framework, the

[8] These probabilities are summarized in Table B.1. of the Appendix.
[9] For parsimony, these additional visualizations are presented in Appendix A.

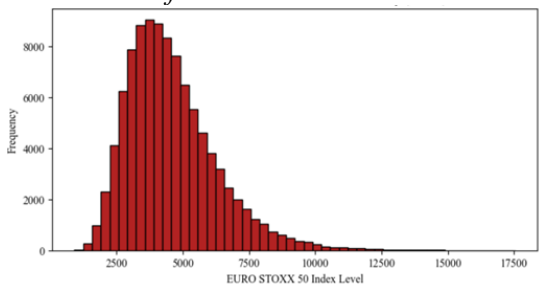
index is simulated as a one-step GBM over a 3-year horizon. The initial index level and the digital option strike are set at 4209.15 index points.

Figure 10. *Distribution of the Eurozone Inflation Index paths at Year 2 and Year 3.*



Note: The left distribution displays the Eurozone Inflation Index paths at Year 2, and the right distribution presents the Eurozone Inflation Index paths at Year 3. Source: Own calculations.

Figure 11. *Distribution of the EURO STOXX 50 Index Paths at Maturity.*



Source: Own calculations.

The distribution exhibits a long right tail, with very few paths reaching levels above 10,000 index points. Moreover, it is centred around the initial level, resulting in a nearly even split of paths ending above and below this threshold. The probability of the index finishing above its initial level is 52.21%. This moderate probability, combined with the small nominal payout (EUR 1), results in a very low present value of the digital option (0.05% of notional).

4.2.2. Comparable Security Approach

This section presents the valuation results under the CSA. The simulation methodology remains consistent with the risk-free rate approach, but key inputs are adjusted. The risk-free rate (2.8002%) is replaced by the issuer's funding costs (3.6550%), and the historical EURO STOXX 50 volatility (20.7583%) is updated to its market-implied volatility (19.9638%). All other modelling assumptions are maintained to ensure comparability.

4.2.2.1. Fair Value and Component Breakdown

The estimated fair value of the structured note components can be seen in Table 4. In this case, the structured note's estimated fair value is 100.04% of notional, aligning even more closely with the selling price of 100% than under the risk-free rate approach (100.22%). This highlights the significance of adopting a more market reflective approach when pricing this type of structured products. As before, the most significant contributor to the total value is the

zero-coupon bond, now accounting for 89.61% of the notional. This decrease in present value compared to the previous scenario reflects the use of the issuer's funding rate as the discount factor, which is higher than the one used before.

Table 4. *Present Value of Structured Note Components (CSA).*

Component	Present Value (€)	% of Notional
Year 1 Coupon	€35.87	3.59%
Year 2 Coupon	€34.58	3.46%
Year 3 Coupon	€33.30	3.33%
Digital Option	€0.50	0.05%
Zero-Coupon Bond	€896.15	89.61%
Total	€1,000.40	100.04%

Source: Own calculations.

The value of the digital option remains virtually unchanged in both nominal and proportional terms (0.05% of notional). The slight reduction in equity volatility does not impact the probability of the binary payoff being triggered materially. Besides, regardless of the assumptions, the digital note's nominal payoff remains the same.

The most notable difference lies in the valuation of the inflation-linked coupons, which now account for approximately 10.38% of notional, compared to around 8% in the risk-free case. This increase is driven by the higher expected path of inflation in the CSA scenario, making inflation-linked coupon payments more frequent due to more positive year-on-year inflation changes. The increased drift boosts the probability and size of the coupons, leading to a higher present value for this component.

