Lisbon School of Economics & Management
Universidade de Lisboa

MASTER OF SCIENCE

FINANCE

MASTER'S FINAL WORK

PROJECT

Structured Product Analysis - Cirdan Phoenix

Autocallable Worst of Certificates

Diogo Figueira

OCTOBER - 2024

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By Diogo Figueira

SUPERVISION

Professor Gil Nogueira, Ph.D.

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Abstract

This project was developed with the objective of analyzing the "Cirdan Phoenix Autocallable Worst of Certificate" product issued by Cirdan Capital Management, based on the knowledge acquired from the curricular courses from my master's in finance, particularly Financial Engineering.

This report can be divided in 5 chapters: Literature Review, Description of the Product (General description of features, Product Decomposition and Payout and Risks), Valuation Methods (including origins of inputs and models used to price the product), Product Valuation and Correlation Study.

In this report, it's possible to observe a qualitative approach to the project where there is an in-depth explanation of the product features and its implications in the price of the product regarding changes in the market conditions. I also review the possibility of decomposing this product in simpler derivatives products and its limitations in this case. In this section, you can also observe the risk associated with this product as well as the official risk classification made available by the issuer.

After this part, the report focuses on the inputs used, the models used and the reasons to not use certain models and the methodology of pricing of this product. After this, it was made a comparison based on what the investor paid for the product and what he/she can expect from it, with multiple statistics (i.e. probability of autocall) to interpret and predict what might happen. In the last part, this report specialized in the product's sensitivity to different correlations of the assets within the basket, whilst also changing some of the product's characteristics.

Keywords: Structured Product; Autocallable Product; Memory Coupon; Worst-off basket; Monte Carlo Simulation; Sensitivity Analysis; Correlation.

JEL Codes: G12; G17

Resumo

Este projeto foi desenvolvido com o objetivo de analisar o produto "Cirdan Phoenix Autocallable Worst of Certificate" emitido pela Cirdan Capital Management, baseando-se nos conhecimentos adquiridos nas unidades curriculares do meu mestrado em finanças, nomeadamente Engenharia Financeira.

Este relatório pode ser dividido em 5 capítulos: Revisão da Literatura, Descrição do Produto (Descrição geral das características, Decomposição e Pagamento do Produto e Riscos), Métodos de Avaliação (incluindo a originação dos *inputs* e os modelos utilizados para avaliar quantitativamente o produto) e, finalmente, um estudo do efeito da correlação no produto.

Neste relatório é possível observar uma abordagem qualitativa do projeto onde existe uma explicação aprofundada das características do produto e das suas implicações no preço do mesmo em relação a alterações das condições de mercado. Também é revisto a possibilidade de decomposição deste produto em produtos derivados mais simples e as suas limitações neste caso. Nesta secção poderá ainda observar os riscos associados a este produto bem como a classificação de risco oficial disponibilizada pelo emitente.

A segunda parte do relatório debruça-se sobre os *inputs* utilizados, nos modelos e métodos utilizados e nas razões para não utilizar determinados modelos. Depois disso, foi feita uma comparação com base no que o investidor pagou pelo produto e no que pode esperar dele, com múltiplas estatísticas (i.e., probabilidade de *autocall*) para interpretar e prever o que poderá acontecer. Na última parte, este relatório especializou-se na sensibilidade do produto às diferentes correlações dos ativos do cabaz, alterando também algumas características do produto.

Palavras-chave: Produto Estruturado; Produto Autocallable; Cupão com memória; Worst-off Basket; Simulação de Monte Carlo; Análise de Sensibilidade; Correlação.

Códigos JEL: G12; G17.

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1. Introduction

Structured products are pre-packaged investment strategies that typically involve derivatives to achieve specific risk-return objectives, that can be tailor-made by the issuer from a request of an investor.

These financial instruments, that usually combine a traditional asset like bonds with derivatives, are designed to offer customized payoffs that are linked to the performance of underlying assets such as equities, indices, or interest rates. Structured products are often used for capital protection, yield enhancement, or market access when investors have specific views on asset prices or volatility.

