MASTER OF SCIENCE IN
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PROJECT

PRIIP ANALYSIS: SPRINT CERTIFICATE LINKED TO EUROSTOXX 50

MATTEO FILIPPO ROMANO

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Abstract

This thesis conducts a comprehensive analysis of a Sprint Certificate linked to the EURO STOXX 50® Index, issued in December 2023 by Deutsche Bank AG. The core objective is to demystify this certificate by breaking it down into its fundamental financial components, a process known as decomposition to accurately value it and quantify its risks. Unlike a capital-guaranteed product, this certificate offers leveraged upside participation up to a predefined cap, while fully exposing the investor to any downside decline in the underlying index.

To achieve a robust valuation, this analysis employs and compares three distinct quantitative models: the Binomial Tree Model at issuance, the Black-Scholes analytical model one year into the product's life, and a Monte Carlo Simulation near maturity. This multi-method approach not only validates the consistency of the pricing but also illustrates how the product's fair value evolves over time in response to changing market conditions.

Furthermore, the study extends beyond pricing to include a detailed sensitivity analysis (the "Greeks") and a probabilistic assessment of potential returns for the investor. By dissecting the product's mechanics, risks, and valuation, this thesis aims to provide a transparent and critical evaluation, highlighting both the potential benefits and the significant risks inherent in this increasingly popular investment vehicle. The risk analysis culminates with the estimation of Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR). These measures are employed to assess the scale of potential losses during periods of significant market stress, effectively synthesizing the product's complex risk exposure into a single, comprehensible indicator.

In conclusion, this thesis finds that the Sprint Certificate offers a structured payoff suitable for investors with a specific, moderately bullish view on the EURO STOXX 50. While it provides capital efficiency and enhanced returns within a narrow performance range, the product carries significant tail risk and embedded costs, making it generally unattractive for retail investors seeking transparent or long-term exposure.

Keywords: Sprint Certificate; Structured Product; Decomposition; Valuation; Sensitivity Analysis; Risks.
JEL classification: C63; G12; G13; G17

Resumo

Este projeto realiza uma análise abrangente de um Certificado Sprint vinculado ao Índice EURO STOXX 50® , emitido em Dezembro de 2023 pelo Deutsche Bank AG. O objetivo central é desmistificar este certificado, decompondo-o nos seus componentes financeiros fundamentais – um processo conhecido como decomposição – para o valorizar com precisão e quantificar os seus riscos. Ao contrário de um produto com garantia de capital, este certificado oferece uma participação potencialmente alavancada na valorização do ativo subjacente até um limite predefinido (cap), expondo integralmente o investidor a qualquer queda no valor do índice.

Para alcançar uma avaliação robusta, esta análise emprega e compara três modelos quantitativos distintos: o Modelo de Árvore Binomial na emissão, o modelo analítico de Black-Scholes um ano após o início do produto, e uma Simulação de Monte Carlo próximo do vencimento. Esta abordagem multi-método não só valida a consistência da precificação, como também ilustra a forma como o valor justo do produto evolui ao longo do tempo, em resposta à alteração das condições de mercado.

Além disso, o estudo vai além da avaliação, incluindo uma análise detalhada de sensibilidade (os "Greeks") e uma avaliação probabilística dos retornos potenciais para o investidor. Ao dissecar a mecânica, os riscos e a avaliação do produto, esta tese visa fornecer uma avaliação transparente e crítica, salientando tanto os benefícios potenciais como os riscos significativos inerentes a este veículo de investimento cada vez mais popular. A análise de risco culmina com a estimativa do Valor em Risco (VaR) e do Valor em Risco Condicional (CVaR). Estas medidas são empregues para avaliar a dimensão das perdas potenciais durante períodos de stresse significativo no mercado, sintetizando eficazmente a exposição de risco complexa do produto num indicador único e compreensível.

Em conclusão, esta tese conclui que o Certificado Sprint oferece um payoff estruturado adequado apenas para investidores com uma visão específica e moderadamente otimista sobre o EURO STOXX 50. Embora proporcione eficiência de capital e retornos potencialmente superiores dentro de uma faixa de desempenho estreita, o produto apresenta um risco extremo (tail risk) significativo e custos implícitos elevados, tornando-o geralmente pouco atrativo para investidores retalhistas que procuram exposição transparente ou de longo prazo.

Palavras-chave: Certificado Sprint; Produto Estruturado; Decomposição; Avaliação; Análise de Sensibilidade; Riscos.
Classificação JEL: C63; G12; G13; G17

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1 Introduction

A structured product is a pre-packaged financial instrument that typically combines a traditional investment with one or more derivative components to create a customized risk-return profile. Their payoff is linked to the performance of one or several underlying assets, such as stocks, indices, interest rates or exchange rates. The goal is to provide payoffs that are not available through a direct investment in a standard asset like a stock or a bond. The complexity of structured products often obscures their true risk-return profile from investors. An information asymmetry exists between the issuer, who understands the precise replication cost, and the investor, who may not completely understand the embedded risk such as the short volatility position or unlimited downside.

In the market exist several different types of structured product, among which there are Sprint Certificates. These instruments are called also “double chance certificate” because they allow the investor to double participate in growth of the underlying asset, but just in the specific range of exercise prices of purchased and sold call options. For instance, if at maturity the underlying asset falls below the reference level the value of the certificate will decrease accordingly, while if above the target value, this certificate will no longer increase in value. This feature makes these products particularly appealing for investors who expect a slight increase in the underlying value.

The main purpose of this thesis is to analyze in detail the Sprint Certificate linked to EURO STOXX 50 Index, issued in December 2023 by Deutsche Bank AG. The analysis starts by examining the product's key features, risks, and rewards, with the aim of identifying the investor profile for which this product is most suitable. Subsequently, it presents the product’s decomposition, that provides the foundation for all later valuation and risk analyses. Following this, it involves the application of three distinct pricing models, each chosen for its strengths at different maturity horizons: The Binomial model at issuance, The Black-Scholes model one-year post issuance and a Monte Carlo Simulation at six month to maturity. Finally, it performs a sensitivity analysis through the computation of the following Greeks: Delta, Rho, Gamma, Vega, Lambda and the VaR and CVaR both at issuance and six months to maturity.

2 Literature Review

Structured products emerged in finance in the early 1990s in the United Kingdom. Originally, they were seen as instruments that provided retail investors access to the stock market returns without risking capital. In the beginning, these products were relatively simple, often consisting of basic debt securities combined with derivatives components, later, with the evolution of financial engineering these products have become significantly more sophisticated, capturing the interest of a broad investor base and spreading globally (SRP,2025).

Structured products, such as Sprint Certificate, have been extensively analyzed in academic literature due to their complex payoff structures and increasing importance in retail investment markets. Foundational studies, including Burth, Kraus and Wohlwend (2001) and Stoimenov and Wilkens (2005), demonstrate that these instruments can be decomposed into portfolios of simpler derivatives, typically involving combinations of European call and put options. Such decomposition provides transparency into issuer margins, hedging strategies, and risk exposures.

Since these complex types of products are basically composed by a portfolio of derivatives and bonds, their valuation strongly relies on option pricing theory. Louis Bachelier's 1900 thesis, "*Théorie de la spéculation*", is widely recognized as the pioneering work in establishing a complete, rigorous mathematical theory for pricing options based on stochastic processes. Decades later, Fisher Black, Myron Scholes, and Robert Merton (1973) provided the cornerstone of modern derivatives pricing by deriving an analytical solution, a closed-from formula, for the price of a European option, known as the Black-Scholes-Merton model. As this model is built in a continuous-time framework, it cannot be directly used to price American options or path-dependent derivatives. The need for a more flexible framework let to the development of the Binomial Option Pricing Model by Cox, Ross, and Rubinstein (1979). This discrete-time provides a flexible numerical method that can accurately price American-style options and handle various exotic features by modelling the possible future paths of the underlying asset's price.

For derivatives with even greater complexity, the most robust and large adopted method is the Monte Carlo Simulation. The seminal work of Boyle (1977) introduced Monte Carlo pricing for options, which was later expanded by Boyle, Broadie, and Glasserman (1997). This technique uses random sampling to simulate thousands of possible future asset price paths, estimating the option's value as the average discounted payoff across all simulated scenarios.

The valuation of a structured product provides a single price under a specific set of market assumptions. However, for the issuing bank, the most important concern is risk management, so understanding how this price will change as markets move. This is achieved through sensitivity analysis, quantified by the option “Greeks”. Delta, Gamma, Vega, Rho allow the issuer to understand how the structured product react to changes in the volatility of the underlying asset, interest rates, and time to maturity, revealing the complex risk embedded within its payoff structure.

Parallel to the development of pricing and risk management techniques, the regulatory landscape for retail structured products has evolved significantly. A crucial development in Europe is the Packaged Retail and Insurance-based Investment Products (PRIIPs) Regulation, which mandates the provision of a standardized Key Information Document (KID) to all retail investors (European Union, 2014). The KID aims to reduce the information asymmetry by requiring clear disclosure of costs, risks, via a standardized Summary Risk Indicator (SRI), and potential performance scenarios. Analyzing the KID is therefore essential for assessing the alignment between a product's marketed profile and its underlying economic substance, forming a critical link between financial engineering and investor protection.

Structured products represent a sophisticated synthesis of derivative pricing theory and practical financial innovation. This thesis contributes to the field through a rigorous analysis of a Deutsche Bank Sprint Certificate linked to EURO STOXX50 Index. By deconstructing its payoff into fundamental option strategies, applying advanced valuation methodologies, and conducting a comprehensive sensitivity analysis of its “Greeks”, this research demystifies the product’s complex risk dynamics. This analysis adds to existing research by clarifying the connection between what it costs the bank to create the product, the potential gains and losses for the investor, and the information found in its official disclosure document. These insights are valuable for both professionals in finance and academics studying these products.

3 Product Presentation

3.1 Product Description and Payoff

The structured product under study is the Sprint Certificate linked to EURO STOXX 50 Index, issued by Deutsche Bank AG, Frankfurt. This Sprint Certificate is a German law governed equity-linked certificate, whose return depends on the performance of the underlying asset with no capital protection against market risk. The product has a two-years maturity, running from the Issue date of 12 December 2023 to the Maturity date of 15 December 2025.

The product's risk-return profile, characterized by the absence of capital protection and a capped maximum payout, makes it suitable for investors who anticipate a moderate rise in the underlying index. It is optimally designed for those who expect that the EURO STOXX 50 will settle at maturity within the narrow range that triggers the double-chance payoff.