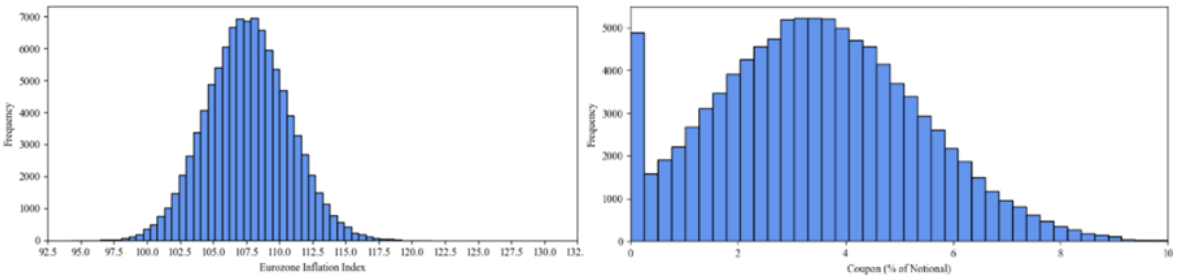
4.2.2.2. Distribution and Probability Analysis

The distributions of the Eurozone Inflation index under the CSA maintain the same overall format as in the risk-free scenario, but are progressively shifted to the right in Years 2 and 3. This rightward shift, clearly visible in the Year 2 histogram (left side of Figure 12), reflects the higher drift applied to the inflation process. This increased expected growth is consistent with the higher present value of the inflation-linked coupons mentioned in the previous subsection.

Consequently, the inflation-linked coupon distributions show a clear shift. The concentration of values near zero has diminished significantly (right side of Figure 12). Across 100,000 simulations, only around 5,000 paths result in a zero (or close to zero) coupon, compared to over 8,500 in the risk-free case. This change highlights the higher likelihood of receiving a payout in each year, which is now 96.29% in Years 1 and 3, and 96.30% in Year 2. As a result, the probability of receiving a coupon in all three years increases markedly, reaching 89.29%, compared to 76.50% under the risk-free approach. This demonstrates the compounding

effect of higher inflation expectations over time. All remaining plots can be found in Appendix B.

Figure 12. *Distribution of the Eurozone Inflation index paths and Inflation-linked coupons at Year 2.*



Note: The left distribution displays the Eurozone Inflation index paths, and the right distribution presents the Inflation-linked coupons at Year 2. Source: Own calculations.

The EURO STOXX 50 Index distribution at maturity remains largely unchanged, given that only a small adjustment was made to its volatility assumption. The probability of receiving the bonus digital coupon at maturity increases to 55.74%, driven by the small volatility reduction, making the digital option slightly more likely to finish in the money.

4.3. Scenario Analysis

This section conducts a sensitivity analysis to assess the impact of key modelling assumptions on the fair value of the structured note. Three categories of scenarios are considered:

(i) variations in the discount rate, with shocks of ± 100 basis points applied to reflect different funding and risk-free rate environments.

(ii) adjustments to the EURO STOXX 50 volatility by ± 5 percentage points, capturing differing market conditions.

(iii) the introduction of correlation between the Eurozone Inflation index and the EURO STOXX 50 index, implemented through Cholesky decomposition.

The next subsections further develop each scenario category.

4.3.1. Discount Rate Sensitivity

To assess the sensitivity of the product's valuation to discounting assumptions, a reduction of 100 basis points (Scenario 1) is applied to the risk-free rate (from 2.8002% to 1.8002%), while an increase of 100 basis points (Scenario 2) is applied over the issuer's funding costs (from 3.6550% to 4.6550%). To capture solely the discount rate effect, volatilities of both indices remain unchanged (historical volatilities). The distributions for both scenarios can be found in Figures C.1. and C.2. of the Appendix, respectively.

Table 5. *Results of Scenario 1 – discount rate of 1.8002%.*

Component	Present Value (€)	% of Notional
Year 1 Coupon	€19.85	1.99%
Year 2 Coupon	€19.49	1.95%
Year 3 Coupon	€19.10	1.91%
Digital Option	€0.46	0.05%
Zero-Coupon Bond	€947.43	94.74%
Total	€1,006.34	100.63%

Source: Own calculations.