The structure of these products allows investors to benefit from positive performance while potentially protecting themselves from significant losses. However, these advantages come with complexity, since they can be difficult to price and risk-manage due to their derivative components. This complexity increases the importance of understanding the underlying mechanisms, such as the derivative pricing models, to grasp their potential risks and returns. Also, many market factors impact the fair value of these product, such as the underlying prices, the interest rates, volatility, systematic risks (i.e. recessions, crisis and geopolitical risks). It compels both the investor and the issuer to understand fully the impact of these many factors on the value of the product. They have to create metrics using mathematical models to fully grasp all the variables impacting the product, so they know what they can expect from the product (either an expected return or an expected risk).

The goal of this project is to understand the features of this structured product and its result in the theoretical price. This theoretical price will be compared with the actual price of the product demanded by the issuer. This project will also be centered around the sensitivity of the product's price and volatility of expected returns due to changes in the constituents of the basket, specifically assets with extreme cases of correlation, and changes in one of the product's features. This study will allow us to understand which features and basket should an investor choose depending on his risk profile.

2. Literature Review

This report is based upon the insights of John C. Hull in the book "Options, Futures, and Other Derivatives" and the book of Edwin Elton and Martin Gruber "Modern Portfolio Theory and Investment Analysis". Two books used thoroughly during my master's in finance.

Firstly, it is important to understand the concept of the models that usually price structured products.

We will start with Black-Scholes-Merton model which is mostly used for the pricing of European-style options. Introduced by Fischer Black, Myron Scholes, and Robert Merton, the model provides a formula for determining the fair price of options based on 5 parameters such as the current price of the underlying asset, the strike price, time to expiration, risk-free interest rate, and volatility. The Black-Scholes-Merton model has the ability to translate market variables into an option price. Its use of geometric Brownian motion to model stock price behavior underpins much of modern financial theory (Hull, 2015). The model assumes that asset prices follow a lognormal distribution, and that volatility remains constant over the life of the option which is a critical

assumption that simplify mathematics while yielding useful insights. However, Hull (2015) shows that the model has some limitations. The assumption of constant volatility is one of its major weaknesses, as financial markets exhibit volatility clustering and shifts over time. Furthermore, the model's original form does not account for dividends, although modifications have been made to include this. Despite these limitations, the Black-Scholes-Merton model remains a cornerstone of options pricing and financial theory, and its influence on both academic literature and practical trading cannot be overstated.

The Binomial Tree model provides a more intuitive and flexible method for pricing options. Hull (2015) explains that this model involves creating a discrete-time framework in which the price of the underlying asset can move up or down by a certain factor over successive time steps. Unlike the Black-Scholes-Merton model (that can only price European options – exercised at maturity), the Binomial Tree model can easily handle American options, which can be exercised before expiration. One of the key strengths of the Binomial Tree model is its simplicity in implementation and its flexibility in accommodating various market conditions, including varying interest rates and dividends. As Hull (2015) notes, this model offers a step-by-step process that allows for the incorporation of changing market dynamics, which is something the Black-Scholes model cannot handle as easily. In each step, the potential up and down movements of the asset price are calculated, creating a "tree" of possible future values.

Regarding the Monte Carlo Simulations Model, it is a powerful tool for evaluating the price of simple and complex financial derivatives, particularly when no closed-form model, like Black-Scholes model, is able to price a certain product. Hull (2015) discusses the utility of Monte Carlo methods in generating multiple future paths for a stock price

based on its volatility and risk-return profile (expected value). The key advantage of Monte Carlo Model lies in its flexibility. As Hull (2015) highlights, Monte Carlo methods can be applied to any type of derivative product, regardless of its payoff structure or the complexity of its underlying asset. This makes it especially valuable in pricing exotic and path-dependent options, which will be very useful in the pricing of the structured product present in this study.