The product is designed to provide a return in the form of a cash payment on the maturity date and the amount of this payment will depend on the performance of the underlying, measured against its initial reference level S_0 = 4,536.61 points. Let S_T denote the final reference level of the index at maturity. The terms of the Sprint Certificate specify the following payoff function, per EUR 100 of invested nominal:

- If $S_T < S_0$ (Capital at Risk):

  The investor bears a 1:1 participation in the index's decline. The cash payment is:

  $$Payoff = EUR\ 100 * \frac{S_T}{S_0}$$

- If $S_0 \leq S_T \leq S_{cap}$ (Double-Chance / Sprint Zone):

  The investor participates at a 2:1 rate in the index's increase. The cash payment is:

  $$Payoff = EUR\ 100 + EUR\ 200 * (\frac{S_T}{S_0} - 1)$$

  The threshold S_{cap} is the index level at which the payoff reaches its maximum.

- If $S_T > S_{cap}$ (Capped Upside):

  The investor's return is capped at a maximum payment. This cap of EUR 147.10 corresponds to a final index level of S_{cap} = 5,604.98 points. Therefore

$$Payoff = EUR\ 147.10 \text{ (Maximum Payment)}$$

This payoff structure demonstrates that the certificate is a leveraged bullish product with a defined maximum profit, exposing the investor to full downside risk below the initial level.

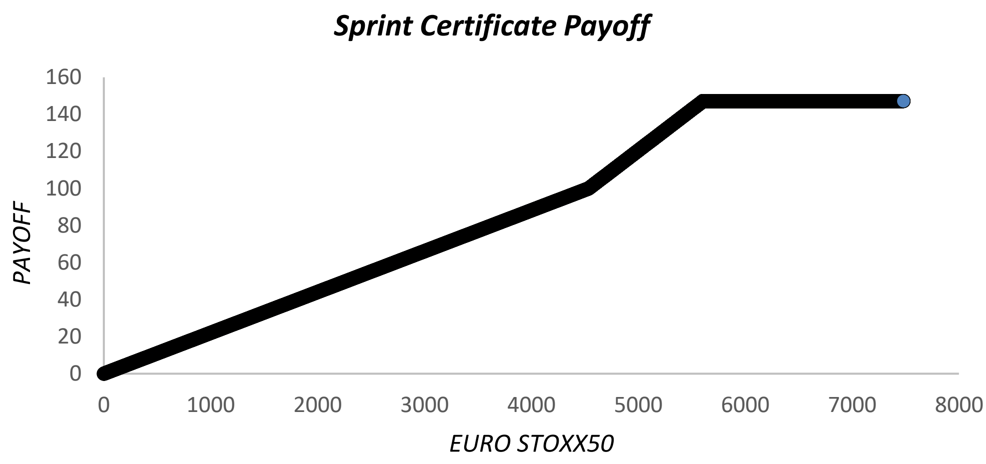

Figure 1 – Sprint Certificate Payoff at maturity (Elaboration on Excel)

3.2 Issuer

Deutsche Bank AG is a German multinational investment bank and financial services company headquartered in Frankfurt, founded in 1870 in Berlin. The German Bank is publicly traded, with primary listings on both the Frankfurt Stock Exchange and the New York Stock Exchange. Deutsche Bank is the largest private bank in Germany, serving retail and wealthy individuals alongside corporate and institutional clients through its European and global network, it operates through four core corporate divisions: Corporate Bank (CB), Investment Bank (IB), Private Bank (PB), and Asset Management (DWS). As of 31 December 2025, the bank reported total assets of €1.4 trillion and €1.8 trillion of assets under management. According to the February 2026 report, Moody's rates the bank's long-term deposit at A1 with a positive outlook, reflecting its strengthened earnings structure, improved capital generation, and robust liquidity buffers of €260 billion in high-quality liquid assets. S&P Global Ratings (February 2026) rates Deutsche Bank's long-term issuer rating at A with a positive outlook, reflecting its capital allocation and cost efficiency, disciplined risk approach, and strong governance. In addition to the periodic fundamental assessments of the Bank's credit quality, CDS spread offer a real-time, market-driven complement to these evaluations. As of February 2026, the bank's 5-year CDS spread was 48.4 basis points, consistent with its investment credit ratings and reflecting market confidence in the bank's improved fundamentals. Deutsche Bank is a significant issuer of structured products in the European market. X-markets is the platform in which is possible to find all the structured products issued by the bank.

3.3 Underlying Asset

The Sprint Certificate under examination is linked to the EURO STOXX 50 Index. The EURO STOXX 50 is a stock index composed of 50 leading eurozone companies. It was launched in 1998 by STOXX Limited, a joint venture founded in 1997 by Deutsche Börse AG, Dow Jones & Company, and the SWX Group. This Index is a free-float market capitalization-weighted index in which, to ensure diversification, individual stock weights are capped at 10%. It captures approximately 60% of the total market capitalization of the broader EURO STOXX Index. The main super-sector weightings include Technology (17.7%), Industrial Goods and Services (14.5%), and Consumer Products and Services (13.5%). By country, the index is dominated by France (41%), Germany (25.7%), and the Netherlands (15.6%).

3.4 Advantages and Disadvantages for Investors

Structured products are powerful instruments because they allow investors to achieve precisely the exposure they are looking for. These products were created to meet investor's demand of alternative investments, and they can be constructed ad hoc to suit individual needs. For example, customizable equity-linked certificates are designed to give investors exactly the exposure they want to an underlying index (e.g., EURO STOXX 50), by allowing them to choose their preferred balance between capital protection and upside participation.

In the same way, the Sprint Certificate analyzed in this thesis offers investors the opportunity to obtain a complex payoff that a retail investor could not easily achieve by investing just in stocks or bonds. In particular, this Sprint Certificate allows investors to earn a leveraged return when the underlying asset's price at maturity falls between its initial level and the cap. Another advantage of this product is that it provides leveraged market exposure at a lower cost compared to directly purchasing the options required to replicate the same strategy. Since the issuer benefits from economies of scale and lower transaction costs, the strategy becomes accessible even to retail investors who would otherwise find it too expensive or complex to implement on their own.

On the other hands, this product also presents some disadvantages that investors should carefully consider. First, this Sprint Certificate doesn't guarantee capital protection, this means that potentially investors could lose all their invested capital if the underlying asset's value falls to zero at maturity. Second, the product includes a cap, with a maximum payment of EUR 147.10, this means that once the underlying asset exceeds a certain level (5,604.98 pts), the investor no longer participates in any further upside, thereby missing out on potential gains that would have been realized by investing directly in the index itself. Finally, the complexity of the product and exposure to issuer default risk are additional factor to be aware of. Assessing the issuer's creditworthiness and incorporating it into the product's valuation is not straightforward and can be a challenge for investors who wish to buy such products without a full understanding of how to evaluate them.

3.5 Investor's Risks

Investing in structured products entails a complex risk profile that extends beyond that of a direct investment in the underlying asset. In particular, for this Sprint Certificate the main risks are:

- Capital loss risk: The certificate offers no capital protection. In downside scenarios where the index finishes below the initial level, the payoff structure replicates a 1:1 participation in the index's decline. This exposes the investor to the potential for substantial, and in a theoretical extreme, total loss of the invested capital. As indicated in the Key Information Document (KID), a stress scenario could result in a loss of up to 47% of the initial investment, highlighting the significant principal-at-risk nature of this product.

- Volatility risk: The product's payoff profile is fundamentally short volatility. While this strategy benefits from stable or moderately rising markets, it performs poorly in high-volatility environments. A significant rise in market volatility increases the value of the embedded options used for replication, but this does not translate into higher value for the certificate holder. Instead, the investor bears the downside of volatile markets without participating in the potential upside beyond the cap, creating a pronounced asymmetry. In essence, the investor sells volatility to finance the leveraged upside but retains the full downside exposure.

- Liquidity risk: Although Deutsche Bank typically acts as a market maker, it is under no contractual obligation to provide continuous liquidity or maintain tight bid-ask spreads. The specialized and complex nature of the certificate can result in a limited secondary market, with few potential buyers besides the issuer itself. Consequently, an investor seeking an early exit may be forced to sell at a significant discount to the theoretical fair value, realizing an unnecessary loss.

- Credit risk: The certificate constitutes an unsecured, senior obligation of Deutsche Bank AG. Its valuation is therefore intrinsically linked to the bank's creditworthiness. In the event of a default or insolvency of Deutsche Bank, investors would become unsecured creditors in the resolution process. Crucially, any recovery would be based on the bank's estate, not on the performance of the EURO STOXX 50 Index, meaning investors could suffer losses even if the index has performed favorably.

4 Product Valuation

The theoretical price of a structured product is the sum of the price of its individual components and represents the real cost of replicating the product. First, it is necessary to decompose the product into its fundamental components, price each component individually, and then sum the prices of the instruments the issuer has to buy while subtracting those that need to be sold.

The price of a structured product is therefore the total cost that the issuer must incur to purchase the replicating portfolio, meaning the portfolio that fully replicates the value of the product for any value of the underlying asset.

It is important to note that the theoretical price derived from this replication method corresponds to the fair value of the product. Any deviation between this price and the issue price offered to investors represent the issuer's profit margin, which typically covers structuring costs, hedging expenses, and credit risk.

As mentioned in the introduction, I priced the Sprint Certificate at different dates using three different models: the Binomial model at issuance (12^{th} December 2023), the Black-Scholes model one-year post issuance (12^{th} December 2024) and a Monte Carlo Simulation at six month to maturity (10^{th} June 2025).

4.1 Variable Inputs

Volatility of the underlying asset

The implied volatility was extracted from Bloomberg using the OVME (Option Valuation and Model Estimation) function, which computes theoretical option prices and implied volatilities through interpolation of the existing volatility surface. For each valuation date, the function was configured with the valuation date as the pricing date, the certificate's maturity date as the expiration, and the current index level as the strike price, so as to extract the at-the-money implied volatility of a European option with time to maturity consistent with the remaining life of the certificate. This approach ensures that the implied volatility input is market-consistent and reflects the risk-neutral expectations of index volatility over the exact horizon of the instrument being valued. The ATM implied volatilities extracted for each valuation date were:

Valuation Date	Remaining Maturity	ATM implied volatility
12 December 2023	2-years	16.93%
12 December 2024	1-year	15.38%
10 June 2025	6-months	16.09%

Table 1: ATM Implied Volatility by Valuation Date

Risk-free interest rate

The risk-free interest rate is the theoretical rate of return of an investment that carries no default risk, with all scheduled payments guaranteed over a fixed period. For the valuation of the Sprint Certificate, since this product was issued by Deutsche Bank, the yield on German government bonds (Bunds) was used as a proxy for the risk-free rate.