In Scenario 1 (Table 5), the overall fair value of the structured note increases (100.63%), primarily driven by the higher present value of the zero-coupon bond (94.74%). Conversely, the contribution of the inflation-linked coupons declines both in absolute and relative terms, falling to around 6% of notional, due to the lower inflation drift. This leads to a reduction in the likelihood of getting a coupon each year (80.97%) and a coupon every year of the product's life (53.08%). The expected magnitude of inflation-linked coupons also decreases. The probabilities obtained for all scenarios are summarized in Table C.1. of the Appendix.

Furthermore, the likelihood of receiving the bonus coupon decreases to 48.89%. While a lower discount rate typically enhances the present value of future payoffs, the equity index simulations under this scenario yield lower average terminal values, reducing the frequency the digital option finishes in the money. In Scenario 2 (Table 6), the estimated fair value of the structured note declines to below its selling price of 100%, standing at 99.91% of notional. This is due to the higher discount rate applied, that decreases the present value of the main component (zero-coupon bond).

Table 6. *Results of Scenario 2 – discount rate of 4.6550%.*

Component	Present Value (€)	% of Notional
Year 1 Coupon	€44.91	4.49%
Year 2 Coupon	€42.94	4.29%
Year 3 Coupon	€41.08	4.11%
Digital Option	€0.51	0.05%
Zero-Coupon Bond	€869.66	86.97%
Total	€999.10	99.91%

Source: Own calculations.

However, the higher drift for inflation is translated into higher coupons, both in frequency and in magnitude. Consequently, the probability of getting a coupon each year jumps to 98.86% and to 96.61% when it comes to receiving a coupon every year. Moreover, receiving the bonus coupon at maturity becomes more likely with a 58.27% probability vs. 52.21% in the risk-free baseline scenario.

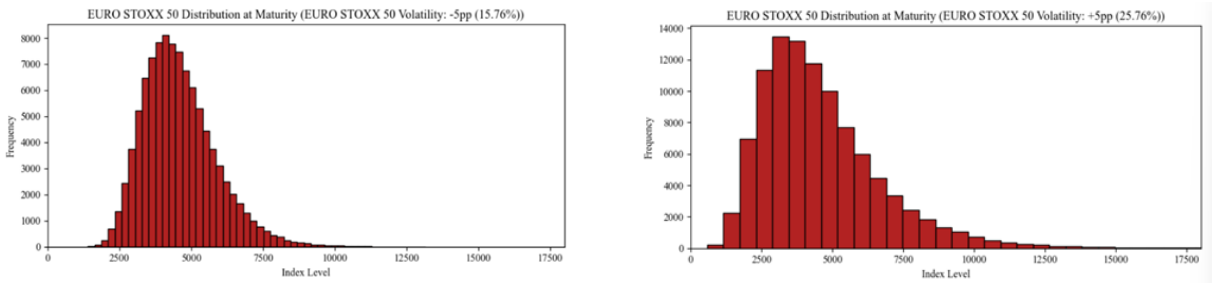
4.3.2. Equity Volatility Sensitivity

This subsection examines the sensitivity of the structured note's fair value to changes in the EURO STOXX 50 Index volatility. Two scenarios are considered: a reduction and an increase of 5 percentage points in volatility relative to the baseline level of 20.7583%, resulting in scenarios of 15.7583% (Scenario 3) and 25.7583% (Scenario 4), respectively. For consistency, the same discount rate (drift) was applied in both scenarios – baseline risk-free rate of 2.8002%.

In both scenarios, the value of the zero-coupon bond remains basically identical comparing to the baseline risk-free case, and the inflation-linked coupons – both in terms of present value and associated probabilities – exhibit negligible variation. In turn, in Scenario 3, the EURO STOXX 50 index distribution (left side of Figure 13) becomes narrower, reflecting reduced dispersion in terminal values. This compression of outcomes increases the concentration of paths near the strike level, thereby enhancing the likelihood of receiving the digital bonus coupon, which rises from 52.21% to 56.77%.