It is also relevant to understand correlation since it will be one of the inputs of this work and the main focus of this project. It is a statistical measure that expresses the degree to which two variables move in relation to each other, and it is a vital concept in portfolio theory and risk management. According to Elton & Gruber (1995), correlation coefficients can range from -1 to +1, where +1 corresponds to a perfect positive correlation, 0 indicates no correlation, and -1 equals to a perfect negative correlation. Correlation helps investors understand how different assets or asset classes behave in relation to each other, which is crucial for constructing diversified portfolios. In modern portfolio theory, correlation plays a key role in diversification strategies. As noted by Elton & Gruber (1995), combining assets with low or negative correlations can reduce the overall risk of a portfolio without necessarily diminishing expected returns. This concept is fundamental to the idea that diversification can protect against market volatility, removing as much market risk as the investor may want. For instance, if one asset performs poorly, another negatively correlated asset may perform well, thus mitigating the overall impact on the portfolio. However, the portfolio will always be subject to systematic risk, the inherent risk to the entire market. Relevant for this project, Hull (2015) also explains the importance of correlation in the context of pricing derivative products, especially for multi-asset derivatives like basket options. The correlation

between the assets in the basket directly influences the option's price, making it a crucial input in valuation models. However, both Elton & Gruber (1995) and Hull (2015) caution that correlation is not constant and can change over time, particularly during periods of market stress when correlations tend to converge, reducing the effectiveness of diversification strategies.

3. Description of the Product

According to the Key Information Document (KID), the Cirdan Phoenix Autocallable Worst of Certificates, issued by Cirdan Capital Management, is a senior, unsecured, bearer, medium-term certificate governed by English law. This structured product is designed for investors seeking high yield returns while accepting the associated risks tied to the performance of a selected basket of underlying stocks.

The underlying assets for this product consist of four major companies listed on the Borsa Italiana: Intesa Sanpaolo SpA, UniCredit SpA, Eni SpA, and initially Fiat Chrysler Automobiles NV, which transitioned to Stellantis NV following the merger between Chrysler and PSA Group in early 2021. The performance of these underlying assets is crucial in determining the product's coupon payments and the possibility of early redemption (autocall). The performance of each stock in this basket will then be tracked at each observation date (monthly until February 2025), where the "Worst-off" feature will kick in. This means that the reference underlying will be the worst performer in that period. The performance of all stocks will start at 100% on the 18th of February 2020. This reference underlying performance will be important to assess on each observation date if it is above the Automatic Early Redemption (AER) barrier and the coupon barrier, so that issuer can proceed with either the early redemption and/or the coupon payments.

The certificates are issued with a denomination of € 1,000, and the issue price is set at 100% of the denomination (issued at par). The minimum investment required is also €1,000, making it accessible to a broad range of investors. The product is structured to offer a memory coupon feature, where the investor is entitled to a monthly coupon payment of 0.5% of the denomination, provided that the reference underlying is above a set barrier level of 60% at the observation date. If the coupon payment is not triggered in any given month due to the underlying's performance, the coupon accumulates and is paid out once the barrier is surpassed in subsequent months. So, for example, if during 6 months there isn't a coupon payment (reference underlying performance is below 60%) and on the 7th month it is above, then the investor will receive 7 coupons: the one for the current month, plus the other 6 months' worth of unpaid coupons. There are a total of 60 observation dates for the coupons with the corresponding possibility of receiving the coupon.

One of the key features of this product is its autocallable mechanism, which is assessed on 55 different observation/valuation dates over a 5-year term, beginning from the strike date on 18th August 2020 and ending on the redemption date of 18th February 2025. In other words, after the first 6 months it is when the autocallable mechanism is activated, meaning that for the first 5 months the investor is only able receive coupons. Regarding the AER barrier, which determines the possibility of early redemption, lowers progressively as the product matures (Table 1). This structure offers increasing opportunities for early redemption if the underlying assets perform favorably. If the AER is triggered, the product matures early, and the investor receives the full principal amount along with any accrued coupons.

