Lisbon School of Economics & Management
Universidade de Lisboa

MASTER

MASTER'S IN FINANCE

MASTER´S FINAL WORK

PROJECT

STRUCTURED PRODUCT ANALYSIS - 95% CAPITAL PROTECTION NOTE WITH DIGITAL COUPONS ON SD3E®

GUILHERME DE PINHO TEIXEIRA

Lisbon School of Economics & Management
Universidade de Lisboa

OCTOBER - 2024

MASTER
MASTER'S IN FINANCE

MASTER´S FINAL WORK
PROJECT

STRUCTURED PRODUCT ANALYSIS - 95% CAPITAL PROTECTION NOTE WITH DIGITAL COUPONS ON SD3E®

GUILHERME DE PINHO TEIXEIRA

SUPERVISION:
JORGE BARROS LUÍS

OCTOBER - 2024

“Deixa as tristezas no
bornal, rapaz. Tens de rir.
Ri! Ri!”

ABSTRACT, KEYWORDS AND JEL CODES

This dissertation provides a comprehensive analysis of the structured product "95% Capital Protection Note with Digital Coupons on SD3E®" issued by Haitong Investment Ireland. It contributes to a better understanding of structured products, their characteristics, and how to price them.

The aim of this work is to deeply explore this product by clearly identifying its risks, advantages, and disadvantages for both investors and the issuer. Additionally, it explains the characteristics of the product and breaks it down into simpler components.

Furthermore, this dissertation applies three different models to value the structured product: Monte Carlo Simulation, Binomial Tree model, and Black-Scholes formula. While Black-Scholes formula was not successfully implemented given the characteristics of the product, the other two approaches led to results slightly different from each other.

This dissertation incorporates some additional topics such as the analysis of the product's memory feature or the calculation of the profitability associated with the structured product. Indeed, the memory feature makes the instrument more expensive and both investor and issuer are expected to profit with the product acquisition and issuance, respectively. Furthermore, I demonstrate the convergence of Binomial Model relatively to the Black-Scholes formula.

KEYWORDS: Structured Products; Returns; Risks; Delta Hedging; Financial Engineering; Product Decomposition.

JEL CODES: C02; C53; G12; G18; G32.

RESUMO

A presente dissertação apresenta uma análise exaustiva e detalhada do produto estruturado "95% Capital Protection Note with Digital Coupons on SD3E®" emitido pela Haitong Investment Ireland. Este trabalho contribui para uma melhor compreensão desta tipologia de instrumento, das suas caraterísticas e dos métodos para avaliação do seu preço teórico.

O objetivo deste trabalho é explorar em profundidade este produto, identificando claramente os seus riscos, vantagens e desvantagens, tanto para os investidores como para o emitente. Para além disso, esta dissertação explica as caraterísticas do produto e decompõe-no em componentes mais simples, constituídas por instrumentos mais comuns.

Concomitantemente, esta dissertação avalia o produto estruturado em causa utilizando três modelos diferentes: *Monte Carlo simulation*, *Binomial Tree model* e *Black-Scholes formula*. Enquanto este último não é implementado com sucesso, devido a características do produto estruturado em causa, as duas outras abordagens culminam em resultados ligeiramente diferentes.

Para além do *pricing*, este trabalho inclui alguns tópicos adicionais como a análise da *memory feature* do produto ou o cálculo da rendibilidade associada ao produto estruturado. A *memory feature* encarece o produto e é esperado que investidor e emitente obtenham retorno com aquisição e emissão do produto, respetivamente. Para além disso, demonstrei a convergência entre *Binomial Tree model* e *Black-Scholes formula*.

TABLE OF CONTENTS

Acknowledgments

As I conclude my second cycle of higher education, I would like to express my heartfelt gratitude to those who have played a significant role in this long but beautiful journey:

To my mother, Ana Maria, for the love, tenderness, and care with which she lights up my life and guides me every day, never letting me fall during the toughest times.

To my father, Carlos Alexandre, my idol, for all the values and teachings he has imparted to me, which are undoubtedly the greatest wealth I will ever have.

To my grandfathers, Carlos and Armindo, for all the interest shown and help provided throughout this odyssey. They are the two kindest men I know, and every day I strive to live by their ethics and values. I dedicate this journey especially to them.

To my siblings, Chico and Rita, for all the fun and camaraderie of these 22 happy years, with the certainty that we will always continue on this path together.

To my grandmothers, Emília and Conceição, for the maternal concern they have always shown me during this journey, revealing the most genuine of loves.

To my girlfriend, Ana Sofia, for always being by my side and being my safe harbor.

To my uncles, cousins, and friends for all the hours of conversation and laughter, adventures, gatherings, as well as all the strength and confidence they have given me.

1. INTRODUCTION

Structured Products continue to constitute a popular financial instrument among investors, even though they were involved in some controversy not a long time ago. In fact, according to the European Structured Investment Products Association, regarding the first quarter of 2024, the market turnover, outstanding volume, new issuances, and the total number of products increased when measured as quarter-by-quarter comparison and as on annual basis. Moreover, according to Structured Retail Products (SRP), the registered note market is set to break its market size record, in 2024.

Despite its popularity, structured products are instruments that can be very complex and difficult to price and trade. Issuers tend to use behavioural factors, like loss-aversion or probability miss-estimation, to catch the attention of investors (Hens and Rieger, 2008) and some authors, such as Wallmeier and Diethelm (2008) and Stoimenov and Wilkens (2004), through empirical evidence, point out overpricing of structured products.

This dissertation aims to add value regarding structured products comprehension. In this work, it is explored the several risks associated to this specific product as well as its advantages and disadvantages, both from the point of view of the investor and the issuer. Since products can be hard to interpret and they tend to vary a lot regarding its characteristics, a product decomposition to enhance its comprehension along with a briefly product explanation are discussed in this dissertation.

This structured product is priced, in this dissertation, using three distinct methodologies, each well-established in both industry and academia.: Monte Carlo simulation, Binomial Tree model, and Black-Scholes formula. Besides applying these methodologies, a theoretical explanation of each one will be presented.

Furthermore, additional topics will be analysed such as the memory feature influence in the theoretical price of the product.

Finally, the profitability of the investor and the issuer are calculated regarding the acquisition and issuance of the structured product, respectively.

2. LITERATURE REVIEW

Despite its considerable popularity, structured products are instruments with several particularities and easily misunderstood by the common investor. Although these products are relatively new in the markets, there is already relevant literature about the topic.

Wallmeier (2011) states that the retail derivatives market and, therefore, the structured products market must see its transparency be improved[1], given that, for instance, many investors did not know the credit risk implicit in structured products before the Global Financial Crisis and investment decisions regarding these products tend to be made using limited information. Kunz et al. (2017) argue that investors in structured products can have its risk perception biased downwards via the strategic selection and composition of the underlying assets made by the issuer of the product. Given this literature, it is crucial to accurately perceive the risks associated with structured products.

Henderson and Pearson (2011) point out that it is difficult to rationalize the purchase of structured products by informed rational investors after assessing 64 issues of a popular retail structured equity product whose price was, on average, almost 8% greater than estimates of the products' fair market values obtained using option pricing methods. Grünbichler and Wohlwend (2005) examined 192 structured products for the Swiss market concluding that, on average, at the issuance, structured products are valued in favour of the issuing institutions and, therefore, penalizing investors. This also holds for the secondary market. This literature unveils the importance of the structured products valuation.

Hens and Rieger (2008), by developing a theoretical framework for the design of an optimal structured product and analysing the maximal utility gain for an investor by introducing structured products, demonstrate with data from the German and Swiss markets that most of the successful structured products are not optimal for a perfectly rational investor. Entrop et al. (2016), based on a large database of trades and portfolio holdings, point out that investors tend to obtain negative alphas when investing in

[1] Despite efforts made since 2011 to improve regulation, particularly in the European Union, there is still room for enhancing transparency around these financial instruments.

structured financial products. This literature highlights the importance of comparing structured products to other financial instruments to allow investors to maximize its utility from their investment decisions.

3. Product Overview

This dissertation analyses a financial instrument which is 95% Capital Protection Note with Digital Coupons on SD3E®.

This instrument is a structured product which underlying is the EURO STOXX Select Dividend 30 Price EUR Index®.[2] The product pays an annual coupon 2.10% if the underlying records a positive performance on each observation date since the inception date. Nonetheless, if the index has a negative or a null performance, the product does not pay any coupon. On the other hand, there is a memory feature incorporated in the product. This feature is common in these instruments. Basically, a memory feature allows the investor to obtain unpaid coupons in subsequent periods if a condition is met. In this case, whenever in a certain observation date the coupon payment condition is met, automatically, the investor will get all the previously unpaid coupons, besides the coupon planned for the present observation date.