This choice is justified by three key principles: currency consistency, credit quality, and maturity alignment. The certificate is denominated in Euros, and the risk-free rate must correspond to the currency of the investment to avoid introducing exchange rate risk. While no asset is perfectly risk-free, German Bunds are considered the closest proxy within the Eurozone. The time value of money is specific to the investment horizon. Therefore, a 2-years Bund was used for valuation a issuance, a 1-year yield for the valuation one year later, and a 6-month yield for the final valuation near maturity. These are the results:

Valuation Date	Remaining Maturity	German Bund Yield
12 December 2023	2-years	3.314%
12 December 2024	1-year	2.016%
10 June 2025	6-months	1.826%

Table 2: Risk-free Interest Rates by Valuation Date

Issuer’s Funding Cost

The cost of funding is defined as the amount spent by lenders to get funds for lending to their customers. To estimate the cost of funding, I used the Credit Default Swap (CDS) spread of Deutsche Bank AG, which serves as a market-based proxy for the bank’s credit risk and marginal funding cost. From a theoretical perspective, the yield on a risky bond can be decomposed into a risk-free component plus a credit spread (Hull, 2022). In efficient markets, the CDS spread provides a close approximation of this credit spread. Therefore:

$$Cost\ of\ Funding\ \approx Risk\ Free\ Rate + CDS\ Spread$$

This approximation is also widely adopted in practice in the valuation of structured products, where CDS spreads are used as proxies for issuer’s funding costs (Deng et al., 2012).

I used the CDS spread matching the product’s maturity at each valuation date, consistently with the risk-free rate employed, in order to ensure a coherent term structure of discounting inputs. I found the issuer’s CDS spread on Bloomberg and the result was:

Trade Date	Remaining Maturity	CDS spread (bps)	Cost of funding
12 December 2023	2-years	71.2834	4.03%
12 December 2024	1-year	26.0331	2.28%
10 June 2025	6-months	21.5800	2.04%

Table 3: CDS spread and issuer’s cost of funding by Trade Date

Dividend yield

The dividend yield must be included in the option pricing model because it represents a continuous cash outflow that reduced the expected future price of the underlying asset. This has a direct impact on option values. Including it is essential for a correct valuation, as it accounts for the reduction in the underlying's price and the associated opportunity cost of holding options instead of the physical asset.

The dividend yield was extracted for each valuation date corresponding to the three pricing models via Bloomberg. The values obtained are as follows:

- **12 December 2023:** 3.45%
- **12 December 2024:** 3.26%
- **10 June 2025:** 2.99%

4.1 Product Decomposition

The decomposition of a structured product is the process of breaking it down into its fundamental financial components.

To price and analyze this product, I decomposed its payoff into a portfolio of fundamental financial instruments: a fixed-income component composed by a zero-coupon bond (ZCB), and a derivative component composed by a short put option, a long call option, and a short call option. The inclusion of the ZCB is crucial. Even though the final product is not capital-guaranteed, the bond ensures the availability of the nominal amount K at maturity, which serves as the foundational capital for the structure.

The options then modify this base payoff to create the desired profile across different market scenarios:

- **Region 1:** $\boldsymbol{S_T < S_0}$
  The short put is exercised, resulting in an obligation for the bank of $K - S_T$, while the calls expire both worthless. Combined with the amount K received from the bond, the net payoff is $K - (K - S_T) = S_T$. This replicates the product's direct exposure to the underlying's downside.
- **Region 2:** $\boldsymbol{S_0 \leq S_T \leq S_{cap}}$
  The put and the short call expire worthless. The bond provides $K$and the long call provides

a payoff of $S_T - K$. The net portfolio payoff is:

$$K + (S_T - K) * conv.factor = S_T * conv.factor$$

Effectively providing double exposure (2x) to the positive performance of the index until the cap is reached.

- **Region 3: $S_T > S_{cap}$**

  Both calls are in-the-money. The bond provides K, the long call pays $(S_T - K_1)$ and the short call results in a payment for the bank of $(S_T - K_2)$. The S_T terms cancel out, leaving a constant net payoff of $K + (K_2 - K_1)$. Given our parameters $K = 100$ and $(K_2 - K_1) = 47.10$, the total payoff is EUR 147.10. This perfectly replicates the product's capped maximum payoff.

Product Decomposition

Position	*Instruments*	*Face Value*	*Strike (k)*	*Conv. Factors*
Long	ZCB	100%	-	0,0220429
Long	Call Option	-	4,536.61 pts	0,0440858
Short	Put Option	-	4,536.61 pts	0,0220429
Short	Call Option	-	5,604.98 pts	0,0440858

Table 4: Sprint Certificate Decomposition

Knowing that the Certificate pays:

$$100 + 200 * (\frac{S_T}{S_0} - 1)$$

we can determine the index return at which the maximum payment is reached. This occurs at a return of 23.55%, corresponding to an index level of 5,604.98 points. Any increase beyond this level does not increase the payoff further. This explains why the strike price of the short call, (K_2), is set at 5,604.98 points.

Because the index quoted in points rather than euros, a conversion factor is necessary to translate the index's point movement into the certificate's euro-denominated payoff.

- The conversion factor of the short put is calculated as:

$$Conversion\ Factor = \frac{Amount\ Invested}{Initial\ Index\ level}$$

  This replicates a 1x exposure to the index

- For the long call, the conversion factor is doubled:

$$Conversion\ Factor = \frac{Amount\ Invested}{Initial\ Index\ level} * 2$$

This reflects the 2x leveraged exposure in Region 2.

The same conversion factor is applied to the short call, because its role is to offset the long call beyond the cap. Applying the same factor ensures that the two calls cancel each other out when the index exceeds K_2 , effectively eliminating any additional upside exposure and producing the capped payoff.

4.3 Pricing Methods and Results

Binomial Model

I used the Binomial model to calculate the theoretical value of the Certificate on the 12th December 2023. I used 24 steps to discretize the 2-year maturity of the options, resulting on a time increment of Δt = 0.083 years per step. Using the parameters discussed in chapter 4, I computed the up-factor *u*, the down-factor *d*, and the risk-neutral probabilities *p* and *(1-p)*. This careful parameter calculation ensures that the binomial tree accurately represents the evolution of the underlying asset and provides a reliable approximation of the option's value.

N. of steps	Δt	***u***	***d***	***p***
24	0.083	1.050	0.952	0.4866

Table 5: Binomial Tree Parameters

First of all, I modelled the underlying asset under the assumptions of the model and then I priced each component by discounting the expected value of the option at each step by the risk-free interest rate.

The value of the ZCB was computed as follows:

$$ZCB = Ke^{-rT}$$

where:

K = Face Value

r = risk-free interest rate

T = time to maturity

The theoretical value of the Sprint Certificate is obtained by summing the long positions (ZCB and long call) and subtracting the short positions (short put and short call):

$$Theoretical\ Value = 93.59 + 17.37 - 8.94 - 4.99 = 97.03€$$

The theoretical values obtained for each component are reported in *Table 6* below:

Position	Instrument	Theoretical Value (€)
Long	ZCB	93.59€
Long	Call Option	17.37€
Short	Put Option	8.94€
Short	Call Option	4.99€
Structured product value	-	**97.03€**

Table 6: Theoretical Value at issuance (using the risk-free)

All values are based on a nominal investment of 100€.

As expected, the theoretical value of the replicating portfolio at issuance (97.03€) is lower than the amount the investor pays (100€). This difference, known as the issuer's margin, represent the bank's profit for structuring, hedging, and distributing the product. By replicating the payoff at a lower cost, the bank locks in a gross profit of 2.97€ (2.97% of the invested capital), regardless of the underlying asset's future performance.

To capture the practical realities of structured product pricing, I evaluate each component of the product using not only the risk-free rate, but also the issuer's cost of funding. By discounting future payoffs at the funding-adjusted rate, the valuation reflects both the financing cost of replicating the payoff and the credit risk associated with the issuer.
The results are reported in *Table 7* below:

Position	Instrument	Theoretical Value (€)
Long	ZCB	92.26€
Long	Call Option	17.13€
Short	Put Option	8.81€
Short	Call Option	4.92€
Structured product value	-	**95.66€**

Table 7: Theoretical Value at issuance (using the cost of funding)

Using a higher funding cost instead of the risk-free rate directly reduces the present value of each component, thereby lowering the total price of the certificate.

Black-Scholes Merton Model

Using the Black-Scholes formula with the parameters described in chapter 4, the theoretical value of the Sprint Certificate was computed one year after issuance, on the 12th December 2024. One year after issuance the market value of the underlying index had increased relative to its initial level ($S_t > S_0$), trading at 4,965.53 points. Results are reported in *Table 8* below:

Position	Instrument	Theoretical Value (€)
Long	ZCB	98.00€
Long	Call Option	22.01€
Short	Put Option	3.06€
Short	Call Option	3.69€
Structured product value	-	**113.25€**

Table 8: Theoretical Value one year after issuance (using the risk-free)

With the index above its initial level, the long call option increased in value because it is positively correlated with the performance of the underlying asset. Despite the reduction in time to maturity, volatility, and interest rates, the long call option increased in value. This is because the option is now deep in-the-money. On the other hand, the short put option decreased in value, as it is now out-of-the-money ($S_t > K$).

Since the short call option is still out-of-the-money the negative impact of a reduced time to maturity, lower volatility, risk-free rate and dividend yield outweighed the positive effect of the underlying price increase, resulting in a net decrease in the short call's value.

The ZCB component increased in value compared to issuance. This is due to a lower risk-free interest rate and time to maturity that increased the present value of the future cash flow.

As discussed before for the binomial valuation, to incorporate the credit risk of the issuer, I priced the product using not only the risk-free but also the cost of funding of the issuer. The results are shown below:

Position	Instrument	Theoretical Value (€)
Long	ZCB	97.75€
Long	Call Option	21.95€
Short	Put Option	3.06€
Short	Call Option	3.69€
Structured product value	-	**112.95€**

Table 9: Theoretical Value one year after issuance (using the cost of funding)

Monte Carlo Simulation

Monte Carlo Simulation is a statistical method that relies on the generation of a large number of simulated paths for the underlying asset, each representing a possible future evolution of its price.

I used Monte Carlo Simulation to compute the theoretical value of the Certificate on the 10th June 2025. I considered δt = 1/252, where 252 is the number of trading days in one year. I simulated 100.000 possible paths for the underlying in Python by generating a matrix of standard normal random variables and this was the result:

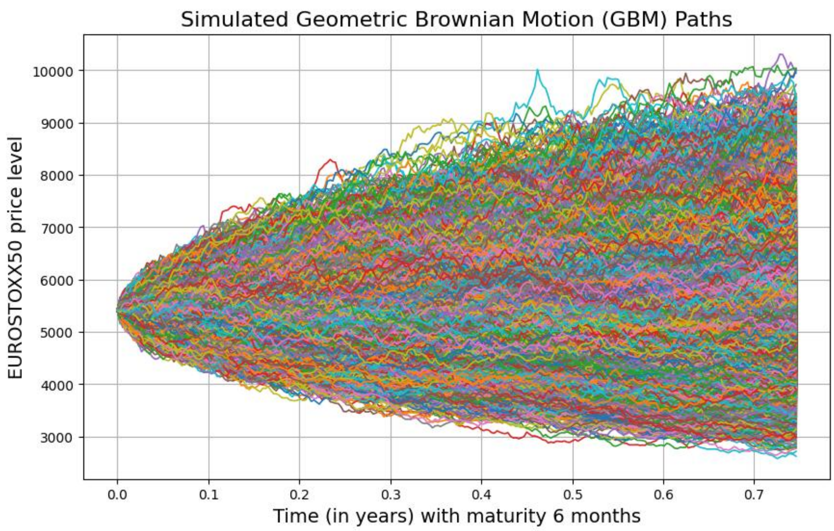

Figure 2: Monte Carlo Simulation of the Underlying Index

For each simulated path, the product's payoff at maturity is computed, then discounted back to the valuation date using the risk-free rate, and then averaged the results across all simulations to obtain the product's expected fair value. I used the Monte Carlo Simulation to find the theoretical value of the Sprint Certificate on the 10th June 2025, when the market value of the underlying index was 5,415.38 points.