In Scenario 4, the expected value of the digital option declines due to increased volatility, which leads to greater dispersion in the simulated equity outcomes. The EURO STOXX 50 distribution at maturity (right side of Figure 13) becomes noticeably wider and flatter, as evidenced by the Y-axis scale roughly doubling compared to previous cases. This indicates a higher frequency of extreme outcomes, with more index levels falling below 2,500. As a result, a larger proportion of equity paths fall below the digital option's strike level, reducing the probability of receiving the bonus coupon to 48.70%. The inflation component remains virtually unchanged.

Figure 13. *Distribution of the EURO STOXX 50 Index paths at Maturity under Scenario 3 and Scenario 4.*



Note: The left distribution displays the EURO STOXX 50 Index paths under Scenario 3, and the right distribution presents same variable under Scenario 4. Source: Own calculations.

4.3.3. Correlation Sensitivity via Cholesky Decomposition

This subsection incorporates potential interdependence between the Eurozone Inflation Index and the EURO STOXX 50 Index by simulating correlated stochastic paths using Cholesky Decomposition (Scenario 5). Although the product's structure does not explicitly link the two indices, macroeconomic dynamics justify the consideration of joint behaviour. As stated previously, the correlation coefficient between the two variables is −0.1480. All other inputs remain unchanged.

Table 7. *Results for Cholesky Decomposition in the Risk-free Approach.*

Component	Present Value (€)	% of Notional
Year 1 Coupon	€28.31	2.83%
Year 2 Coupon	€27.39	2.74%
Year 3 Coupon	€26.57	2.66%
Digital Option	€0.48	0.05%
Zero-Coupon Bond	€919.43	91.94%
Total	€1,002.17	100.22%

Source: Own calculations.

Table 8 shows that the introduction of correlation between the two underlying variables had virtually no impact on the note's valuation. This outcome is attributable to the product's structure, in which each payoff component is path-independent and additive. The inflation-linked coupons depend solely on the Eurozone Inflation index, while the digital option is triggered only by the EURO STOXX 50 index at maturity. Cholesky Decomposition was also employed in the CSA framework, yielding negligible differences in the results as well[10].

Consequently, correlation has limited impact on the activation and valuation of the individual payoff components. Nonetheless, implementing the Cholesky decomposition enhances the robustness of the simulation framework and confirms that, under the product design, correlation does not materially affect the final valuation.

4.4. Discussion

This chapter encompasses the practical part of the case study, focusing on the structured notes' quantitative valuation using a Monte Carlo Simulation-based pricing framework.

The risk-free approach established a baseline fair value slightly above par (100.22%), while the CSA, reflecting issuer-specific funding costs, provided a value virtually equal to par (100.04%), aligning with the selling price of 100%. This underscores the importance of

[10] Due to the minimal effects the Cholesky Decomposition had on the results under both approaches, the tables and distributions are available upon request.

considering the issuer's perspective in valuation, as incorporating funding costs yields a more realistic estimate of the instrument's market value.

The detailed component breakdowns revealed the dominant role of the zero-coupon bond, consistently accounting for around 90% of the product's fair value. Inflation-linked coupons were highly sensitive to assumed inflation drifts – the higher the drift (discount rate), the higher the fair value of the inflation-linked component due to the increased likelihood and magnitude of positive year-over-year inflation changes, leading to more frequent and larger coupon payments over the product's life.

The distributional and probability analysis enabled to contextualize expected payoffs, particularly in relation to coupon variability and the likelihood of receiving the equity-linked bonus payout. Scenario analyses further demonstrated the sensitivity of the note's value to shifts in key inputs. Lower discount rates significantly increased the fair value via the bond component, while higher equity volatility led to broader EURO STOXX 50 index distributions, reducing the probability of getting the bonus coupon. Notably, introducing correlation between the underlying assets through Cholesky Decomposition had negligible impact on valuation due to the path-independent and additive nature of the payoff components.