The product, which is an unsecured debt instrument governed by English law, is issued by Haitong Investment Ireland Plc. In the moment of issuance, this entity was a wholly owned subsidiary of Haitong Bank, S.A., an investment bank with its headquarters in Lisbon. Throughout the life of the product, the Irish subsidiary was sold to Haitong International Holdings Limited, Haitong Bank's parent company, which in turn is owned by Haitong Securities. Nonetheless, Haitong Investment Ireland Plc is engaged in the issuance of own debt securities, the extension of credit to counterparties which are typically corporate entities, trading securities for its own account as well as entering derivatives contracts to manage the risks derived from those activities.

Despite the product being only available through private placement, it is listed, with Haitong Bank S.A. ensuring a daily secondary market during the life of the product. Furthermore, the product's currency is the euro, and the minimum investment are 1,000

[2] This index is composed by 30 high-dividend-yielding companies from 11 Eurozone countries, including, Portugal. Its Bloomberg ticker is SD3E, and the identification code is CH0020751589.

euros. In the appendix, it is possible to find more information regarding the product characteristics, including, the issuance, maturity, and observation dates.

It is very important to mention that in contrast with many structured products, this instrument does not offer 100% capital protection. Instead, it offers 95% capital protection, meaning that the investors incur in the risk of not only obtaining a null return, as it might, in fact, obtain a negative return in its investment. In fact, at maturity, if the underlying verifies a negative performance since inception on the final observation date, the investor will receive 95% of the invested capital, whereas otherwise it receives back 100% of the invested capital. As mentioned above, the investor might not only do not receive any coupon, as at maturity only get 95% of its invested capital.

The issuer, with this product, aims investors who know the underlying index and look for exposure to it, accept having part of its capital at risk, have a financial situation that allows them to hold the product for the full life of the product, understand that due to several variable values the secondary market for this product can be volatile and, finally, have experience with similar instruments and are able to understand the product. All this information can be found in the key information document (KID) provided by the issuing institution.

As usual with other financial instruments, this product has its costs. The issuer provides the costing information in the KID and a simulation for the costs with this product for different holding periods is also made. According to that information, the reduction in yield[3] (RIY) is 0% for the investors who cash-in at the end of the recommended holding period (RHP). However, the RIY may be higher for investors who cash-in before the RHP. Those estimates are made for an investment of 10 000€ and may change in the future.

It is important to state the RHP for this product is four years and a half which is the same period as the product maturity. As already mentioned, Haitong Bank S.A. holds a daily secondary market during the products life. Nonetheless, this secondary market may be interrupted during abnormal market conditions. As it is expected, investors who

[3] Reduction in yield refers to the decrease in an investment's expected return due to fees and charges, representing the difference between the gross and net returns.

are trying to sell their products before maturity can face significant losses, as the price in the secondary market is driven by several variables. In the same way, investors might not be able to operate in the secondary market due to lack of liquidity or even due to its interruption.

4. Product Decomposition

Structured products are combinations of several financial instruments that lead to a wide and varied range of potential payoff structures. In fact, decomposing a structured product is an important step for valuing it appropriately and, sometimes, it might be a difficult task. The idea is simple: replicate the payoff structure of the product by breaking it into a portfolio of simpler financial products. On the other hand, as structured products are complex instruments, it can be very challenging to, firstly, understand the payoff structure and, secondly, finding appropriate instruments to replicate it.

Typically, structured products are a combination of a capital component and a performance component. The first one provides the investor capital protection by ensuring that the investor gets a certain level of its invested capital at product's maturity. The second, typically composed by a portfolio of derivatives, is the performance component, which is responsible for the payoff structure of the product and so, for the potential return that investor might get or not.

The product analysed in this dissertation has 95% capital protection. Therefore, at maturity, the investors shall receive, at least, 95% of its invested capital. This capital protection is ensured with a zero-coupon bond with a facial value of 950€[4] maturing in the exact same date as the structured product final observation date. Then, the performance component must be replicated, as well. As it was mentioned, there are payments when in the observation dates, the underlying has positive performance, since the inception date. This product has five potential payments, according to its payoff structure. Five binary call options can replicate exactly the payoff structure. Their maturity should cover all the observations date, this is, each binary should have its maturity on one of the five observation dates mentioned in the KID. The strike price for

[4] For one note of the structured product, with facial value of 1000€ and issued at the par (1000€*0,95)

all of them should be the closing quotation of the underlying at the inception date. The payoff of each binary call option must be the same amount as the coupon for that observation date. Finally, this product has memory feature so all the binary calls should have it, as well. If there are unpaid coupons, whenever a binary meets the condition, it will pay its coupon, but also all the unpaid coupons. That's why the term "memory feature" is used. This feature will make the valuation of the product more complex.

Before concluding, it is important to explain binary options, more concretely, binary call options. This instrument is an exotic option that provides a fixed payout if the underlying's price is higher than a pre-established barrier[5] at maturity, and if not, it does not pay any amount. For a binary put option would be the opposite. Basically, in this instrument, the investor is exposed to a "all-or-nothing" situation by receiving the payoff if the option expires in the money and by not receiving it when it expires out the money.

In sum, one note of this structured product can be decomposed in one zero-coupon bond and five binary call options. If the 1000€ received for each sold note of this structured product are higher than the price of the portfolio that replicates the payoffs of this structured product, then, that difference represents the profit of the product issuer.

TABLE 1: CAPITAL COMPONENT

Instrument Type	Position	Face Value	Maturity
Zero-Coupon Bond	Long	950.00 €	15/12/2022

Source: Own elaboration based on product's KID

TABLE 2: PERFORMANCE COMPONENT

Instrument Type	Position	K [points][6]	Q [euros]	Maturity
Binary Call	Long	2014.58	21[7]	10/06/2019
Binary Call	Long	2014.58	21	08/06/2020
Binary Call	Long	2014.58	21	08/06/2021
Binary Call	Long	2014.58	21	08/06/2022
Binary Call	Long	2014.58	60.5[8]	08/12/2022

Source: Own elaboration based on product's KID

[5] Also known as strike price.
[6] The closing quotation of the underlying at the inception date.
[7] 1000€ * 2,1% = 21€ (1000€ - face value; 2,1% - annual coupon rate)
[8] 1000€ * 5% + 1000€ * 1,05% = 60,5€ (1000€ - face value; 5% - capital that was at risk; 1,05% - annual coupon rate corresponding to half period)

5. PRODUCT'S RISKS

5.1 Investor's Risks

An appropriate risk assessment is essential to robust and coherent investment decision. This is even more important, especially, when the instrument being considered is a structured product. In fact, according to Chen et al. (2019), overconfidence leads investors to underestimate the perceived risk of structured financial products, as they overestimate the probability of favourable outcomes based on their reliance on private signals. The "private signals" are all the knowledge that investors acquire through their own efforts about the underlying asset's price at maturity.

Firstly, due to a legal obligation imposed by the European Union[9], the issuer provides a Summary Risk Indicator, which is a guide to the level of risk of this product compared to other products, in the KID. It shows how likely is the product to make the investor lose money because of movements in the markets or because the issuer is not able to pay the investor. It is important to mention that this indicator assumes that the investor keeps the product until maturity. The indicator is between a range from 1 to 7, and for this product, it is 3, this is, medium-low risk class. In fact, there are potential losses from future performance at a low level, and poor market conditions are unlikely to impact the capacity of the issuer to pay back to the investor. As it was already mentioned, there is a 95% capital protection feature, however, if the issuer, Haitong Investment Ireland Plc, is unable to payout, for instance, it declares bankruptcy, the investor may suffer a partial or total loss of the initial amount invested in the product.

Having in mind the typical risks associated to financial instruments, this structured product has associated to it, credit risk, market risk and interest rate risk, among others[10]. The credit risk is present given that investors are subject to Haitong Investment Ireland Plc's credit risk. Investors may lose all or a portion of their money if the issuer defaults or applies for bankruptcy, as it was already mentioned. Thus, unlike when investors pick directly the underlying, whose risks are linked to its market performance,

[9] Regulation (EU) No 1286/2014 of the European Parliament and of the Council of 26 November 2014 on KIDs for PRIIPs.

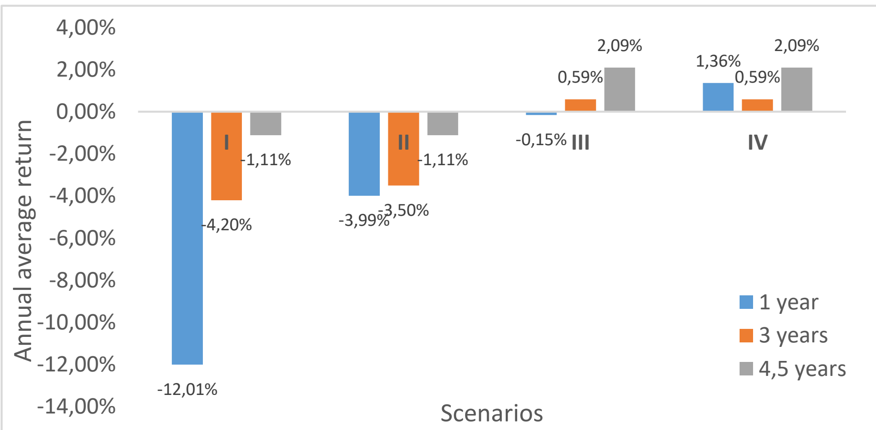
[10] In appendix, there's a table describing all risks associated to the structured product, in the investor's perspective.

with structured products investors are subject, additionally, to the issuer's creditworthiness.