Position	Instrument	Theoretical Value (€)
Long	ZCB	98.65€
Long	Call Option	37.80€
Short	Put Option	0.81€
Short	Call Option	8.64€
Structured product value	-	**127.00€**

Table 10: Theoretical Value 6-months to maturity (using the risk-free)

The long call option (strike 4,536.61 pts) remained deep in-the-money as the underlying index rose to 5,415.38 pts, with its value rising from €17.37 at issuance to €37.80 with six months before maturity. Conversely, the short put declined from €8.94 to €0.81, reflecting its increasingly out-of-the-money position. Regarding the short call (strike 5,604.98 pts), as the underlying approached the strike, the delta effects became dominant, increasing its value to €8.64 at six months to maturity. The zero-coupon bond component rose to €98.65, driven by lower discount rates and shorter time to maturity.

As a result, the theoretical value of the certificate at six months to maturity is €127.00. This corresponds to an increase of approximately 31% compared to its theoretical value at issuance. In *Table 11* below the theoretical prices computed using the issuer's cost of funding are reported:

Position	Instrument	Theoretical Value (€)
Long	ZCB	98.49€
Long	Call Option	37.74€
Short	Put Option	0.81€
Short	Call Option	8.63€
Structured product value	-	**126.79€**

Table 11: Theoretical Value 6-months to maturity (using the cost of funding)

5. Scenario Analysis

To fully understand the risk-return of the Sprint Certificate, it is useful to examine its payoff under different market scenarios. This chapter presents a "what-if" analysis, showing the estimated return for a range of possible index levels at maturity.

The analysis is based on the payoff formula discussed in chapter 3. I computed the certificate's payoff for a range from 50% decline to a 40% increase in the index level at maturity, capturing both downside risk and upside potential up to the cap level.

The results are shown in *Table 12* below:

Scenario	**Index Performance**	**Final Index level**	**Certificate Payoff**	**Investor Return**
Strong rally	+40%	6,351.25	147.10€	+47.1%
Moderate rally	+30%	5,897.59	147.10€	+47.1%
Cap level	**+23.55%**	**5,604.98**	**147.10€**	**+47.1%**
Strong rise	+20%	5,443.93	140.00€	+40%
Moderate rise	+10%	4,990.27	120.00€	+20%
No change	**0%**	**4,536.61**	**100.00€**	**0%**
Moderate decline	-10%	4,082.95	90.00	-10%
Decline	-20%	3,629.29	80.00	-20%
Severe decline	-30%	3,175.63	70.00	-30%
Extreme decline	-40%	2,721.97	60.00	-40%
Deep decline	-50%	2,268.30	50.00	-50%

Table 12: Payoff and Investor Return under different index performances

Table 12 illustrates the behaviour of the Sprint Certificate's payoff under different market scenarios, providing a clear visualization of its main structural features.

When the underlying index at maturity is below the initial level ($S_t < S_0$), the investor incurs a loss that is proportional to the decline of the index. In this region, the product offers no capital protection, and the investor participates linearly in the downside.

For positive performances of the index ($S_t > S_0$), the investor benefits from leveraged upside participation: the return is doubled (2x) until the index reaches the cap level of 5,604.98 points. At this point, the certificate pays its maximum value of 147.10€, corresponding to a +47.1% return for the investor.

For any index level above this cap, the payoff remains constant at 147.10€. The investor does not participate in further increases of the underlying, reflecting the capped nature of the product's upside.

Comparison with a Direct Index Investment

A Key benchmark for evaluating the Sprint Certificate is a direct investment in the underlying index. This comparison is essential because it helps answer a fundamental question: "Why should an investor buy the Sprint Certificate instead of simply purchasing the underlying index?" The answer lies in the embedded leverage (2×) offered by the product.

At the Valuation date, on 10 December 2025, the EURO STOXX 50 index closed at 5,708.12 points. As a result, the Sprint Certificate paid its maximum value of €147.10, corresponding to a return of 47.10%. In contrast, an investor who had simply bought the index at issuance (12 December 2023, at 4,536.61 points) would have realised a final value of €125.83, and a return of only 25.83%.

To achieve the same 47.10% return with a direct index investment, the index would have needed to rise by 47.10%, reaching 6,673.35 points. By contrast, for the Sprint Certificate to pay its maximum, the index only needed to reach or exceed the cap strike of 5,604.98 points.

To better understand this difference, Monte Carlo simulations were run from the issuance date, assuming an initial index level of 4,536.61 points. The probability that the index would reach or exceed 6,673.35 points at maturity was found to be 4.00%, while the probability of reaching or exceeding 5,604.98 points was 15.32%, a probability almost four times higher.

Table 13 below reports, for each target payoff, the index level required to achieve that payoff and the corresponding probability of obtaining at least that amount, comparing a direct long-only investment in the underlying index with an investment in the Sprint Certificate.

Payoff Target	Index Level (long index)	Index Level (long Sprint)	Prob. Index(%)	Prob. Certificate (%)
50.00	2,268.30	2,268.30	99.69%	99.69%
80.00	3,629.29	3,629.29	78.81%	78.81%
100.00	4,536.61	4,536.61	44.69%	44.69%
110.00	4,990.27	4,763.44	29.65%	36.81%
120.00	5,443.93	4,990.27	18.48%	29.65%
130.00	5,897.59	5,217.10	10.93%	23.63%
147.10	6,673.35	5,604.98	4.00%	15.32%
150.00	6,804.91	-	3.33%	0.00%
160.00	7,258.58	-	1.79%	0.00%

Table 13: Comparison of Required Index Levels and Probabilities – Long-Only Investment vs Sprint Certificate (at issuance)

The table shows that, thanks to its 2× leverage, the Sprint Certificate requires a lower index level than a direct long-only investment to achieve the same payoff. In the downside region, the required index levels and probabilities are identical. For instance, there is a 99.69% probability of receiving a payoff greater than €50, and a 78.81% probability of receiving a payoff greater than €80.

For target payoffs above €100, however, the Sprint Certificate consistently offers a higher probability of achieving at least that amount. This means that an investor holding the certificate has a significantly greater chance of obtaining the desired payoff at maturity compared to an investor who simply buys the underlying index.

Since the Sprint Certificate is capped at €147.10, the probability of receiving a payoff greater than €150 is zero. In contrast, a direct index investment still retains a 3.33% probability of achieving such an outcome, low, but not zero. This highlights the trade-off embedded in the structured product: it offers a higher likelihood of moderate gains in exchange for giving up the possibility of extreme upside.

Probability of Achieving Key Payoff Levels

The main objective of this section is to show how the probabilities of achieving certain payoff levels change depending on the valuation date. I computed the probabilities of receiving the maximum payoff of 147.10€, at least 125€, at least 100€ and 80€ or less, both at issuance and 6-months to maturity, using the Monte Carlo Simulation. As expected, these probabilities differ across the two dates, reflecting changes in current market condition, in particular the current value of the underlying index.

Table 14 reports the results:

Payoff	Probability (issuance)	Probability (6m to maturity)
147.10€	15.32%	35.14%
≥ 125€	26.56%	61.76%
≥ 100€	44.69%	87.46%
≤ 80€	21.19%	0.29%

Table 14: Probability of Achieving Key Payoff Levels (issuance vs 6m to maturity)

All probabilities are higher at six months than at issuance. This is because the index had risen from 4,536.61 pts at issuance to 5,415.38 pts at the later date. Starting from a higher level increases the chance of reaching the cap or any other payoff level.

For example, the probability of receiving the maximum payoff increased from 15.32% to 35.14%. The probability of not losing money (payoff ≥ 100€) rose from 44.69% to 87.46%, meaning that at six months, the investor had an 87.46% chance of at least recovering the initial investment. Conversely, the probability of receiving a payoff of at least 80€, dropped from 21.19% to just 0.29%.

The graph below shows the payoff distribution at issuance and at 6-months to maturity:

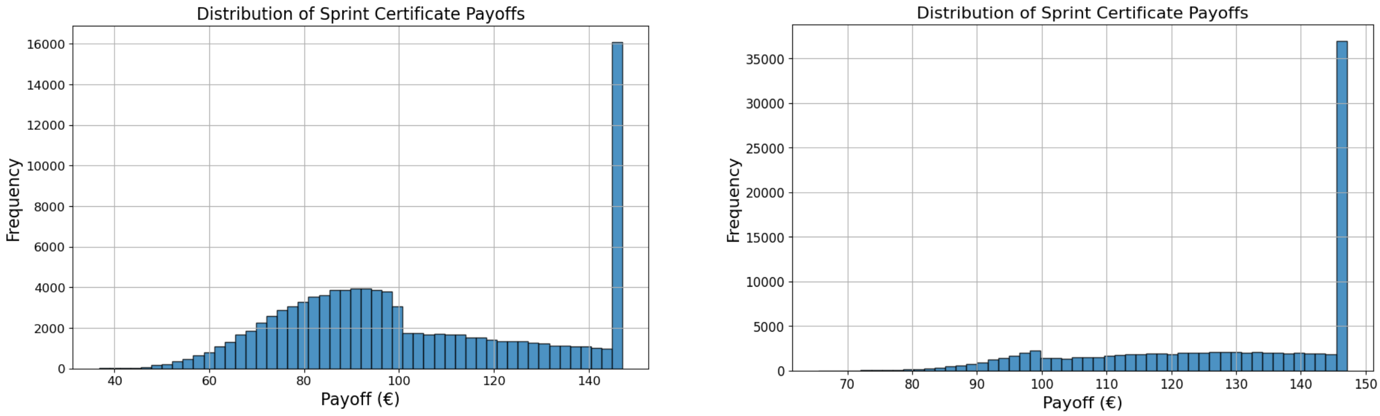

Figure 3: Distribution of Sprint Certificate Payoff (at issuance vs 6m to maturity)

At issuance, the distribution is spread across a wide range of payoffs. The probability of receiving a payoff below 100€ is relatively high, reflecting the uncertainty over two years. As the payoff increases toward the cap, the probability rises, with a noticeable spike at 147.10€. This spike captures all scenarios where the payoff would have exceeded the cap, since the product is capped at that value.