Valuation Date(s)	3/18/2020	4/18/2020	5/18/2020	6/18/2020	7/18/2020	8/18/2020	9/18/2020	10/19/2020	11/18/2020	12/18/2020		
AER Barrier	NO AER	NO AER	NO AER	NO AER	NO AER	100%	100%	100%	100%	100%		
Valuation Date(s)	**1/18/2021**	**2/18/2021**	**3/18/2021**	**4/19/2021**	**5/18/2021**	**6/18/2021**	**7/19/2021**	**8/18/2021**	**9/20/2021**	**10/18/2021**	**11/18/2021**	**12/20/2021**
AER Barrier	100%	100%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Valuation Date(s)	**1/18/2022**	**2/18/2022**	**3/18/2022**	**4/19/2022**	**5/18/2022**	**6/20/2022**	**7/18/2022**	**8/18/2022**	**9/19/2022**	**10/18/2022**	**11/18/2022**	**12/19/2022**
AER Barrier	95%	95%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Valuation Date(s)	**1/18/2023**	**2/20/2023**	**3/20/2023**	**4/18/2023**	**5/18/2023**	**6/19/2023**	**7/18/2023**	**8/18/2023**	**9/18/2023**	**10/18/2023**	**11/20/2023**	**12/18/2023**
AER Barrier	90%	90%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
Valuation Date(s)	**1/18/2024**	**2/19/2024**	**3/18/2024**	**4/18/2024**	**5/20/2024**	**6/18/2024**	**7/18/2024**	**8/19/2024**	**9/18/2024**	**10/18/2024**	**11/18/2024**	**12/18/2024**
AER Barrier	85%	85%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
Valuation Date(s)	**1/20/2025**	**2/18/2025**										
AER Barrier	80%	60%										

Table 1 - Dates of AER and corresponding barrier

In terms of capital protection, the product provides a partial protection level at 10%, meaning the investor may lose a large portion of their capital if the underlying assets perform poorly and the worst performer breaches the capital protection barrier at maturity.

When considering investing in this product, the investors should also ponder about the entry costs of this product, 3.93% of the invested amount if they are investing at issuance of the product. The impact of the costs of exiting the investment when it matures is 0%. Ongoing costs Portfolio transaction costs are also at 0.00%.

3.1 Product Decomposition & Payout

At maturity the product has a simple payoff (Figure 1) that can be decomposed in simpler financial instruments. In the perspective of the investor, it can be deconstructed into a short position in a down-and-in Put option (DIP) with strike at 100% and barrier level at 59.(9)% (if the reference underlying finishes right at 60%, the investor will receive the 100% nominal value, therefore only at 59.(9)% level and below is when the investor receives the corresponding performance in the nominal value), a long position in a vanilla put option with strike at 10% and finally a long position in a zero coupon bond with face

value of 100.5% (Nominal value plus the coupon, assuming that the coupon payment and the nominal payment are on the same date) of the investment made by the investor.

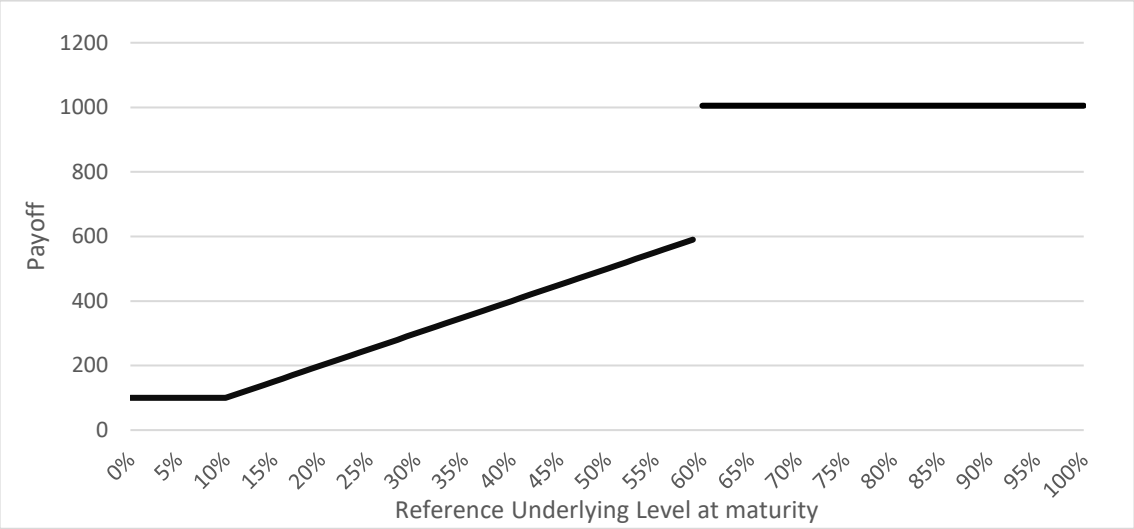

Figure 1 - Note's Payoff at maturity

However, when it comes to simplifying the structure during the life of the product becomes quite difficult since there isn't a simpler instrument that replicates the memory feature of the coupons.