5. CONCLUSIONS

This internship report set out to bridge academic theory and practical application by documenting my experience within ATLANTICO Europa's Capital Markets Division and presenting a detailed case study of a structured note distributed by the Bank.

My ATLANTICO Europa internship significantly contributed to my professional and personal development. Technically, I acquired hands-on experience across multiple asset classes and deepened my understanding of capital markets. Exposure to new analytical tools and the opportunity to refine my proficiency with established platforms enabled me to translate academic knowledge into practical skills.

Enhancing my soft skills was equally important. Collaborating with multidisciplinary teams improved my ability to communicate and present complex financial concepts to diverse audiences. The dynamic, fast-paced environment of capital markets fostered adaptability, resilience, effective time management, and problem-solving skills. While my academic background in Finance provided a strong theoretical foundation, the internship brought these concepts to life through direct exposure to market practices.

The Digital Equity and Eurozone Inflation-linked Note case study provided a comprehensive perspective on product structuring, valuation, and risk assessment within the macroeconomic context at the time of issuance. The results highlight that the discount rate has a more significant impact on the product's fair value than the EURO STOXX 50 index volatility or the correlation between the underlying indices. The theoretical price derived under the Comparable Security Approach (100.04%) aligns more closely with the actual selling price (100%) than the estimate from the Risk-Free model (100.22%), underscoring the importance of incorporating issuer funding costs into the valuation process for this type of structured product.

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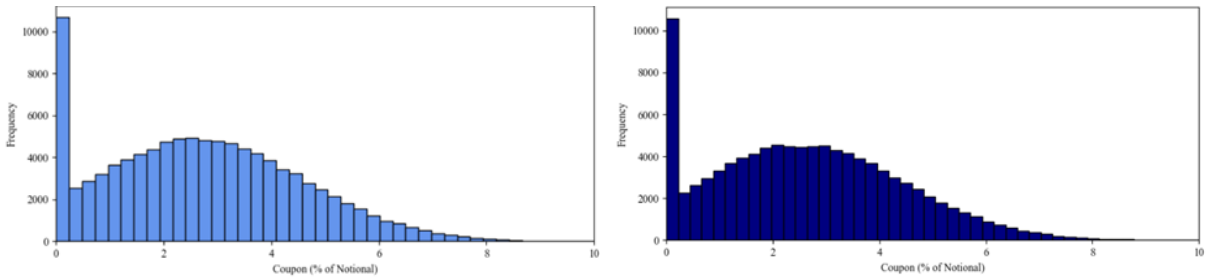
APPENDIX

Appendix A. Risk-free Approach

Figure A.1. *Distribution of the Inflation-Linked Coupons at Year 2 (left side) and at Year 3 (left side). Source: Author's elaboration.*



Appendix B. Comparable Security Approach

Figure B.1. *Distribution of the Eurozone Inflation Index paths (left side) and Inflation-linked coupons (right side) at Year 1. Source: Author's elaboration.*