At six months to maturity, the distribution is much more concentrated. The probability of low payoffs drops, while the spike at the cap becomes significantly larger. This reflects the higher starting index level and the reduced time remaining.

Overall, the comparison shows that as the index rises and maturity approaches, the probability of reaching the cap increases, and the distribution becomes more concentrated at the upper bound.

6 Features Sensitivity Analysis

The Sprint Certificate is defined by three key features: no capital protection, 2x leverage, and a predefined cap. The objective of this chapter is to analyse how each features affect the product's theoretical value and to understand how the price responds to changes in these parameters.

6.1 Sensitivity to the cap level

The first feature analysed is the cap level, the graph below shows the price sensitivity of the Sprint Certificate to changes in the cap:

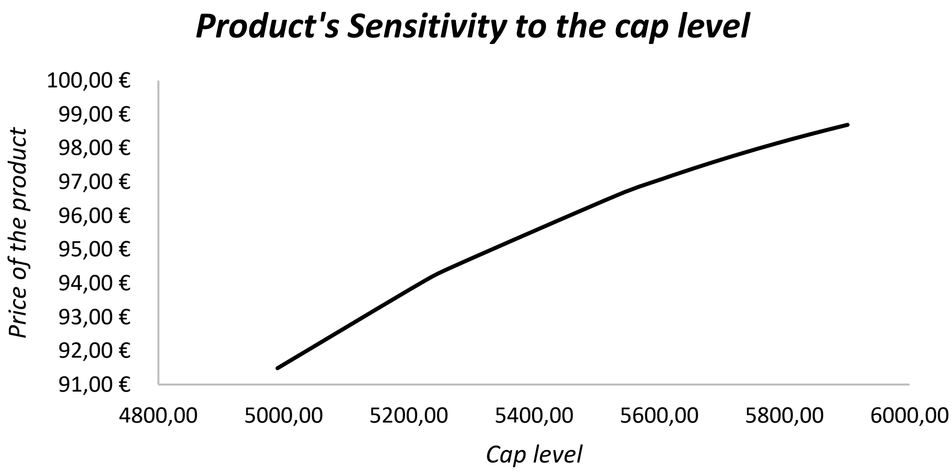

Figure 4: Product's Sensitivity to the cap level

To assess its impact, the theoretical value of the Sprint Certificate was computed at issuance for a range of different caps. While the original valuation at issuance used the Binomial model, this analysis employs the Black-Scholes model for simplicity and efficiency. Consequently, the base theoretical value differs slightly: €97.03 under the Binomial model versus €97.09 under Black-Scholes.

Changing the cap level involves adjusting the strike price of the short call option while keeping all other options unchanged. A higher strike price reduces the fair value of the short call, which increase the overall cost of the replicating portfolio. As illustrated in *Figure 4*, the price of the product increases as the cap level increases. This means that for the issuer, replicating the product becomes more expensive when a higher cap is offered.

The numerical results are presented in *Table 15* below:

Cap level (points)	Cap level (%)	Theoretical Value (€)
4,990.27	10.00%	91.48€
5,217.10	15.00%	93.98€
5,269.27	16.15%	94.48€
5,532.74	21.96%	96.61€
5,604.98	**23.55%**	**97.09€**
5,670.76	25.00%	97.49€
5,727.47	26.25%	97.82€
5,784.74	27.51%	98.13€
5,842.59	28.79%	98.42€
5,901.02	30.08%	98.69€

Table 15: Impact of cap level on Product Value (at issuance)

6.2 Sensitivity to the leverage

The same approach was applied to analyse the impact of leverage. The theoretical price of the product was computed at issuance under several different leverage levels. *Figure 5* illustrates how the product's price responds to changes in leverage:

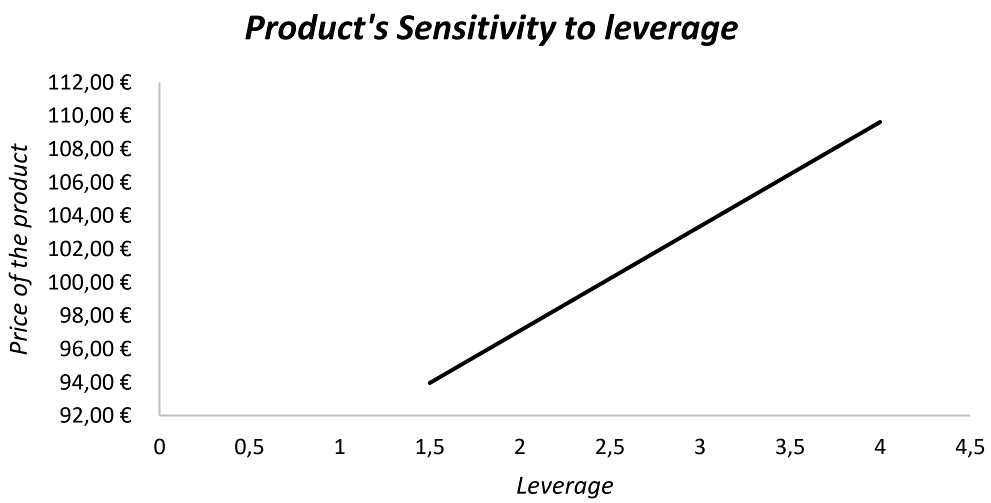

Figure 5: Product's Sensitivity to leverage

The Sprint Certificate exhibits a clear linear dependence on leverage, increasing the leverage leads to a proportional increase in the product's theoretical value. From a replication perspective, increasing leverage means increasing the number of call options in the portfolio. This is implemented by scaling the call conversion factor, defined as (Amount Invested) / (Initial Index Reference Level) multiplied by the leverage. The leverage amplifies the difference between the long and short call values. Since the long call is inherently more valuable than the short call, this amplification results in a net positive contribution to the overall product price. The numerical results are detailed in *Table 16*:

Leverage	**Conv. Factor calls**	**Theoretical Value(€)**
1.5x	0.0330643	93.95€
2x	**0.0440858**	**97.09€**
2.5x	0.0551072	100.22€
3x	0.0661287	103.36€
3.5x	0.0771501	106.49€
4x	0.0881716	109.62€

Table 16: Impact of leverage on Product Value (at issuance)

6.3 Sensitivity to Capital Protection

The original Sprint Certificate offers no capital protection, meaning the investor is exposed to the full downside risk of the underlying index. This section analyses how the product's price would change if a capital protection feature were introduced.

Capital protection is introduced by adding a long put option with a strike price corresponding to the guaranteed portion of the initial investment (e.g., a 50% protection level implies a strike price of 2,268.30 points). This new long put, combined with the existing short put, forms a bull put spread, which effectively creates a floor for the product's value in downside scenarios.

The theoretical value of the product was computed for a range of capital protection levels from 0% to 100%. The results are illustrated in *Figure 6*:

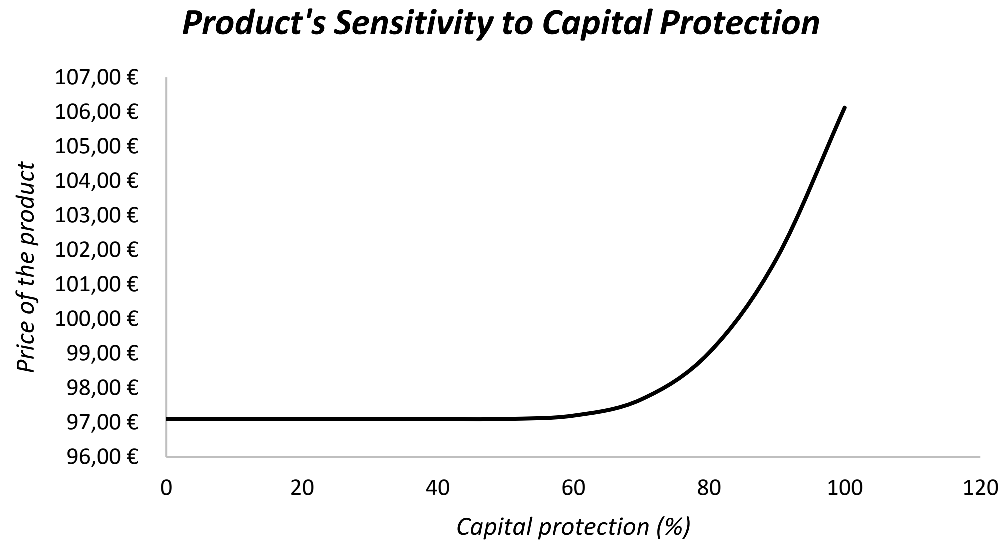

Figure 6: Product's Sensitivity to Capital Protection

As shown in *Figure 6* and detailed in *Table 17*, the impact of capital protection on the product's price is highly insightful. For protection levels between 10% and 40%, the product's price is stable at 97.09€. At these levels, the long put's strike price is so low that the option is deeply out-of-the-money and its theoretical value becomes zero. Consequently, adding further protection does not increase the replication cost.

For higher protection levels (≥ 50%) the cost of replication starts to increase, because the strike of the long put is always closer to the reference level of the index, leading to higher price of the put. For instance, introducing a 90% capital protection means to buy a put option with strike of 4082.94, for a price of 4.67€, and consequently the theoretical value of the product increase to 101.76€.

It is important to note that to guarantee 100% capital protection, the issuer would only need to hold the zero-coupon bond, the long call, and the short call. The put options become redundant as the bond itself guarantees the full repayment of the principal. This leads to an higher replication cost for the issuer of 106.12€.

Capital Protection (%)	Strike Price Long Put (pts)	Long Put Price	Theoretical Value (€)
0%	**-**	**-**	**97.09€**
10%	453.61	0.00€	97.09€
20%	907.32	0.00€	97.09€
30%	1,360.98	0.00€	97.09€
40%	1,814.64	0.00€	97.09€
50%	2,268.30	0.01€	97.10€
60%	2,721.96	0.10€	97.19€
70%	3,175.62	0.57€	97.66€
80%	3,629.28	1.93€	99.02€
90%	4,082.94	4.67€	101.76€
100%	-	-	106.12€

Table 17: Impact of Capital Protection on Product Value (at issuance)

7. Risk Measures: Greeks, VaR and CVaR

7.1 Greek Analysis

The Greeks letters measure the sensitivity of the product's price to changes in the key market parameters: the underlying asset, time to maturity, implied volatility and the risk-free interest rate. These measures are essential for assessing risk, guiding investment decisions, and designing a replicating portfolio that effectively hedge exposure.

I computed the following Greeks: Delta (Δ), Gamma (Γ), Vega (ν), Lambda (λ), and Rho (ρ).

To ensure a comprehensive and robust analysis, I used two distinct methodological approaches: the analytical Black-Scholes model and the numerical Monte Carlo Simulation. All the Greeks are computed at 6-months to the maturity of the product, on the 10th June 2025.