Secondly, as with many other instruments, this structured product is exposed to interest rate risk. In fact, the value of the structured product may change in response to changes in interest rates. As expected, the present value of future cash flows, including coupon payments, may decline if interest rates go up and, in this way, impact on investor's total return. On the other hand, within a context of falling interest rates, the present value of future cash flows might be boosted. It is also important to state that interest rate risk might affect not only the product's theoretical value, but how well it performs in relative terms, when compared with other instruments.

Another risk associated to this product is market risk. According to Bank for International Settlements, market risk is described as the risk of losses emerging from movements in market prices. When analysing this product and its features, it's clear that it's subject to market risk. Undoubtedly, market swings and downturns leading to poor performances of the underlying can result in zero or even negative returns to the investor. As it was already mentioned, the yearly coupon is only payable if the index performs well[11] on each observation date. Otherwise, the coupon payments might not be paid at all and there is even the possibility of losing some part of the invested capital.

FIGURE 1: PERFORMANCE SCENARIOS CALCULTED BY THE ISSUER[12]



[11] If the underlying, the index, verifies a positive performance since inception, on each expected observation date.

[12] These are calculation that indicate some possible returns based on recent returns, assuming an initial investment of 10 000€ and already accounting for all costs of the product. Nonetheless, market developments cannot be accurately predicted.

Source: Own elaboration based on the product's KID. (I – stress scenario; II – unfavourable scenario; III – moderate scenario; IV – favourable scenario)

5.2 Issuer's Risks

In this section, I explore the various risks that the issuer of the structured product faces. While the goal of designing these financial instruments is to maximize investor's demand, the issuer is inevitably confronted with a variety of possible difficulties. The financial stability and operational sustainability of the issuer may be considerably impacted by several risks, including legislative changes, reputational issues, market fluctuations, and liquidity pressures. Stakeholders can more accurately evaluate the issuer's capacity to fulfil its responsibilities and maintain its market position in a changing financial environment by being aware of these risks. Ruf (2011) argues that issuers have great power when setting the price of their securities and this is because, investors do not perceive correctly not only the risks of the products, but the issuer's risks that can affect its ability to meet the product's obligation with investors.

When analysing the product in the issuer's point of view, several risks are easily identifiable[13]. In first place, the issuing institution is subject to reputational risk. For instance, if the underlying performs poorly, the investors might get null or even negative returns, leading to a bad impact in the investor's perception and confidence regarding the issuing institution and, possibly, leading to poorer future structured products issuances. Other risk that must be understood and, in fact, can be materialized is the hedging risk. In order to protect against potential negative market fluctuations, the issuer may adopt certain hedging strategies. If these strategies are not effective, due to either wrong strategy designing or unexpected volatility in the underlying, the issuer might face losses that can affect the rentability of this product. Finally, another risk that was identified when analysing this structured product was the regulatory risk. The issuer is exposed to changes in financial regulation, concretely, in the United Kingdom since this instrument is governed by the English law. These changes can impose additional costs, modify the product's conditions, or even cease the product life earlier than its maturity and, thus, leading to an adverse financial impact.

[13] In appendix, there's a table describing all risks associated to the structured product, in the issuer's perspective.

Evidently, there are other risks for the issuing institution which are properly analysed in the appendix.

6. Advantages and Disadvantages

6.1 Advantages

Opting for this structured product offers several advantages, including diversification, as it provides exposure to the EURO STOXX Select Dividend 30 Price EUR Index® without the need to individually acquire each constituent. The fixed annual coupon of 2.10% ensures a predictable income stream, contingent on the index's positive performance on each Observation Date. Additionally, investors benefit from a level of principal protection, receiving 95% of their invested notional at maturity, even if the index underperforms. If the index has a positive performance in the future, the product's memory feature allows for the recovery of unpaid coupons, enhancing potential returns. This structured product offers a transparent risk-reward profile, with clearly defined and predetermined return parameters.

6.2 Disadvantages

However, there are significant drawbacks to investing in this structured product. It offers limited upside potential, as returns are capped, meaning investors may miss out on higher gains if the index performs exceptionally well. Additionally, there is a risk of zero or even negative remuneration, as the absence of positive index performance on Observation Dates can lead to no coupon payments, reducing overall returns. Investors are also exposed to credit risk tied to the issuer, Haitong Investment Ireland plc, which raises the possibility of partial or total loss in the event of default or bankruptcy. The structured product's fixed terms and conditions limit flexibility, restricting the ability to adjust the investment strategy in response to changing market conditions. Furthermore, the complexity of certain features, such as the memory mechanism and specific conditions for coupon payments, may complicate the understanding and decision-making for some investors that have less expertise. Finally, other disadvantage that investors must be aware of is that the structured product is less liquid than the underlying itself, this is, the EURO STOXX Select Dividend 30 Index.

6.3 Comparison to investing directly in the underlying.

In summary, the distinct characteristics of investing in the structured product become evident when compared to a direct investment in the underlying asset. While direct investment carries greater market risk, it offers full market exposure and the potential to capture the entire range of returns. In contrast, the structured product provides capped returns. One advantage of the structured product is that it delivers capital protection to the investors (up to 95%), whereas direct investment in the underlying does not provide that protection, at least directly. Direct investments also offer greater flexibility, allowing for customization based on individual preferences and risk tolerance. Additionally, direct investment in underlying assets tends to provide higher liquidity, with the ability to buy and sell individual securities more easily. Structured products, particularly those with complex features, often face limitations in liquidity.

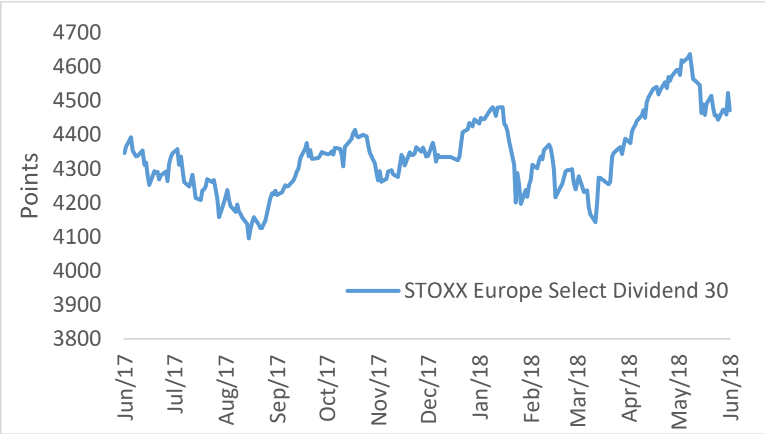
TABLE 3: UNDERLYING TOP 10 COMPOSITION[14]

Company	Supersector	Country	Weight (%)
EDP Energias de Portugal	Utilities	PT	5.58
Intesa San Paolo	Banks	IT	4.79
Fortum	Utilities	FI	4.13
Aegon	Insurance	NL	3.98
Daimler	Automobiles & Parts	DE	3.94
Assicurazioni Generali	Insurance	IT	3.93
Unibail-Rodamco	Real Estate	FR	3.86
Klepierre	Real Estate	FR	3.83
Proximus	Telecommunications	BE	3.82
Total	Oil & Gas	FR	3.8

Source: EURO STOXX Select Dividend 30 - March 2018 factsheet

[14] As of 29/03/2018

FIGURE 2: UNDERLYING CLOSING PRICE HISTORY



Source: https://www.investing.com/indices/stoxx-europe-select-dividend-30-historical-data

7. DATA

7.1 Risk-Free Rate

The Risk-Free Rate (Rf) is a theoretical concept that represents the rate of return that, allegedly, zero-risk instruments should yield. In this way, it is a threshold for the minimum return required on assets with risk and, furthermore, it is widely used in valuation models.

Assuming that a risk-free instrument is the one that whose return at maturity date we surely know, implies that there's no default risk nor reinvestment risk. The chosen approach to obtain this rate, according to what was previously mentioned, was to use the German sovereign yields, as Germany was at the product's inception date the triple A rated economy with the lowest yields in the eurozone.

This information was obtained via *MarketWatch.*

7.2 Dividend Yield

The Dividend Yield (Dy) is a financial ratio that helps investors to perceive the income generated by its investment via dividends. This ratio will be used in our calculation as it is incorporated in the chosen methodologies to value the product.

The value for Dy to incorporate in the calculations is the average of the daily underlying's dividend yield in the 365 before the product's inception date.

This value was computed via *Refinitiv Eikon*.

7.3 Volatility

Volatility is widely known concept in finance, and it is used as measure of an asset risk. Typically, the higher the volatility, the riskier the asset. This concept is very important for option pricing and there are many ways to calculate it.

In our calculations, the choice was to use implied volatility instead of historical volatility. While this last only measures price changes over past time periods and, thus, observes past trends using historical prices, implied volatility measures how volatile the market as it reflects market expectations about the future volatility of the underlying asset.