This structured product offers a complex payout, where the investor can receive a monthly coupon (0.5% of the investment). This coupon has a "memory" feature where if multiple coupons are not paid due to the reference underlying not being above the coupon barrier (60%), in the following date where it is above this barrier the investor will receive the coupon from that month plus the sum of all previous unpaid coupons.

The product also incorporates an early redemption feature, in each observation date, also monthly, starting 6 months after the issuance, the investor will observe if the reference underlying is above the Automatic Early Redemption (AER) barrier. This barrier decreases as the life of the product shortens. If at maturity the product has not been early redeemed, there are 3 scenarios. The first one is that if the reference underlying is

above 60%, the investor will receive 100.5% of the investment (Nominal plus the coupon of that month). The second scenario is if the reference underlying is between 10% and 60%, the investor will receive the according registered performance of the reference underlying, such as for example, if the reference underlying is at 40%, the investor will receive 40% of his/her investment. The 3 scenario is if the reference underlying is at below 10%, the investor is guaranteed to receive by the issuer at least 10% of his/her investment, in other words, a capital protection of 10%.

3.2 Risks

If the investors buy the product outright (without hedging it), they will be subject to a market risk, where in this case if the one of the stocks performs poorly or defaults during the life of the product, the investors will lose up to 90% of their initial investment. Furthermore, the present diversification of sectors within the basket (Banks, financial services and automotive manufacturer) may hinder the expected value of the product, due to the "Worst-off" feature. If one stock performs well and another one poorly, it will be the poorer performer that will count for the payments, resulting in a reduction of the expected value of the product.

The investors will be also exposed to credit risk of the issuer (Cirdan Capital Management), if this firm defaults the investors will lose all of their investment (as stated in the KID), due to the inability of the issuer to fulfil its obligations in respect of the product to the investor. This product is an unsecured certificate, this means that there isn't collateral or guarantee scheme to compensate the investor in case of defaulting. However, this is a senior note, so in case of the issuer's default, when distributing the assets these investors receive what remains of the firm first then the subordinated noteholders and

shareholders. In this case of insolvency, it is not applicable the capital protection of 10%, that is only applicable in the case of a market movement of the underlying's.

As is written in the KID, the product cannot be easily cashed in as the investors want to close earlier their positions, creating a liquidity risk. Due to the illiquidity present in the structured products market, they will need to incur high costs while possibility making a large loss. This happens since there are difficulties finding a buyer for the product willing to pay it at fair value. This buyer will demand an illiquidity premium, since he/she will also then struggle to sell the product if he/she wishes to.

This product also endures interest rate risk, since it is a factor impacting the underlying assets performance on the stock market as well as impacting the hedging cost from the perspective of the noteholders and the issuer. Firstly, stock prices fluctuate when there is new guidance to the monetary policy by the central banks. These monetary policies will directly impact how these companies will finance themselves. If there are higher interest rates due to an aggressive monetary policy, these firms will register higher costs in their operations, leading to smaller profits which will is seen as negative for the stockholders, resulting in a lower stock price. In the event of lower stock prices, it can significantly hinder the performance of the Structured due to its "worst off" feature. Secondly, from a hedging perspective both the noteholder and the issuer will verify higher costs. I.e. both are delta hedging, where the noteholder will need to short each stock and the issuer will need to be long on each asset accordingly to the delta. Both operations require borrowing, when the investor is short on the assets, he/she will need to borrow the stock from a shareholder and pay interest for the time that the short operation occurs. The issuer will also need to borrow funds to be able to go long on the assets. In both cases,

depending on the conditions of the financing of each party, higher interest rates may create higher costs.

Finally, there is a risk of complexity due to the nature of the product and its multiple complex and intricated features, the investor may be exposed to risk that he/she does not fully comprehend. Considering this, the investor will not be able to hedge his position accordingly.

Regarding the risk assessment showcased in the product's KID, it is possible to observe a risk level of 6, which classifies itself as the second highest risk class (goes from 1 to 7, from low risk to high risk). In this rating category it's aggregated the possibility of poor market conditions plus the inherent difficulty in the issuer's ability to pay back the investor due to insolvency issues.