The results are shown in *Table 18*:

Greeks	Black-Scholes	Monte Carlo Simulation
Delta (Δ)	0.0235	0.0233
Gamma (Γ)	-0.000017	-0.000017
Vega (ν)	-0.6181	-0.6043
Lambda (λ)	1.0025	0.9956
Rho (ρ)	0.2349	0.1459

Table 18: Greeks letters (6-months to maturity)

Delta (Δ): it is defined as the rate of change of the option price with respect to the price of the underlying asset:

$$\Delta = \frac{\partial c}{\partial S}$$

The delta of a structured product is the sum of the deltas of each asset multiplied by their respective quantity w_i:

$$\Delta_{SP} = \sum w_i \Delta_i$$

As reported in *Table 18*, the Delta of the Sprint Certificate at 6 months to maturity is 0.0235 according to Black-Scholes model and 0.0233 according to Monte Carlo Simulation. This means that for a 1-point increase in the index, the product's value increases by about 0.0235€. The relative low Delta reflects the product's structure: the long call contributes positive Delta, but it is partially offset by the short put and the short call. The result is a balanced portfolio with limited directional risk. The graph below illustrates the Delta profile of the Sprint Certificate as a function of the underlying level at six months to maturity.

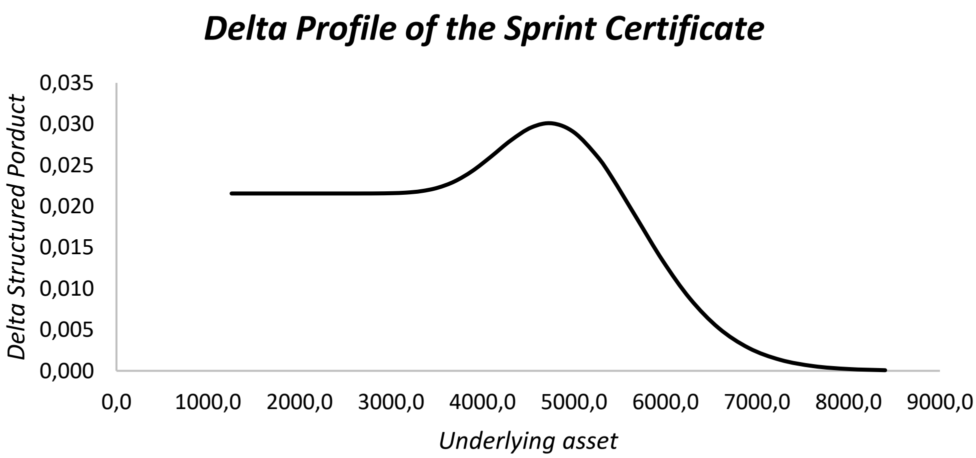

Figure 7: Delta Profile of the Sprint Certificate

For index levels below approximately 3,000 points, Delta remains relatively stable around 0.022. This reflects a region where the long call is still out-of-the-money and the short put provides a limited offset, resulting in a low but positive sensitivity.

As the index rises toward the long call strike of 4,536 points, Delta begins to increase steadily, reaching a peak of about 0.030 near the strike. This increase is driven by the growing contribution of the long call, which enters its leveraged region.

Beyond the strike, Delta gradually declines. The decrease becomes more pronounced after 5,500 points, as the short call begin to have a negative influence. By the time the index reaches approximately 8,000 points, Delta returns to zero, indicating that the product is no longer sensitive to further increases in the underlying, a direct consequence of the capped payoff structure.

This profile clearly illustrates how the product's sensitivity is concentrated in the region between the long call strike and the cap, while remaining very low elsewhere.

Gamma (Γ): it measures the rate of change of an option's Delta with respect to changes in the price of the underlying asset:

$$\Gamma = \frac{\partial \Delta}{\partial S} = \frac{\partial^2 V}{\partial S^2}$$

The near-zero Gamma indicates that the Delta of the Sprint Certificate is very stable and exhibits negligible convexity. This is a direct consequence of the product's structure, the long call contributes positive Gamma, while the short put and short call contribute negative Gamma. Their magnitudes are balanced, resulting in a net Gamma close to zero. *Figure 8* illustrates the Gamma Profile of the Sprint Certificate as a function of the underlying index:

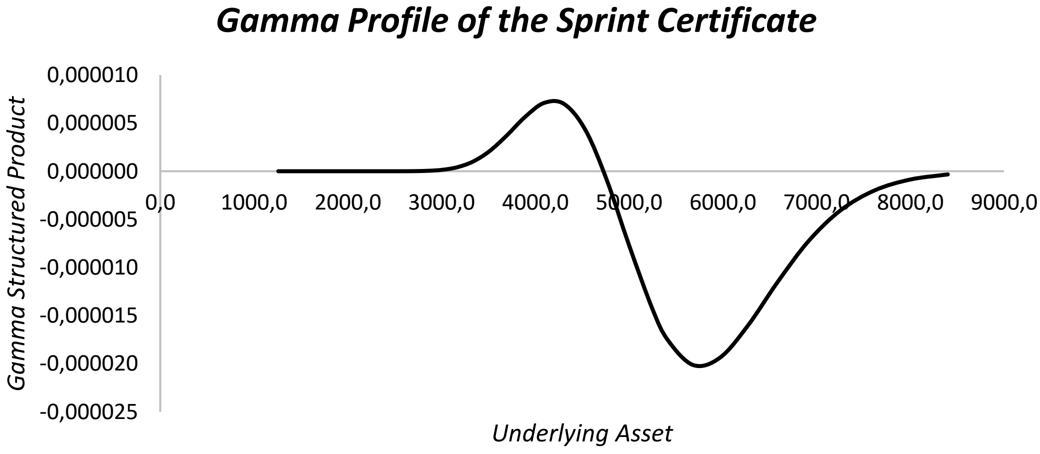

Figure 8: Gamma Profile of the Sprint Certificate

For index levels below 3,000 points, Gamma is close to zero. In this region, the delta of each options is relatively stable. As the index rises toward the strike of 4,536.61 points, Gamma became positive, indicating that Delta increases most rapidly in this region, reflecting the growing dominance of the long call in the leveraged part of the payoff. After the peak, Gamma starts to decrease and becomes negative.
Overall, the near-zero Gamma indicates that the product's Delta is stable across most market conditions, reducing the need for frequent hedging adjustments.

Vega (ν): measures the sensitivity of an option's price to a change in the implied volatility of the underlying asset:

$$\nu = \frac{\partial V}{\partial \sigma}$$

The slightly negative Vega indicates that the Sprint Certificate is short volatility, an increase in implied volatility would reduce its value. The long call contributes positive Vega, while the short put and short call negative. The net effect is a small negative value of -0.6181, under the Black-Scholes model, and -0.6043, under the Monte Carlo Simulation.

The graph below illustrates the Vega Profile of the Sprint Certificate as a function of the underlying index, showing how the product's sensitivity to change in implied volatility varies across different market scenarios.

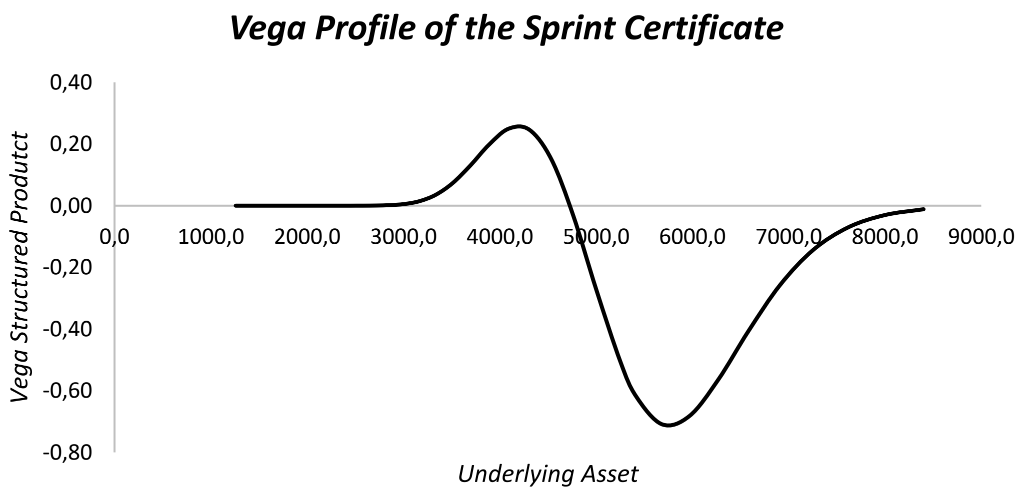

Figure 9: Vega Profile of the Sprint Certificate

For low index levels (below approximately 2,800 points), Vega is close to zero. In this regions, all the options are largely insensitive to changes in volatility.

As the underlying rises toward the strike price of the long call, Vega become positive, reflecting the dominant effect of the long option. In this region, an increase in volatility would increase the product's value. For higher index levels, Vega turns negative, as the short put and short call begin to dominate. Here, the product would lose value if volatility increases.

The most negative Vega occurs around the region where the short call becomes active. For very high index levels, Vega gradually returns toward zero, confirming that the product becomes insensitive to volatility when the options are deep ITM or OTM.

Lambda (λ): measures the percentage change in the option price for a 1% change in the underlying asset price:

$$\lambda = \Delta * \frac{S}{V}$$

For a portfolio of options, the same formula applies using the portfolio Delta and the portfolio price.

A Lambda of 1 means that if the underlying index increases by 1%, the product's value increases by approximately 1%. This indicates that the product's percentage return is proportional to the index return.

Figure 10 illustrates the Lambda Profile of the Sprint Certificate, showing how the product's percentage elasticity changes across different values of the underlying index and where the leveraged region is most pronounced.

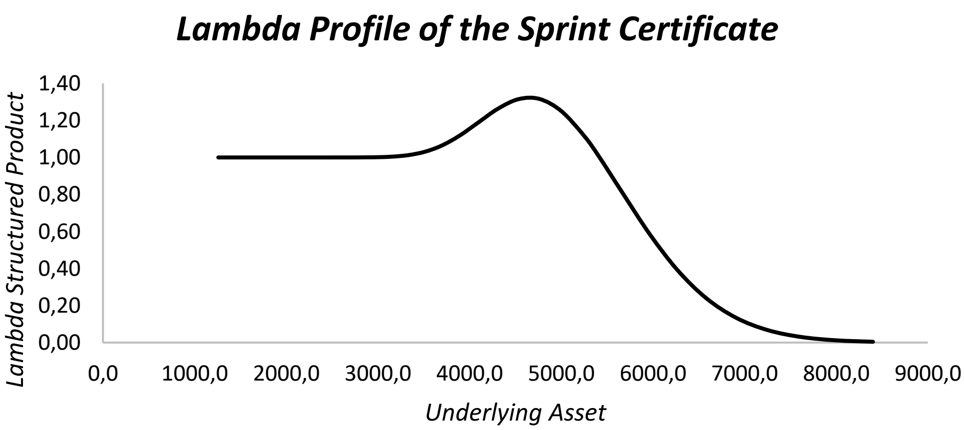

Figure 10: Lambda Profile of the Sprint Certificate

For low index levels, Lambda is 1, indicating that the product moves proportionally with the index in percentage terms. It increases in the leveraged region, reflecting the amplified sensitivity of the long call, and reaches its maximum around the strike price.