In fact, this is the reason behind the decision of using implied volatility, this is, it is calculated from current option prices and reflects the market' perception of future volatility, which can be far more relevant than just looking at historical volatility.

This value was computed via Bloomberg.

7.4 Cost of Funding

In order to properly discount the cash-flows of the structured product to obtain its present value, the cost of funding needed.

Cost of funding refers to the overall expense incurred by a company to obtain financial resources. This includes interest payments on debt, such as loans and bonds, as well as the cost associated with equity financing, if applicable. It reflects the company's effective rate for securing capital to support its operations and growth.

There are several ways to obtain cost of funding. The chosen approach was the one used in Aymanns et all (2016). According to these authors, the ratio of total interest expense to total liabilities can be used as measure of the funding cost. Nonetheless, the same authors give examples of other ways to calculate the funding cost, including, credit institutions.

This value was computed by calculating the mentioned ratio using the data available in the most updated financial statements of the issuing institution before the product inception date.

TABLE 4: ISSUER'S COST OF FUNDING

	31/12/2017	31/12/2016	Δ
Interest expense and similar charges	33 754 031.00 €	45 322 598.00 €	-25.52%
Total Liabilities	1 214 869 567.00 €	1 366 159 887.00 €	-11.07%
Cost of Funding	2.78%	3.32%	-0.54 pp

Source: Haitong Investment Ireland Plc 2017 annual report

Please note that despite Haitong Investment Ireland Plc being a subsidiary firm, as it is has own legal personality and activity, when calculating the cost of funding we do not take into account any influence of Haitong Bank, S.A..

8. METHODOLOGY

In this section, all the used valuation methods will be explained, firstly, in a theoretical way and then, how they were implemented for this product. The methods incorporated in this project are Monte Carlo Simulation, Binomial Tree model and Black-Scholes model.

The integration of these methodologies provides a comprehensive set of techniques for accurately pricing complex financial derivatives.

All these methods are applied with the purpose of valuing the performance component, this is, the five binary calls that replicate the potential cash-flows of the product. If we manage to value the performance component, it is straightforward to get the product theoretical value, since the capital component it's just a zero-coupon bond maturing in the product's last observation date.

Mathematically, this means:

$$Structured\ Product = ZCB + \sum_{i=1}^{5} \text{Binary Call}_i \tag{1}$$

Thus, the structured product value is the sum of the capital component, composed by the zero-coupon bond, with the performance component, which is formed by a portfolio of 5 binary calls that perfectly replicate the structured product potential payoffs.

8.1 Monte Carlo Simulation

Monte Carlo simulation is a computational technique used to model and analyse complex systems or processes using random sampling. In fact, Boyle (1977) developed a Monte Carlo simulation approach to option valuation, providing an early and influential exploration of this technique in financial modelling.

Nowadays, this approach is widely known and has several applications specially in finance. For instance, Monte Carlo simulation can be used in corporate finance, portfolio management, and as it is used in this dissertation, in options pricing. When using it, there’s an assumption that that the probability of varying outcomes cannot be determined because of random variable interference. Thus, a Monte Carlo simulation relies on repeatedly generating random samples to obtain specific results.

The first step is to define the parameters. The strike price is the closing quotation observed in the initial observation date, which is the same value as the current price, this is the value from which we simulate. Both volatility and risk-free interest rate were already explained. Time to maturity corresponds to the product life which is 4,5 years. Last but not least, the number of simulations will be 10 000. This number is an equilibrium between computational power and accuracy.

In second place, it is needed to generate random underlying prices. This was done by using the Geometric Brownian Motion (GBM) model, which is very popular in finance for price dynamics simulation. According to this model, stock prices follow:

$$dS_t = \mu S_t \, dt + \sigma S_t \, dW_t \quad (2)$$

where dS_t is the change in the stock price, μ is the drift rate, σ is the volatility and dW_t is the increment of a Wiener process[15].

The solution to the equation (2) is an expression for the instrument price at any future time. The solution is:

$$S_T = S_0 \cdot e^{\left(r - \frac{\sigma^2}{2}\right)T + \sigma\sqrt{T}Z} \quad (3)$$

[15] The increment of a Wiener process (or Brownian motion) represents the random change in a stochastic process over an infinitesimal time interval. In sum, it captures the inherent randomness in the evolution of asset prices.

where $\mathrm{S_t}$ is the underlying price at time t, $\mathrm{S_0}$ is the initial underlying price, r is the risk-free interest rate, σ is the volatility of the underlying, T is time to maturity, and Z is is a standard normal random variable (mean = 0, variance = 1).

However, the formula is missing a key component that, indeed, has impact and influence in the underlying price: dividends. The formula adjusted for the lack of dividends consideration is:

$$\mathrm{S_T} = \mathrm{S_0} \cdot \mathrm{e}^{\left(\mathrm{r}-\mathrm{q}-\frac{\sigma^2}{2}\right)\mathrm{T}+\sigma\sqrt{\mathrm{T}}\mathrm{Z}} \tag{4}$$

where q is the underlying dividend yield.

In third place, it was necessary to simulate the underlying price path over the period corresponding to the product's maturity. As already mentioned, 10 000 simulations were done. This was done using Microsoft Excel. Once we got all those simulations, the following step was to calculate the payoff of binary call, according to their maturity, following this formula:

$$\text{Payoff} = \text{coupon} + \text{unpaid coupons if } S_T > K \text{ and 0 if } S_T \leq K \tag{5}$$

For each binary call at its maturity, 10 000 potential payoffs were calculated. Finally, to calculate the theoretical value for each one of them, we average all the simulations for the payoffs of each binary, and by discounting that average payoff for each one of them, the value for each binary call option. Note that the discount rate is the cost of funding of the issuer.

In this section, I described how Monte Carlo simulation for calculating the value of the performance component of the structured product was used. This component is the more difficult to calculate since the capital component calculation is very simple. The sum of both components is the theoretical value of the product, as stated in the equation (5) above.

8.2 Binomial Tree Model

The Binomial Tree Model is other very important and known model for options valuation. This approach models the future movements of an underlying's price over discrete time intervals. The model assumes that a price has two possible directions at each time point: either it goes up or down. Therefore, the result of the model is a distribution of possible paths for the underlying price, that allows the user to calculate the expected payoffs for the options. This model was a proposal made by William Sharpe in 1978 and formalized by Cox, Ross and Rubinstein in the following year, 1979.

One assumption of this model is that stock price movement follows random walk, this is, changes in prices are not explained by historical prices, trends nor patterns. Random walk meets the efficient market hypothesis and, therefore, price changes are completely unpredictable.

The process of determining binary call options through a binomial tree requires a systematic method to simulate the possible price changes of the underlying asset, in this case, an index. As already explained binary call options pay a set amount when the asset price is higher than a specific strike price at the end, if not, they payout nothing. Moreover, when it comes to these binary options, it is important to take into account that they have a memory feature, otherwise the value of the product would be wrong.

When incorporating this model, the first step is to define the timestep (Δt) used in the tree. It is an important parameter as it has impact in terms of the model accuracy and its computational complexity. In the same way, Cox et al. (1979), state that the bigger the number of timesteps, the closer the binomial tree gets relatively to the Black-Scholes formula. In this dissertation, the timestep is 1 month.

Having this first and important parameter, the second step should be calculating the up (u) and down (d) factors. These factors represent the potential changes in the price of the underlying at each timestep. They are calculated in the following way:

$$u = e^{\sigma\sqrt{\Delta t}} \quad (6)$$

$$d = \frac{1}{u} = e^{-\sigma\sqrt{\Delta t}} \quad (7)$$

where σ is the volatility of the underlying asset.

Then, as under this model there's an assumption that we live under risk neutrality, meaning that investors are indifferent to risk and thus simplifying the pricing of financial derivatives, an estimation of risk-neutral probabilities is needed for those up and down factors. The probability of an upward movement (p) and a downward movement ($1 - p$) are calculated according to the following equations:

$$p = \frac{e^{r\Delta t} - d}{u - d} \tag{8}$$

After having all these parameters properly defined, the binomial tree must be generated. Firstly, the price path of the underlying must be constructed. The price of the underlying in the node (i, j) is given by:

$$S_{i,j} = S_0 \cdot u^j \cdot d^{i-j} \tag{9}$$

where i is represents the timestep in the binomial tree, whereas j is the number of upward movements that have occurred at certain timestep i.

The next step is to calculate the option payoffs at their maturity. These payoffs can be obtained via equation (5). Once all payoffs are calculated, the last step regarding this model is to discount those values from each binary call maturity to the present, using the proper discount rate. Therefore, the model, in this last part, operates in a backward induction logic, which is operationalized via the following equation:

$$C_{i,j} = e^{-r\Delta t} \cdot \left(p \cdot C_{i+1,j} + (1 - p) \cdot C_{i+1,j+1}\right) \tag{10}$$

This equation is used until the root and first node is reached. At that node ($C_{0,0}$), the model should give the theoretical value of each binary call option. This model was implemented in Microsoft Excel.