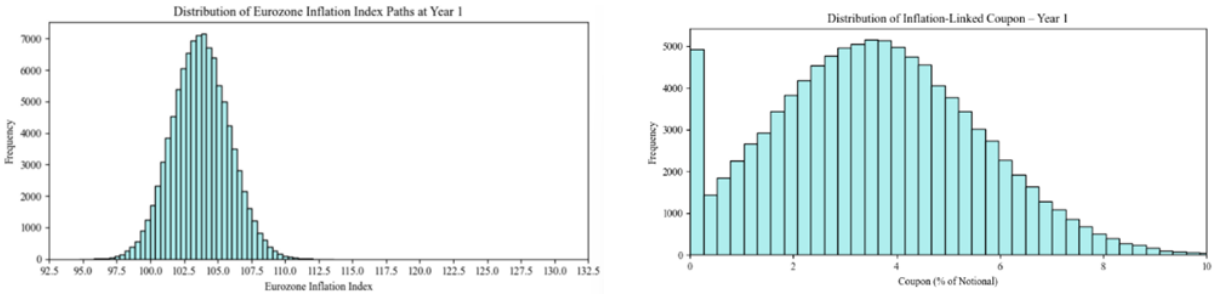
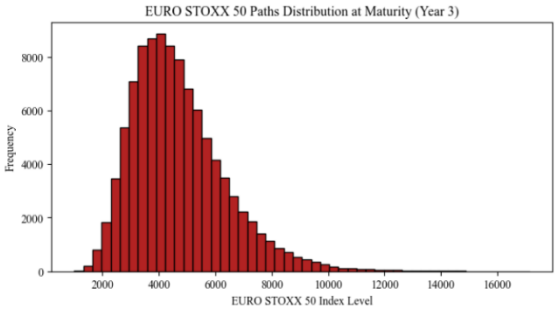


Figure B.2. *Distribution of the EURO STOXX 50 Index paths at Maturity. Source: Author's elaboration.*



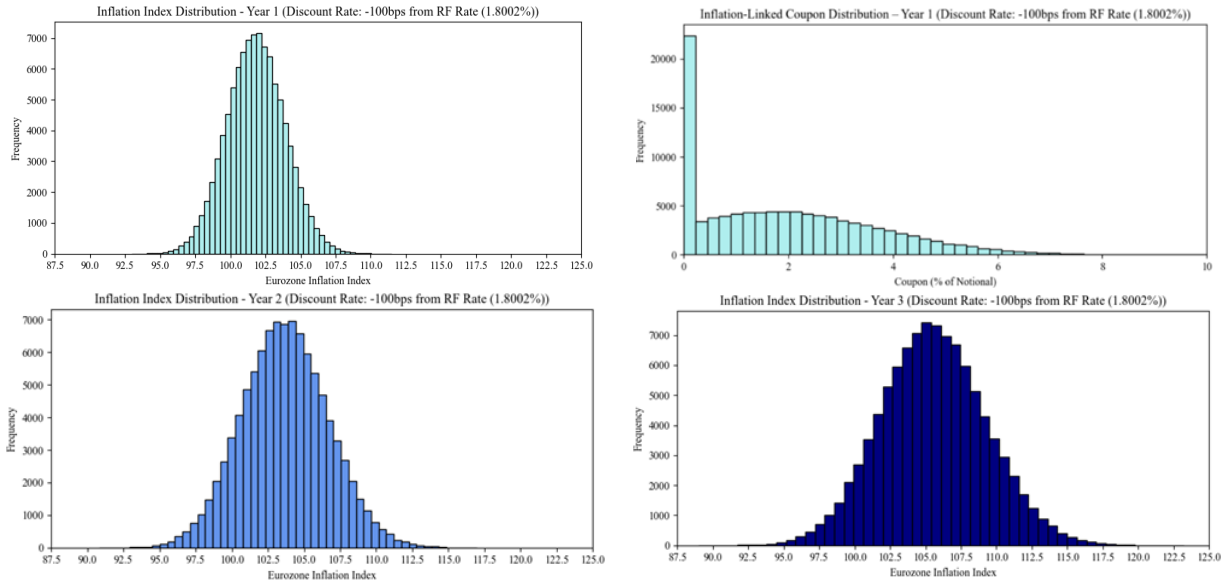
Note: The distributions for Year 3 are available upon request.