For higher index levels, Lambda gradually decreases and, as the index increases significantly, it approaches zero, confirming that the product becomes insensitive to further upward movements due to the capped payoff structure.

Rho (ρ): measures the sensitivity of an option's price to a change in the risk-free interest rate:

$$\rho = \frac{\partial V}{\partial r}$$

The positive Rho is primarily driven by the long call component, and the short put position, whose combined positive contributions more than offset the negative Rho of the zero-coupon bond and the short call. The near-zero net value indicates that the Sprint Certificate is largely insensitive to interest rate movements at the current valuation point.

The graph below illustrates the Rho Profile of the Sprint Certificate as a function of the underlying index, showing how the product's sensitivity to changes in interest rates varies across different market scenarios.

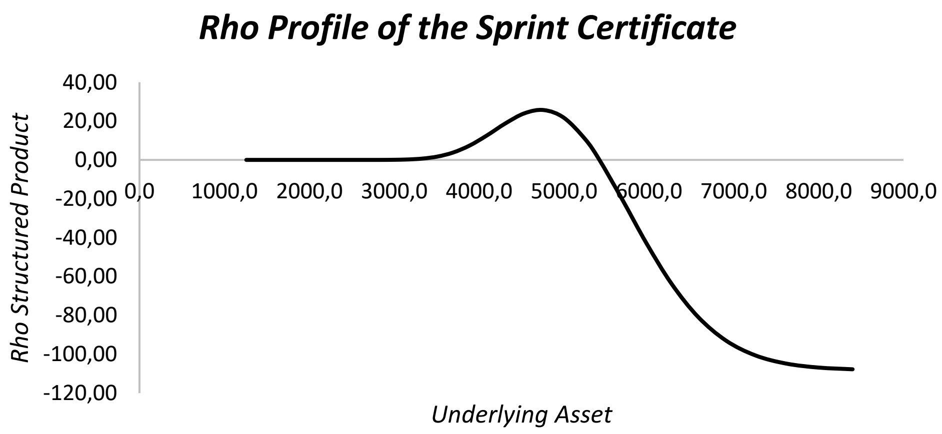

Figure 11: Rho Profile of the Sprint Certificate

For low index levels (below approximately 3,500 points), Rho is close to zero, indicating that the product is largely insensitive to interest rate changes in this region. As the underlying rises toward the long call strike of 4,536 points, Rho becomes positive and reaches its peak around the strike price. In this region, the long call dominates, and the product would gain value if interest rates increase. For index levels above 5,500 points, Rho starts to decrease significantly and becomes increasingly negative. This behaviour reflects the growing dominance of the short call option, which has a negative sensitivity to interest rates. Overall, the Rho profile shows that the product's interest rate sensitivity varies widely with the level of the underlying index, ranging from near zero to positive and then to strongly negative values.

7.2 Value-at-risk and Conditional Expected Shortfall

The Value-at-risk (VaR) estimates the maximum loss that an investment is expected to suffer over a given time horizon at a specified confidence level. However, VaR has a well-known limitation: it does not provide any information about the severity of losses beyond the confidence threshold. This is where CVaR, also known as Expected Shortfall, becomes useful. CVaR measures the expected loss in the worst $(1-\alpha)\%$ of scenarios, offering a more complete picture of tail risk.

In this paragraph, both risk measures are computed using the Monte Carlo Simulation. The analysis is based on the pnl distribution of the Sprint Certificate at maturity, obtained from 100.000 simulated paths of the underlying index. The results are presented for different confidence levels, 95%, 97.5%, 99%, and 99.9%, at two distinct valuation dates: at issuance and six months before maturity, providing a comprehensive view of how the product's risk profile evolved over its life.

	Issuance		**6 months**	
Confidence level	**VaR (€)**	**CvaR (€)**	**VaR (€)**	**CvaR (€)**
99.9%	53.69	56.89	23.72	25.94
99%	44.75	48.86	15.12	18.96
97.5%	39.46	44.66	10.70	15.17
95%	34.72	40.80	6.68	11.83

Table 19: Issuance vs 6-months VaR and CVaR

The comparison between the two dates reveals a dramatic reduction in downside risk. At issuance, the VaR(95%) stood at 34.72€, meaning that with 95% confidence, the investor's loss would not exceed 34.72€ over the full two-year horizon. Six months before maturity, the same measure dropped to 6.68€, a reduction of approximately 80%. This sharp decline is driven by two concurrent factors: the strong performance of the EURO STOXX 50, which rose from 4,536.61 to 5,415.38 points, significantly reducing the probability of the index finishing below the initial level, and the reduced time to maturity, which mechanically compresses the range of possible outcomes.

The CVaR tells a consistent story: at issuance the expected loss in the worst 5% of scenarios was 40.80€, falling to 11.83€ six months before maturity. Similarly, the VaR(99.9%) decreased from 53.69€ to 23.72€, confirming that even in the most extreme scenarios the tail risk had substantially diminished. These figures confirm that, given the favourable market conditions prevailing six months before maturity, the product's downside risk was substantially contained, consistent with its position near the cap and the reduced time remaining.

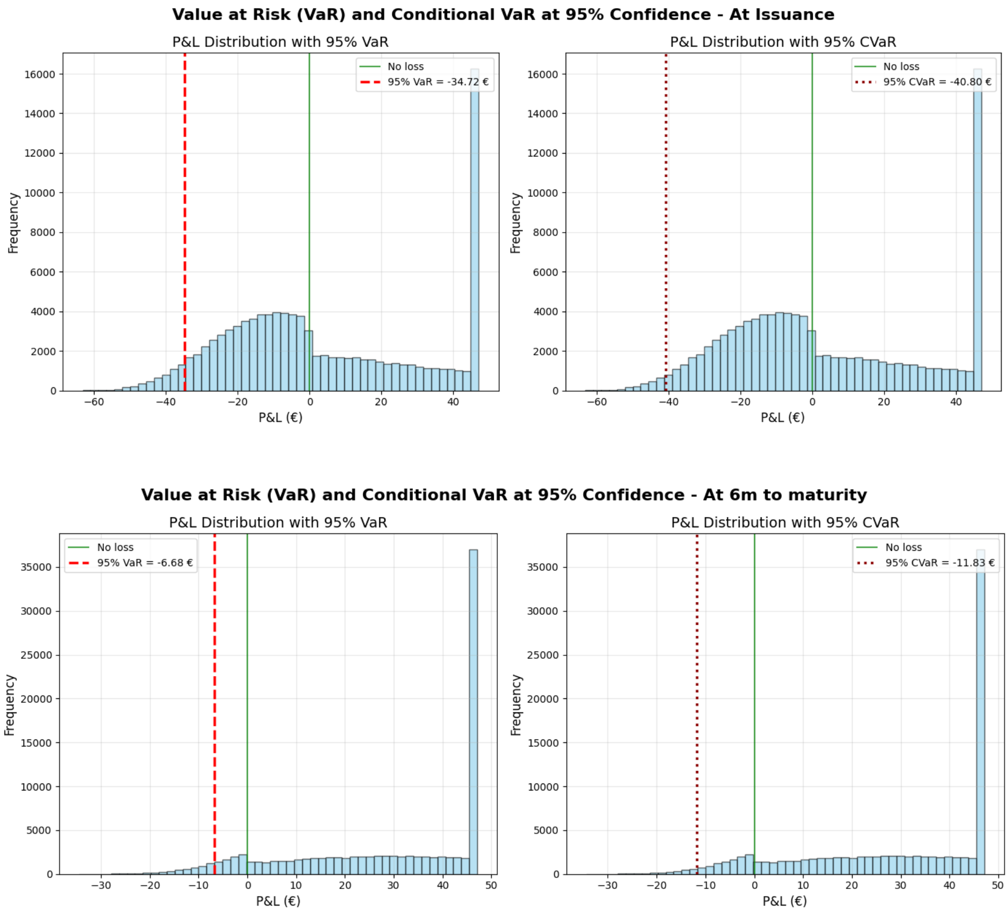

Figure 12: Issuance vs 6-months VaR(95%) and CVaR (95%)

The comparison between the two valuation dates highlights how dramatically the product's risk profile improved over its life. At issuance, with the index at 4,536.61 points and two years of uncertainty ahead, the VaR and CVaR figures reflected a wide distribution of possible outcomes, including substantial downside scenarios. Six months before maturity, with the index trading at 5,415.38 points and close to the cap of 5,604.98, both measures contracted sharply across all confidence levels, driven by the strong performance of the underlying and the reduced time remaining. These figures confirm that the product's downside risk is highly path-dependent, rewarding investors who held through a rising market with a progressively more favorable risk profile.

8 Conclusion

The objective of this thesis was to analyze in details the structure, valuation and risk characteristics of a Sprint Certificate linked to EURO STOXX50 index. Through product decomposition, the certificate was replicated using a portfolio consisting of a zero-coupon bond, a long call option, short put option and a short call option. This decomposition provided a clear understanding of the product payoff profile: full participation in downside movements, leveraged upside participation and a capped maximum return.

Three valuation methodologies were employed: The Binomial model was used at issuance, the Black-Scholes model one year after issuance and Monte Carlo Simulation 6-months before maturity. All models produced economically consistent results and highlighted how the product's value evolved as market conditions changed. The theoretical value increased from 97.03€ at issuance to 127.00€ 6-months before maturity, mainly driven by the strong performance of the index.

The scenario analysis demonstrated the product's key trade-off. Compared with a direct investment in the EURO STOXX 50, the Sprint Certificate offered a significantly higher probability of achieving moderate positive returns due to its 2x leveraged participation. The comparison with a direct index investment showed that the certificate reached its maximum payoff with a substantially lower required index performance, making it particularly attractive in moderately bullish market environments.

The sensitivity analysis further confirmed that leverage, cap level, and capital protection are the primary drivers of the product's value. Increasing leverage, the cap and introducing capital protection can significantly increase the product's theoretical price. The Greek analysis showed limited directional risk, low convexity, and a slightly negative volatility exposure, while the VaR and CVaR measures indicated a dramatic reduction in downside risk over the product's life, driven by the strong performance of the underlying index and the reduced time remaining before maturity.

Overall, the Sprint Certificate represents an effective solution for investors with a moderately bullish outlook who are willing to sacrifice extreme upside potential in exchange for enhanced participation in positive market movements. The results of this thesis demonstrate how financial engineering can be used to tailor risk-return profiles to specific investment objectives while highlighting the importance of understanding the embedded risks and trade-offs within structured products.