In this section, I described how Binomial Tree model for calculating the value of the performance component of the structured product was used. This component is the more difficult to calculate since the capital component calculation is very simple. The sum of both components is the theoretical value of the product.

8.3 Black-Scholes model

Black and Scholes (1973) created a theoretical valuation formula for options, under the principle that if options are properly priced in the market, it is not possible to make profits by creating portfolios in options and their underlying assets. It assumes markets are efficient and there is no arbitrage, meaning no risk-free profit opportunities. The model is widely used in financial markets for pricing options and managing risk.

The original model developed by the mentioned authors aimed to estimate the price of European options, taking into account several variables such as the price of the underlying, its volatility, eventual dividends, among others. Mathematically:

$$C = S_0 N(d_1) - Ke^{-rT} N(d_2) \quad (11)$$

$$\mathrm{P} = \mathrm{Ke}^{-\mathrm{rT}}\mathrm{N}(-\mathrm{d}_2) - \mathrm{S}_0\mathrm{N}(-\mathrm{d}_1) \quad (12)$$

where C is the estimated price for the call option, while P is the estimated price for the put option. Moreover, d_1 and d_2 are given by:

$$d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \quad (13)$$

$$\mathrm{d}_2 = \mathrm{d}_1 - \sigma\sqrt{\mathrm{T}} \quad (14)$$

However, the decomposition of this structured product assigns the performance component to a portfolio of five binary call options. These are exotic options, therefore are not similar to vanilla options. In this way, the formulas previously mentioned do not properly price those instruments. Despite of that fact, it is possible to use Black-Scholes model if we derive the original formula to consider the characteristics of binary call options.

A binary call option pays a predefined and fixed amount if the underlying price (S_T) is above the strike price (K) at maturity (T). This is, the binary call option price is the present value of the expected payment at its maturity. Under the Black-Scholes model, a probability of S_T being higher than K at maturity is given by $\mathrm{N}(\mathrm{d}_2)$ which is the cumulative normal distribution function at d_2.

Therefore, the price of a binary call option under a derivation of Black-Scholes is given by:

$$\text{Price}_{\text{binary call}} = Pe^{-rT} N(d_2) \quad (15)$$

However, there's a problem. The performance component of this structured product is a portfolio composed by five binary call options with memory feature. This last part is the real problem. Black-Scholes does not work directly for options with those characteristics, since it was projected for traditional options, like Europeans which only depend on the underlying price at maturity, whereas options with memory feature incorporated depend on the path of the underlying throughout the life of the option. In this way, I was not able to calculate the price of the structured product using the Black-Scholes formula.

Nonetheless, I calculated assuming there was no memory feature. Those calculations were done using Microsoft Excel.

9. Results

In this section, I describe the results obtained with the use of the several previously mentioned models, aiming to obtain a theoretical price for the structured product.

The product is decomposed in two different components, a capital component, and a performance component. Both parts are subject to valuation. Furthermore, the capital component assumes the same value independently of the chosen model.

As already mentioned, the capital component of this structured product ensures that the investors get the 95% of its invested capital. This is, independently of the underlying performance, investors always get back, at least, 95% of its invested capital. In this way, the value of this component is the present value of a zero-coupon bond maturing at 15/12/2022 (product's maturity date) and with the face value of 950€[16]. This value is given by:

$$PV = FV \cdot e^{-rt} \tag{16}$$

where FV is the face value of the zero-coupon bond, r is the issuer's cost of funding and t is the number of years to maturity.

Applying the equation 16 leads to:

TABLE 5: CAPITAL COMPONENT VALUE

	Capital Component
Value	838.29 €

Source: Own elaboration

9.1 Monte Carlo Simulation

The Monte Carlo Simulation was implemented in Microsoft Excel, according to what as described in section 8.1. As already mentioned, I did 10 000 simulations for the path price of the underlying index. In this way, I was able to calculate the average payoff for each one of the binary call options composing the performance component of this structured product. Having the average payoff for each one of these, allowed me to discount and, finally, obtain the theoretical price for the binary call options, that compose the performance component of this structured product.

[16] Capital Protection * Calculation Amount = 95% * 1000€ = 950€

TABLE 6: PARAMETERS FOR MONTE CARLO SIMULATION

Dividend Yield	Volatility	Rf	Cost of Funding	TimeStep	S[0] (points)
3.68%	12%	-0.22%	2.78%	0.0833333	2014.58

Source: Own elaboration

TABLE 7: BINARY CALL OPTIONS THEORETICAL PRICE (MONTE CARLO)

	Binary #1	Binary #2	Binary #3	Binary #4	Binary #5
Average Payoff	21.00 €	20.89 €	21.03 €	21.09 €	60.17 €
Price of Binary Options	20,43 €	19.77 €	19.35 €	18.88 €	53.13 €

Source: Own elaboration

TABLE 8: PRODUCT THEORETICAL PRICE (MONTE CARLO)

Capital Component	838.29 €
Performance Component	131.56 €
Structured Product Value	969.85 €

Source: Own elaboration

9.2 Binomial Tree Model

Once again, the implementation of this model was done with Microsoft Excel. The methodology and theory behind the implementation of this model is available in the section 8.2.

TABLE 9: PARAMETERS FOR BINOMIAL TREE MODEL

	Binary #1	Binary #2	Binary #3	Binary #4	Binary #5
S[0] (points)	2014.58	2014.58	2014.58	2014.58	2014.58
K (points)	2014.58	2014.58	2014.58	2014.58	2014.58
Q	21.00 €	21.00 €	21.00 €	21.00 €	60.50 €
Issue Date	15/06/2018	15/06/2018	15/06/2018	15/06/2018	15/06/2018
Observation Date	10/06/2019	08/06/2020	08/06/2021	08/06/2022	08/12/2022
Implied vol.	12.00%	12.00%	12.00%	12.00%	12.00%
r	-0.66%	-0.63%	-0.54%	-0.40%	-0.22%
T	0.99	1.98	2.98	3.98	4.48
n	12	24	36	48	60
Div Yield	3.68%	3.68%	3.68%	3.68%	3.68%
dt	0.08	0.08	0.08	0.08	0.07
u	1.03	1.04	1.04	1.04	1.03
d	0.97	0.97	0.97	0.97	0.97
p	43.97%	43.99%	44.09%	44.25%	44.75%
1-p	56.03%	56.01%	55.91%	55.75%	55.25%

Source: Own elaboration

TABLE 10: BINARY CALL OPTION THEORETICAL PRICE (BINOMIAL)

	Binary #1	**Binary #2**	**Binary #3**	**Binary #4**	**Binary #5**
Price	4.85 €	8.40 €	10.90 €	12.84 €	22.21 €

Source: Own elaboration

TABLE 11: PRODUCT THEORETICAL PRICE (BINOMIAL)

Capital Component	838.29 €
Performance Component	59.20 €
Structured Product Value	897.49 €

Source: Own elaboration

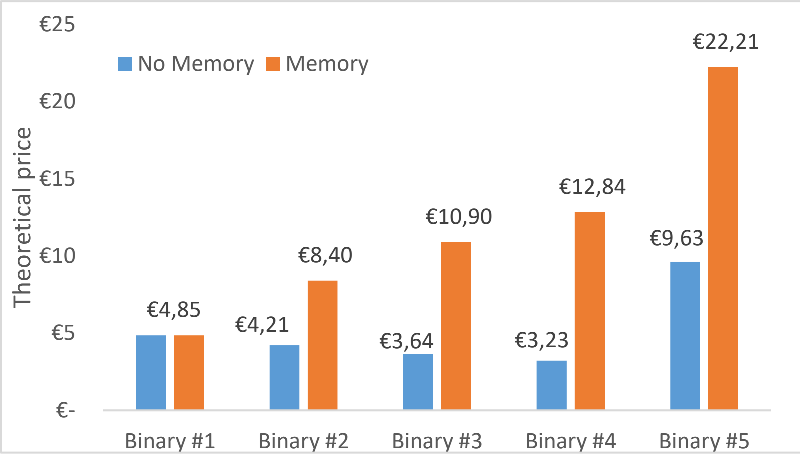
10. MEMORY FEATURE VALUE

This structured product has a memory feature incorporated, as it was explained. This feature is relatively common in structured products and increases complexity in interpreting properly this type of products, which is essential for correctly valuate a product. However, this feature enhances the attractiveness of structured products. In fact, the memory feature allows the product to “remember” the past performance of the underlying. This is, all unpaid coupons can be recovered by the investor, if a certain condition is met. Obviously, this feature is a benefit for investors since it might increase returns and provides additional protection.

Nonetheless, there’s no such thing as a free lunch. Evidently, this benefit comes to the investor at a certain cost. In this section, I try to assess the value of this memory feature and how it impacts the theoretical price of the product. Naturally, this feature makes the product more expensive, as it increases associated potential returns. My approach to value the product was to valuate again the product, using the same two methodologies, but now assuming that there is no memory feature incorporated. The difference between the theoretical price with and without the feature is the value for the memory feature. At least, indicates what is the impact in the value of the product. Still, it is expected that it increases the price, as it was already mentioned.