Table B.1. *Probabilities obtained for the baseline approaches. Source: Author's elaboration.*

Probabilities	Risk-Free Approach	CSA
Receiving a coupon in Year 1	91,45%	96,29%
Receiving a coupon in Year 2	91,44%	96,30%
Receiving a coupon in Year 3	91,44%	96,29%
Receiving a coupon in all 3 years	76,50%	89,29%
Receiving the bonus coupon	52,21%	55,74%

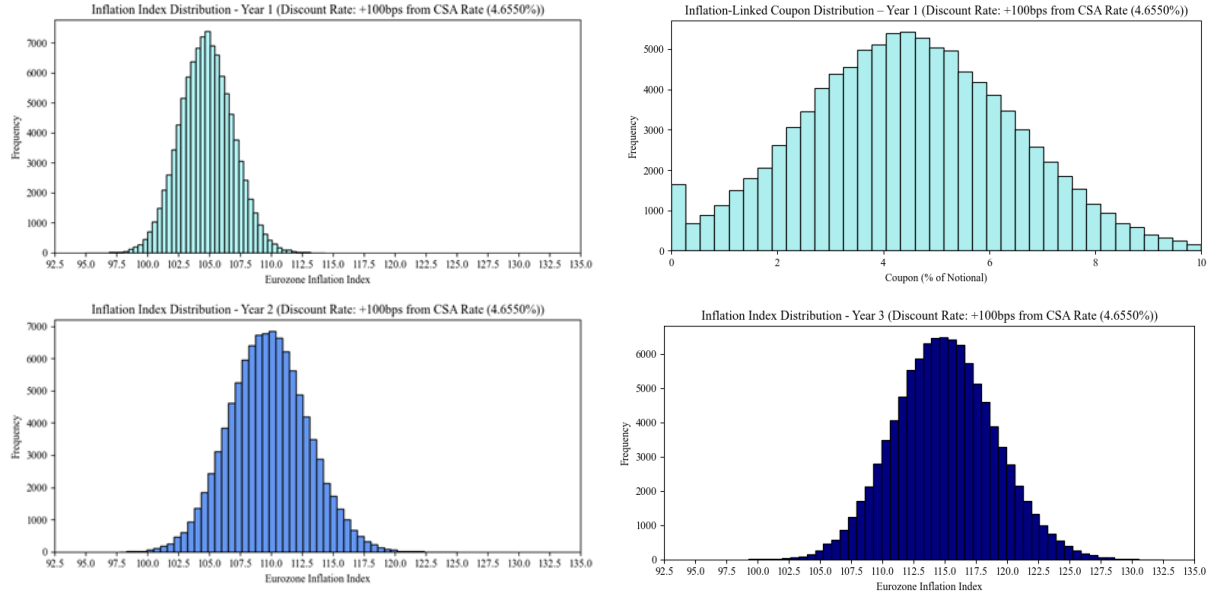
Appendix C. Scenario Analysis

Figure C.1. *Results of Scenario 1 – discount rate of 1.8002%. Source: Author's elaboration.*



Note: The distributions of the Inflation-linked coupons for Years 2 and 3 are virtually identical to Year 1. The EURO STOXX 50 distribution is similar to the one obtained in the baseline scenario. For these reasons, they are available upon request.

Figure C.2. *Results of Scenario 2 – discount rate of 4.6550%. Source: Author's elaboration.*



Note: The distributions of the Inflation-linked coupons for Years 2 and 3 are virtually identical to Year 1. The distribution of the EURO STOXX 50 index is similar to the one obtained in the baseline scenario. For these reasons, they are available upon request.

Table C.1. *Probabilities obtained for each scenario. Source: Author's elaboration.*

Probabilities	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Receiving a coupon in Year 1	80,91%	98,86%	91,32%	91,17%	91,53%
Receiving a coupon in Year 2	80,97%	98,86%	91,25%	91,24%	91,43%
Receiving a coupon in Year 3	80,97%	98,84%	91,30%	91,52%	91,34%
Receiving a coupon in all 3 years	53,08%	96,61%	76,03%	76,06%	76,44%
Receiving the bonus coupon	48,89%	58,27%	56,77%	48,70%	51,93%