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Appendix: Official PRIIP KID Document

Key Information Document

Purpose

This document provides you with key information about this investment product. It is not marketing material. The information is required by law to help you understand the nature, risks, costs, potential gains and losses of this product and to help you compare it with other products.

Product

Product name	Sprint Certificate linked to EURO STOXX 50® Index (Price Index)
Product identifiers	ISIN: DE000DB9VMJ6 | WKN: DB9VMJ
PRIIP manufacturer	Deutsche Bank AG. The product issuer is Deutsche Bank AG, Frankfurt.
Website	www.db.com/contact
Telephone number	Call +49-69-910-00 for more information.
Competent authority of the PRIIP manufacturer	Federal Financial Supervisory Authority (BaFin)
Date of production	16 September 2025

You are about to purchase a product that is not simple and may be difficult to understand.

1. What is this product?

Type

German law governed equity-linked certificates / Return depends on the performance of the underlying / No capital protection against market risk

Term

The product has a fixed term and will be due on 15 December 2025.

Objectives
(Terms that appear in **bold** in this section are described in more detail in the table(s) below.)

The product is designed to provide a return in the form of a cash payment on the **maturity date**. The amount of this payment will depend on the performance of the **underlying**.

On termination of the product on the **maturity date** you will receive:

1. if the **final reference level** is at or above 4,536.61, a cash payment equal to (i) EUR 100 plus (ii) an amount directly linked to the performance of the **underlying**. This amount will equal (i) EUR 200 multiplied by (ii) (x) (A) the **final reference level** divided by (B) 4,536.61 minus (y) 100.00%. However, if this cash payment exceeds EUR 147.10, you will only receive EUR 147.10 (the maximum payment); or
2. if the **final reference level** is below 4,536.61, a cash payment directly linked to the performance of the **underlying**. The cash payment will equal (i) EUR 100 multiplied by (ii) (A) the **final reference level** divided by (B) 4,536.61.

Under the product terms, certain dates specified below will be adjusted if the respective date is either not a business day or not a trading day (as applicable). Any adjustments may affect the return, if any, you receive.

You do not have any entitlement to a dividend from the **underlying** and you have no right to any further entitlement resulting from the **underlying** (e.g., voting rights).

Underlying	EURO STOXX 50 (Price return index) (ISIN: EU0009658145)	**Initial reference level**	4,536.61
Underlying market	Equity	**Reference level**	The closing level of the **underlying** as per the **reference source**
Product currency	Euro (EUR)	**Reference source**	STOXX Limited, Zurich
Underlying currency	Euro (EUR)	**Final reference level**	The **reference level** on the **valuation date**
Issue date	12 December 2023	**Valuation date**	10 December 2025
Value date	14 December 2023	**Maturity date / term**	15 December 2025

The issuer may terminate the product with immediate effect in the event of obvious written or mathematical errors in the terms and conditions or if certain extraordinary events provided in the terms and conditions occur. Examples of extraordinary events include (1) material changes, particularly in connection with the **underlying**, including where an index ceases to be calculated, and (2) events, in particular due to changes in certain external conditions that hinder the issuer in meeting its obligations in connection with the product or – depending on the terms and conditions of the security – otherwise affect the product and/or the issuer. In case of immediate termination, the return (if any) may be significantly lower than the purchase price, but will reflect the product's market value and, if higher, any minimum redemption (alternatively, in some cases the corresponding compounded amount may be paid out at the product's scheduled maturity). Instead of immediate termination, the issuer may also amend the terms and conditions.

Provided that in the event of any inconsistency and/or conflict between the foregoing paragraph and any applicable law, order, rule or other legal requirement of any governmental or regulatory authority in a territory in which this product is offered, such national requirements shall prevail.

Intended retail investor

The product is intended for private clients who pursue the objective of general capital formation / asset optimization and have a short-term investment horizon. This product is a product for clients who have sufficient knowledge and / or experience to make an informed investment decision. The investor can bear losses up to the total loss of the capital invested and attaches no importance to capital protection.

2. What are the risks and what could I get in return?

Risk indicator

1	2	3	4	**5**	6	7

Lower risk — Higher risk

The risk indicator assumes you keep the product until 15 December 2025. The actual risk can vary significantly if you cash in at an early stage and you may get back less.

The summary risk indicator is a guide to the level of risk of this product compared to other products. It shows how likely it is that the product will lose money because of movements in the markets or because we are not able to pay you.

We have classified this product as 5 out of 7, which is a medium-high risk class. This rates the potential losses from future performance at a medium-high level, and poor market conditions are very unlikely to impact our capacity to pay you.

Inflation erodes the purchasing value of cash over time and this may result in the decline in real terms of any capital reimbursed.

This product does not include any protection from future market performance so you could lose some or all of your investment.

If we are not able to pay you what is owed, you could lose your entire investment.

Performance scenarios

What you will get from this product depends on future market performance. Market developments in the future are uncertain and cannot be accurately predicted.

The scenarios shown are illustrations based on results from the past and on certain assumptions. Markets could develop very differently in the future.

Recommended holding period:		3 months
Example investment:		EUR 10,000
Scenarios		***If you exit after 3 months (Recommended holding period)***
Minimum	**There is no minimum guaranteed return. You could lose some or all of your investment.**	
Stress	**What you might get back after costs** Percentage return (not annualised)	EUR 5,298 -47.0%
Unfavourable	**What you might get back after costs** Percentage return (not annualised)	EUR 8,311 -16.9%
Moderate	**What you might get back after costs** Percentage return (not annualised)	EUR 10,115 1.1%
Favourable	**What you might get back after costs** Percentage return (not annualised)	EUR 10,767 7.7%

The favourable, moderate, unfavourable and stress scenarios represent possible outcomes that have been calculated based on simulations using the past performance of the **underlying** over a period of up to 5 years. The stress scenario shows what you might get back in extreme market circumstances.

The figures shown include all the costs of the product itself, but may not include all the costs that you pay to your advisor or distributor. The figures do not take into account your personal tax situation, which may also affect how much you get back.

3. What happens if Deutsche Bank AG, Frankfurt is unable to pay out?

You are exposed to the risk that the issuer might be unable to fulfil its obligations in respect of the product – e.g. in the event of insolvency (inability to pay / over-indebtedness) or an administrative order of resolution measures. In case of a crisis of the issuer such an order can also be issued by a resolution authority in the run-up of an insolvency proceeding. In doing so, the resolution authority has extensive intervention powers. Among other things, it can reduce rights of the investors to zero, terminate the product or convert it into shares of the issuer and suspend rights of the investors. With regard to the basic ranking of the issuer's obligations in the event of action by the resolution authority, please see www.bafin.de and search for the keyword "Haftungskaskade". A total loss of your capital invested is possible. The product is a debt instrument and as such is not covered by any deposit protection scheme.

4. What are the costs?

The person advising on or selling you this product may charge you other costs. If so, this person will provide you with information about these costs and how they affect your investment.

Costs over time

The tables show the amounts that are taken from your investment to cover different types of costs. These amounts depend on how much you invest and how long you hold the product. The amounts shown here are illustrations based on an example investment amount and different possible investment periods.

We have assumed:

- You would get back the amount that you invested (0% return).
- EUR 10,000 is invested

	If you exit after 3 months
Total costs	EUR 0
Cost impact*	0.0%

*This illustrates the effect of costs over a holding period of less than one year. This percentage cannot be directly compared to the cost impact figures provided for other PRIIPs.

We may share part of the costs with the person selling you the product to cover the services they provide to you. They will inform you of the amount.

Composition of costs

One-off costs upon entry or exit		If you exit after 3 months
Entry costs	0.0% of the amount you pay when entering this investment. These costs are already included in the price you pay.	EUR 0
Exit costs	0.0% of your investment amount if you return this product before its settlement date. These costs are already included in the price you receive. The costs indicated assume that normal market conditions apply.	EUR 0

5. How long should I hold it and can I take money out early?

Recommended holding period: 3 months

The product aims to provide you with the return described under "1. What is this product?" above. However, this only applies if the product is held to maturity. It is therefore recommended that the product is held until 15 December 2025 (maturity).

The product does not guarantee the possibility to disinvest other than by selling the product either (1) through the exchange (where the product is listed) or (2) off-exchange. Save as otherwise disclosed in exit costs (see section "4. What are the costs?" above), no fees or penalties will be charged by the issuer for any such transaction. However if you sell the product in the secondary market you will incur a bid/offer spread. By selling the product before its maturity, you may receive back less than you would have received if you had kept the product until maturity.

Exchange listing	Börse Stuttgart and Deutsche Börse AG	**Last exchange trading day**	9 December 2025 (Börse Stuttgart) and 9 December 2025 (Deutsche Börse AG)
Smallest tradable unit	1 unit	**Price quotation**	Units

In volatile or unusual market conditions, or in the event of technical faults/disruptions, the purchase and/or sale of the product can be temporarily hindered and/or suspended and may not be possible at all.

6. How can I complain?

Any complaint regarding the conduct of the person advising on, or selling, the product can be submitted directly to that person.

Any complaint regarding the product or the conduct of the manufacturer of this product can be submitted in writing at the following address: Mainzer Landstrasse 11-17, 60329 Frankfurt am Main, Germany, by email to: x-markets.team@db.com or at the following website: www.xmarkets.db.com.

7. Other relevant information

Any additional documentation in relation to the product and in particular the prospectus, any supplements thereto and the final terms are published on the manufacturer's website (www.xmarkets.db.com/DocumentSearch ; after entering of the respective ISIN or WKN), all in accordance with legal requirements. In order to obtain more detailed information - and in particular details of the structure and risks associated with an investment in the product - you should read these documents. These documents are also available free of charge from Deutsche Bank AG, Mainzer Landstrasse 11-17, 60329 Frankfurt am Main, Germany, in accordance with legal requirements.

Disclaimer

This report is for academic purposes only and does not constitute investment advice. It was prepared by a Master's student in Finance at ISEG – Lisbon School of Economics and Management, exclusively for the Master's Final Work. The analysis is based on public information and theoretical models. The opinions expressed and estimates contained herein reflect the personal views of the author about the product under analysis, for which he/she is sole responsible.

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The information is not intended to be used as the basis of any investment decisions by any person or entity.

AI Disclosure

I disclose that AI tools were utilized during the development of this MFW a follows:
AI tools were only used for grammar correction, spell-checking and improving the conciseness of the written text.
All final thoughts, writing, synthesis, and critical analysis are my work. I have made sure that my work's integrity and uniqueness have not been compromised by the employment of AI techniques. Every information source, whether conventional or AI-assisted, has been properly referenced in compliance with academic guidelines.
As this thesis was being prepared, the ethical application of AI in research and
writing served as a compass. The substance and uniqueness of this work are entirely my responsibility, and I recognize how important it is to uphold academic integrity.
The content of this PRIIP analysis is all my own. All academic work, including data analysis,
interpretation, and conclusions, is the result of the author's own effort.

Matteo Filippo Romano
30/06/2026