Having the calculations for the theoretical price of the structured product, assuming there’s memory feature, facilitates the process now. Actually, to calculate assuming there’s no memory feature, I just had to eliminate the part of the formulas in Excel that replicated this feature.

FIGURE 3: MEMORY FEATURE VALUE – BINOMIAL TREE



Source: Own elaboration

TABLE 12: MEMORY FEATURE VALUE – BINOMIAL TREE

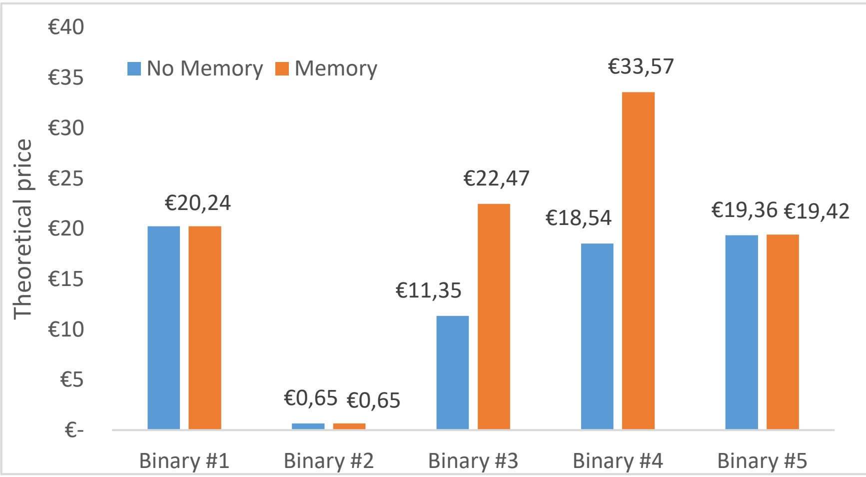
	No Memory	Memory
Capital Component	838.29 €	838.29 €
Performance Component	25.55 €	59.20 €
Structured Product Value	863.84 €	897.49 €

Source: Own elaboration

Firstly, I computed the value of the memory feature with the binomial tree model. As it might be seen in Figure 3 and Table 12, the memory feature turns the product more expensive. The capital component does not change, as it was not impacted by the memory feature. The changes happen at the performance component. That component is composed by the portfolio with five binary call options and all of them are cheaper without memory feature, except the binary option maturing on the first observation date, as like the capital component, it has not the memory feature. In sum, according to this model, the memory feature implies a difference of more 33,65 euros in the theoretical price of the product.

In the same way, I computed the memory feature value, again, but this time according to the Monte Carlo model. Nonetheless, the conclusions are similar, to not say the same. As it is seen in Figure 4 and Table 13, the memory feature points the product to higher prices, the same behavior detected when using the binomial model. Again, there are no changes regarding the capital component. The performance component is the one impacted since the memory feature is incorporated in the binary call options. Please note that, I computed other value for the product under the assumption of memory feature incorporation, since the one that I previously calculated was very extreme and unlikely, since almost all coupons were paid for the 10 000 simulations. Consequently, the memory feature hadn't to be used and, therefore, the price of the product with and without the memory feature. In this way, I ran again the 10 000 simulations, and I got a more reasonable price for the structured product, given that now the simulations are less extreme. Having this new calculation, and comparing to the one without memory feature, apparently, according to this model, the feature implies a difference of more 26,21 euros.

FIGURE 4: MEMORY FEATURE VALUE – MONTE CARLO



Source: Own elaboration

TABLE 12: MEMORY FEATURE VALUE – MONTE CARLO

	No Memory	Memory
Capital Component	838.29 €	838.29 €
Performance Component	70.14 €	96.35 €
Structured Product Value	908.43 €	934.64 €

Source: Own elaboration

In conclusion, as it expected, the incorporation of a memory feature, that under certain condition allows the investor to receive unpaid coupons, impacts the price of the product with an increase regarding its value. Theoretically, this is expected given that the incorporation of the structured product leads to this instrument having higher expected payoffs, less risk for the investor and, finally, additional flexibility. As all these attributes are important for rational investors, it is reasonable to expect this behavior regarding the memory feature and a structured product.

11. Does Binomial Tree approximates to Black-Scholes model?

As already mentioned, Cox et al (1979), showed that as the time steps increase in the Binomial Tree Model, it tends to converge to the Black-Scholes pricing formula. In this section, my intention is to prove this using the example of the chosen structured product for this dissertation.

Both models are built on different assumptions. Binomial Tree is a discrete model and simulates the price of the underlying over several time steps. For each step, the price can either move up or down, under a certain factor. In other hand, the Black-Scholes Model is continuous and assumes that the price follows a Geometric Browian Motion, where the price evolves continuously over time.

In the Binomial Tree, the time to maturity is divided into steps, the already mentioned, time steps. For a fixed time to maturity, as we increase the number of steps, the dimension of each one becomes smaller. In the limit, the dimension of each steps gets infinitesimally small, as the number of steps go to infinity and so the model converges to the continuous-time Black-Scholes model by simulating the random walk behavior of the Geometric Brownian Motion.

My approach to prove this, was to select the binary call option with the shortest time to maturity and calculating its theoretical price following the Binomial Tree Model several times, but for each repetition increasing the number of time steps. Then, I calculated the theoretical price for the exact same option using the Black-Scholes formula.

Table 13: Parameters and Option Price – Black Scholes

S(0)	2014.58	**Coupon rate**	2.10%	**N(d1)**	0.38
K	2014.58	**Coupon**	21	**d2**	-0.42
Implied Volatility	12.00%	**T**	0.99	**N(d2)**	0.34
R	-0.66%	**Dividend Yield**	3.68%	**Price**	6.90 €
Notional Principal	1000	**d1**	-0.30		

Source: Own elaboration

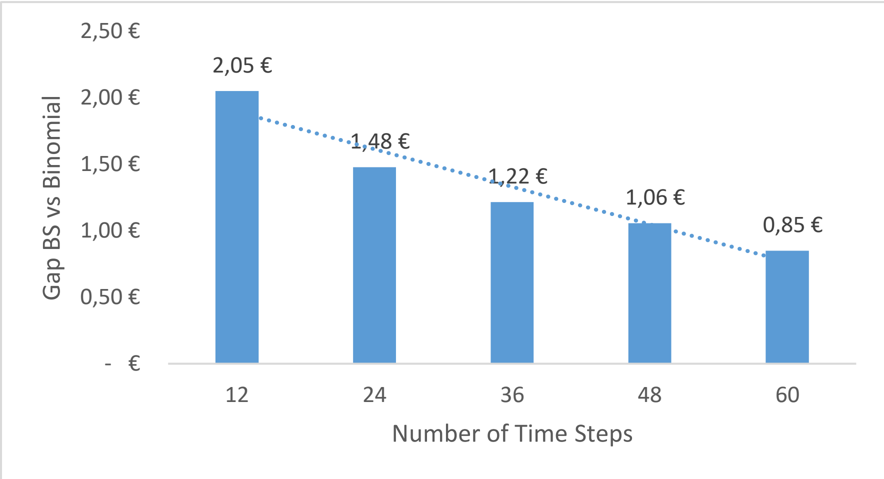
As stated above, the obtained price for the option under the Black-Scholes was 7,14 euros. Below, I show the theoretical price for the same option, but with increasing number of time steps.

TABLE 14: OPTION PRICE WITH INCREASING TIME STEPS – BINOMIAL TREE

n	12	24	36	48	60
Price	4.85 €	5.42 €	5.68 €	5.84 €	6.05 €

Source: Own elaboration

FIGURE 5: BINOMIAL TREE CONVERGING TO BLACK-SCHOLES



Source: Own elaboration

Thus, using this structured product, we confirmed that the bigger the number of time steps, the closer the Binomial Tree gets to the Black-Scholes formula. If I had increased even more the number of time steps, eventually, the difference would be null.

Apparently for this example, the binomial model tens to move upwards towards the value of the Black-Scholes model. This means that, initially, the binomial model underestimates the value compared to the Black-Scholes formula, and as the number of steps increases, the value rises and converges. The approximation of the binomial model to the Black-Scholes formula depends on the type of option (call or put) and its structure (European or American). In general, convergence can occur either from the bottom up or from the top down, depending on these factors, as well as, on some characteristics of the underlying asset, such as its volatility or eventual dividends.

Indeed, with the number of steps N increasing, Δt becomes infinitesimally small ($\Delta t \rightarrow 0$) and the binomial models converges to the Black-Scholes. The relationship between both models is seen with $N \rightarrow \infty$.

12. PROFITABILITY

Deng, et al. (2014), state that ex-post returns of structured products, in the US market, are highly correlated with large capitalization equity markets when aggregated, but individually structured products generally underperform simple and alternative investments and bonds.

Benet et al. (2006), point out the significant pricing bias favoring the issuing institution, a fact very discussed and documented in the literature.

In this way, it is very important to properly calculate the return when deciding to invest in a product like this one, which is complex, but issuing institutions also need to properly calculate since the success of the issuance largely depends on that.

12.1 Issuer's profitability

When investors buy one note of a certain product, part of the notional is used to buy a ZCB to guarantee the capital protection and the remaining part is used to fund the performance component of the product. Therefore, in this case, in which performance component is composed by five binary call options, the difference of the price of the performance component and the remaining part of the notional after acquiring the capital component, if positive is the return of the issuing institution, since the price of the product already takes into account all costs regarding the product distribution.

Therefore, it is straight forward to calculate the profitability given that I already calculated the theoretical value of the product following two different methods.

TABLE 15: ISSUER PROFITABILITY

	Monte Carlo	**Binomial**
Capital Component	838.29 €	838.29 €
Performance Component	131.56 €	59.20 €
Structured Product Value	969.85 €	897.49 €
Issuer Profit	30.15 €	102.51 €

Source: Own elaboration

In Table 15, I present the expected profit for the issuer of this product, assuming that my valuation is robust and proper. Yet, this profit is at risk given that it still depends on market conditions and the issuer's capacity to correctly mange or hedge its positions. Nonetheless, the profit is considerably different depending on which method is chosen to perform its calculation. The reason why is explained in the following section.

12.2 Investor's Profitability

The method that I chose to perform the calculation of the profitability of the investor was the Monte-Carlo simulation, since it provides a clear way to assess the potential performance of the structured product in terms of returns, though it's important to also consider the associated risks and model assumptions. Furthermore, I already had previously implemented Monte Carlo to simulate the different scenarios for the coupon payments, therefore, it is not hard to now find the issuer profitability.

My approach was similar to the one used by Mendes (2023). The author calculates the profitability of a certain structured product under the perspective of the investor by calculating the total payoff of each one of the 32 potential coupon payment scenarios and multiplying it by the probability associated to each one of those potential scenarios for coupon payments. Those probabilities were calculated by dividing the number of times each scenario occurred in the run simulations by the total number of simulations, which was 10 000 simulations.

More information about this implementation can be found in the appendix.

After doing my calculations under this approach, I figured out an expected profit of 131,56 euros for the investor.

TABLE 16: COUPON PAYMENT SCENARIOS IN THE SIMULATIONS

	Coupon 1	Coupon 2	Coupon 3	Coupon 4	Coupon 5
Scenario #1	21.00 €	- €	42.00 €	21.00 €	60.50 €
Scenario #2	21.00 €	21.00 €	- €	42.00 €	60.50 €
Scenario #3	21.00 €	21.00 €	21.00 €	21.00 €	- €
Scenario #4	21.00 €	21.00 €	21.00 €	21.00 €	60.50 €

Source: Own elaboration

13. Discussion

The implementation of the different approaches had not led to similar results. Firstly, it was not possible to use the Black-Scholes formula. Despite this being a widely known approach in financial theory to price options, it is not suitable for options path-dependent. In fact, Black-Scholes is designed for options where the payoff depends solely on the terminal asset price. Nonetheless, there are possible derivations of the original formula to price path-dependent options, still they require complex and advanced mathematical technics. Nevertheless, Binomial Tree model and Monte Carlo simulation were successfully implemented for this structured product, yet, with slightly different results, even though both models shared the same parameters. In fact, Monte Carlo simulation led to a valuation considerably higher than the one performed by Binomial model. When using Monte Carlo Simulation, I noticed that for every time I ran the 10 000 simulations, results were considerably different. The quantity of simulations and the random character of the Monte Carlo approach are the main causes of the notable differences between simulations. Even after 10 000 iterations, significant deviations could still occur because of the structured product's complexity and randomness. Increasing the number of simulations is the easiest way to improve the accuracy of the results. However, due to the lack of computational power I was not able to perform a bigger number of simulations. Consequently, the theoretical value that I advocate for this structured product under Monte Carlo, might not be the most appropriate, as in fact represents a very optimistic scenario.

Furthermore, as expected, the incorporation of a memory feature in the product, makes it more expensive, as the feature increases the expected payoff and, thus, gives additional protection to the investor. I also showed the convergence of the Binomial Tree model to the Black-Scholes formula, as the number of time steps increases, as already widely explored in literature.

Finally, it is important to mention that the reported value for the expected profit of the investor is large, since the Monte Carlo simulation led to a very optimistic prediction of the underlying’s path during the product’s life. When considering investing in this product, investors should take into account not only the potential returns, specially, this very optimistic valuation under Monte Carlo simulation, but also the risks associated, as the ones that were identified in this dissertation.

14. Conclusion

In sum, structured products are, indeed, complex instruments with multiple idiosyncrasies that impose difficulties to a comprehensive and a proper analysis.

Nonetheless, I was able to overcome these challenges, understanding and studying deeply this instrument, which has enriched me both as a student and a professional. I truly believe that this dissertation and all the knowledge obtained within its elaboration will be very useful in the future.

In fact, given the characteristics of the product, Black-Scholes model was not successfully implemented. Despite this, Monte Carlo and Binomial Tree model were used to obtain theoretical price, even though the results differ. Besides expected profit, both investors and issuers should consider all the risks involved and perform a risk-analysis as the one I did. The memory feature makes the product more expensive. The product has expected positive return for both investors and issuer. Finally, the convergence between Binomial Tree model to the Black-Scholes formula was successfully demonstrated.

Overall, structured products are a very particular topic in finance, and I hope that my thesis has a positive contribute to the common knowledge about these instruments, its specifications, and methods for their valuation.

Ultimately, I was only able to do this by using all the concepts and experience learnt in my master's in finance, to which I'm grateful for all the knowledge that allowed me to obtain, during the past 2 years in ISEG – Institute of Economics and Management.

15. References

Benet, B. A., Giannetti, A., & Pissaris, S. (2006). Gains from structured product markets: The case of reverse-exchangeable securities (RES). *Journal of Banking & Finance*, *30*(1), 111–132. https://doi.org/10.1016/j.jbankfin.2005.01.008

Black, F., & Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. *The Journal of Political Economy*, *81*(3), 637–654.

Boyle, P. P. (1977). Options: A Monte Carlo approach. *Journal of Financial Economics*, *4*(3), 323–338. https://doi.org/10.1016/0304-405X(77)90005-8

Chen, X., Wang, Z., Deng, S., & Fang, Y. (2019, July 1). *Risk measure optimization: Perceived risk and overconfidence of structured product investors. | EBSCOhost*. https://doi.org/10.3934/jimo.2018105

Cox, J. C., Ross, S. A., & Rubinstein, M. (1979). Option pricing: A simplified approach. *Journal of Financial Economics*, *7*(3), 229–263. https://doi.org/10.1016/0304-405X(79)90015-1

Deng, G., Dulaney, T., Husson, T., McCann, C. J., & Yan, M. (2014). *Ex-Post Structured Product Returns: Index Methodology and Analysis* (SSRN Scholarly Paper No. 2350285). Social Science Research Network. https://doi.org/10.2139/ssrn.2350285

GOOVAERTS, B. (2023). *EXPLORING CORRELATION PATTERNS IN MULTI-CORRELATED STRUCTURED PRODUCTS*. ISEG.

Grünbichler, A., & Wohlwend, H. (2005). The Valuation of Structured Products: Empirical Findings for the Swiss Market. *Financial Markets and Portfolio Management*, *19*(4), 361–380. https://doi.org/10.1007/s11408-005-6457-3

Haitong Bank vende subsidiária irlandesa por 12 milhões. (n.d.). Retrieved 11 October 2024, from https://www.jornaldenegocios.pt/empresas/banca---financas/detalhe/haitong-bank-vende-subsidiaria-irlandesa-por-12-milhoes

Henderson, B. J., & Pearson, N. D. (2011). The dark side of financial innovation: A case study of the pricing of a retail financial product. *Journal of Financial Economics*, *100*(2), 227–247. https://doi.org/10.1016/j.jfineco.2010.12.006

Hens, T., & Rieger, M. O. (2008). The Dark Side of the Moon: Structured Products from the Customers' Perspective. *NCCR FINRISK Working Paper*, *459*, Article 459. https://doi.org/10.5167/uzh-95107

Kunz, A. H., Messner, C., & Wallmeier, M. (2017). Investors' risk perceptions of structured financial products with worst-of payout characteristics. *Journal of Behavioral and Experimental Finance*, *15*, 66–73. https://doi.org/10.1016/j.jbef.2017.07.005

Mendes, P. (2023). *Structured Product Analysis—SG EUR REVOLUÇÃO AUTOMÓVEL 2018-2023*. ISEG.

Ribeiro, B. P. (n.d.). *AUTOCALLABLE STRUCTURED PRODUCTS: EXPLORING THE EUROPEAN EQUITY MARKET*.

Ruf, T. (2011). *The Dynamics of Overpricing in Structured Products* (SSRN Scholarly Paper No. 1787216). Social Science Research Network. https://doi.org/10.2139/ssrn.1787216

Stoimenov, P. A., & Wilkens, S. (2005). Are structured products 'fairly' priced? An analysis of the German market for equity-linked instruments. *Journal of Banking & Finance*, *29*(12), 2971–2993. https://doi.org/10.1016/j.jbankfin.2004.11.001

The performance of individual investors in structured financial products | Review of Quantitative Finance and Accounting. (n.d.). Retrieved 11 October 2024, from https://link.springer.com/article/10.1007/s11156-014-0479-8

Volatility: Meaning in Finance and How It Works With Stocks. (n.d.). Investopedia. Retrieved 11 October 2024, from https://www.investopedia.com/terms/v/volatility.asp

Wallmeier, M. (2011). Beyond payoff diagrams: How to present risk and return characteristics of structured products. *Financial Markets and Portfolio Management*, *25*(3), 313–338. https://doi.org/10.1007/s11408-011-0163-0

Wallmeier, M., & Diethelm, M. (n.d.). *Market Pricing of Exotic Structured Products: The Case of Multi-Asset Barrier Reverse Convertibles in Switzerland*.

16. APPENDIX

16.1 Product Information

TABLE 17: INFORMATION OF THE STRUCTURED PRODUCT

Issuer	Haitong Investment Ireland Plc
Listing	Yes
Currency	EUR
Minimum Investment	1 000 €
Issue Price	100%
Capital Protection	95% at maturity
AER[17]	No
Issue Date	15/06/2018
Maturity Date	15/12/2022
IOD[18]	15/06/2018
FOD[19]	08/12/2022
Redemption	95 per cent of Calculation Amount if index verifies a negative performance since inception; otherwise, 100%
ODs[20]	(1) 10/06/2019; (2) 08/06/2020; (3) 08/06/2021; (4) 08/06/2022; and Final Observation Date.
PDs[21]	(1) 17/06/2019; (2) 15/06/2020; (3) 15/06/2021; (4) 15/06/2022; and Maturity Date.

Source: Own elaboration based on product's KID

TABLE 18: UNDERLYING OF THE STRUCTURED PRODUCT

Reference Underlying	Bloomberg Ticker	ISIN[22]
Euro Stoxx Select Dividend 30 Index®	SD3E	CH0020751589

Source: Own elaboration based on the product's KID

[17] Automatic Early Redemption (AER)
[18] Initial Observation Date (IOD)
[19] Final Observation Date (FOD)
[20] Observation Dates (ODs)
[21] Payment Dates (PDs)
[22] Identification Code

The price return determined by the percentage difference between the Underlying Closing Value on the applicable Observation Date and its Initial Value represents the Underlying Performance.

The closing value of the Reference Underlying as observed on the Initial Observation Date is its Initial Value.

The closing level of the Reference Underlying as observed on the pertinent Observation Date is known as the Underlying Closing Value.

The Final Value of the Reference Underlying is the closing level of the Reference Underlying observed on the relevant Final Observation Date.

Extraordinary events may lead to changes to the product's terms or the early termination of the product and could result in losses in the investment.

TABLE 19: COUPONS OF THE PRODUCT

Coupon #1	If index verifies a positive performance since inception: (2.10% + previously unpaid coupons); otherwise, 0%
Coupon #2	If index verifies a positive performance since inception: (2.10% + previously unpaid coupons); otherwise, 0%
Coupon #3	If index verifies a positive performance since inception: (2.10% + previously unpaid coupons); otherwise, 0%
Coupon #4	If index verifies a positive performance since inception: (2.10% + previously unpaid coupons); otherwise, 0%
Coupon #5	If index verifies a positive performance since inception: (1.05% + previously unpaid coupons); otherwise, 0%

Source: Own elaboration

16.2 Risk for the Investor

TABLE 20: RISKS FOR THE INVESTOR

Credit Risk	As mentioned in the KID, in the case of bankruptcy or default by the issuing institution, the investor is exposed to a potential loss of total capital invested, or at least part of that, as the product is not covered by any compensation scheme.
Market Risk	The product has its performance linked to an underlying, an index. In the case that index performs poorly, for instance, since the issuance date the index plunges, the investor is not able to cash-in coupons and at maturity may loss part of the capital invested.
Inflation Risk	Over the life of the product, inflation might negatively impact the real return of the product as the purchasing power of the investor, although the product has capital protection, inflation is still a concern. Spikes in inflation rate would have high impact on the real return for the investor.
Complexity Risk	Structured Products, in general, are instruments very complex and hard to understand for the average investor. This product is no exception, and, in fact, investors should check if they fulfill the recommended conditions to invest in this product, or at least, look for professional guidance. Indeed, a wrong comprehension of the product can cause negative and harmful outcomes for the investor.
Liquidity Risk	Although there's a secondary market for this product, investors are recommended to hold this product during all life of the product. In fact, secondary market is subject to influence of several conditions and investors if facing lack of liquidity and want to sell the product in the secondary market, will face those conditions that may be negatively affecting the product's price leading to financial losses.
Interest Rate Risk	Interest rates play a key role in the performance of financial assets. Indeed, changes in the interest rates have impact in the product. During a context of increasing interest rates, firstly the underlying index probably will be under pressure as higher interest rates are associated to negative impacts in the economic activity and then, the actual product's valuation decreases.

Source: Own elaboration

16.3 Risks for the issuer

TABLE 21: RISKS FOR THE ISSUER

Reputational Risk	The reputation of the issuing institution may be damaged if the issuance does not succeed. In the case that conditions are not properly communicated or misunderstood by clients or if the product has negative performances, the reputation of the issuer can be damaged leading surely to negative impacts on its future business, specially, in future issuances of this type of instruments.
Liquidity Risk	The issuing institution has the role to organize a secondary market for the product. Although the issuer has the right of, under certain conditions, cease the secondary market operation, under adverse market conditions providing liquidity might be a challenge with financial impact, if the issuer does not want to close the secondary market. In the issuer prefers to close the secondary market, this decision can impact its reputation.
Market Risk	As the investor is exposed to market conditions, so is the issuer, as the underlying is the same. In fact, adverse market conditions can hamper returns and increase cost of hedging.
Interest Rate Risk	A context of increasing interest rates, has the potential to lead to increasing in costs associated to hedging or reduce the demand for the product.
Operational Risk	These products are not only complex for investors. The operation of issuing and then managing the structured product is hard task for the issuer as it is subject to mispricing, errors in the hedging strategy, administrative mistakes in payments regarding coupons and many other potential events that can cause problems for the institution.
Regulatory Risk	This product, as a common financial asset, is subject to regulation. If the issuance of the product and its characteristics do not meet the regulation in place, the issuer institution may have legal problems due to its lack of compliance.

Source: Own elaboration

16.4 More on the profitability for the investor

TABLE 22: COUPON PAYMENT POSSIBILITIES AND PROBABILITIES

Possibility	Binary #1	Binary #2	Binary #3	Binary #4	Binary #5	Frequency	Probability
1	0	0	0	0	0	0	0.00%
2	0	0	0	0	1	0	0.00%
3	0	0	0	1	0	0	0.00%
4	0	0	0	1	1	0	0.00%
5	0	0	1	0	0	0	0.00%
6	0	0	1	0	1	0	0.00%
7	0	0	1	1	0	0	0.00%
8	0	0	1	1	1	0	0.00%
9	0	1	0	0	0	0	0.00%
10	0	1	0	0	1	0	0.00%
11	0	1	0	1	0	0	0.00%
12	0	1	0	1	1	0	0.00%
13	0	1	1	0	0	0	0.00%
14	0	1	1	0	1	0	0.00%
15	0	1	1	1	0	0	0.00%
16	0	1	1	1	1	0	0.00%
17	1	0	0	0	0	0	0.00%
18	1	0	0	0	1	0	0.00%
19	1	0	0	1	0	0	0.00%
20	1	0	0	1	1	0	0.00%
21	1	0	1	0	0	0	0.00%
22	1	0	1	0	1	0	0.00%
23	1	0	1	1	0	0	0.00%
24	1	0	1	1	1	53	0.53%
25	1	1	0	0	0	0	0.00%
26	1	1	0	0	1	0	0.00%
27	1	1	0	1	0	0	0.00%
28	1	1	0	1	1	41	0.41%
29	1	1	1	0	0	0	0.00%
30	1	1	1	0	1	0	0.00%
31	1	1	1	1	0	54	0.54%
32	1	1	1	1	1	9852	98.52%

Source: Own elaboration

TABLE 23: PRESENT VALUE COUPON POSSIBILITIES

	Coupon #1	Coupon #2	Coupon #3	Coupon #4	Coupon #5
Possibility #1	20.43 €	- €	38.66 €	18.80 €	53.41 €
Possibility #2	20.43 €	19.88 €	- €	37.60 €	53.41 €
Possibility #3	20.43 €	19.88 €	19.33 €	18.80 €	- €
Possibility #4	20.43 €	19.88 €	19.33 €	18.80 €	53.41 €

Source: Own elaboration

TABLE 24: VALUE OF COUPON POSSIBILITIES

Value	Probability
131.30 €	0.53%
131.32 €	0.41%
78.44 €	0.54%
131.85 €	98.52%

Source: Own elaboration