It is also present in the KID the analysis of the performance in 4 scenarios of this structured product (Table 2), based on a €10,000 investment, it's interpretable that it comes with a wide range of potential outcomes, highlighting the volatile nature of the product's returns.

In the worst-case (stressed) scenario, if the market faces extreme difficulties as stated in the KID, you could end up with as little as €2,090.87 after one year, or just €686.17 after five years. This translates to an annualized loss of nearly -79% in the first year and -41% by the end of five years, which is essentially a steep decline that shows how risky this product can be in bad conditions.

Even in an unfavorable scenario, where the market doesn't perform very well, you could still see losses. After one year, you might get back just €4,318.95, and this could drop to €1,694.70 after five years, with average annualized losses of -57% in the first year

and -30% over five years. It's a clear sign that even moderately bad market conditions can severely impact the investor's returns.

In the moderate scenario, where the market performs sideways, neither bullish nor bearish, the product shows better outcomes. After five years, the investor could receive about €10,300 which is practically breaking even with a modest positive annualized return of 0.59%. This shows that if you hold onto the investment for the long term, there's a chance for some recovery, even though the early years may still bring losses.

In the best-case (favorable) scenario, the product outputs the best expected return for the investor. After five years, the investor might expect to get €11,300 back, which translates to a 2.47% average annual return. These returns showcase the yield enhancement that this product offers compared to the risk-free investment that would yield a negative return of -0.64%. This yield enhancement comes at the cost of inputting risk on the investor. The investor should consider if these returns match his/her risk appetite.

Performance Scenarios

Investment EUR 10,000

Scenario		1 Year	3 Year	5 Year
Stressed Scenario	What you might get back after costs	EUR 2,090.87	EUR 1,217.95	EUR 686.17
	Average return each year %	-78.91%	-50.40%	-41.45%
Unfavourable Scenario	What you might get back after costs	EUR 4,318.95	EUR 2,691.89	EUR 1,694.70
	Average return each year %	-56.61%	-35.41%	-29.86%
Moderate Scenario	What you might get back after costs	EUR 7,062.52	EUR 9,084.62	EUR 10,300.00
	Average return each year %	-29.24%	-3.15%	0.59%
Favourable Scenario	What you might get back after costs	EUR 10,350	EUR 10,800.00	EUR 11,300.00
	Average return each year %	3.48%	2.60%	2.47%

Table 2 - Performance Scenarios included in the KID

However, it's important to note that this product is hard to cash out early, and doing so might come with high costs or losses. This makes it suitable only for those who can handle the high risks and are prepared to commit for the long term.

4. Valuation Methods

In this section, it is possible to understand the models used to value the Structured Product and the inputs used in the valuation.

With the objective of valuing the Structured Product, it was only used the Monte Carlo Simulation model, since it's able to capture all features included in the product, particularly, memory coupons. Another advantage over the other models is that it also has the ability to capture the correlation between the assets, in which Black-Scholes Merton Model and the Binomial Tree Model do not consider the relationship between the underlying's.

Furthermore, it was considered to decompose the Structured Product into simpler instruments, with a long position in a call spread and a binary call option for the maturity of the product. However, it is not possible to decompose the memory feature within the Structured Product in a simpler product. Due to this the inability to decompose the Structured Product into simpler products, it was decided to not use the Black-Scholes Merton Model nor the Binomial Tree Model. Additionally, the failure to capture correlations between assets aided on the decision.

4.1 Data

This section will explain the inputs used in the product valuation.

The risk-free rate assumed in this paper for the purpose of drift was retrieved from the mid yield-to-maturity (-0,638%) observed in the market at the strike date (18/02/2020) of a bond issued by the German Government maturing in 2/15/2025 (DBR 0 ½ 02/15/25, ISIN: DE0001102374).

The cost of funding was acquired through the Annual Accounts of the issuer for the year ended December 31, 2019, since it was the last produced document before the issuance of the Structured Product. From the Income Statement, the finance cost reported was £7135 divided by the total amount of Loans & Debt outstanding that was £507315 (retrieved from the Balance Sheet), achieving a cost of funding in GBP of 1.44%. To transform this value to a cost of funding in EUR it was subtracted from the cost of funding in GPB the spread between the risk-free rate in GBP and the risk-free rate in EUR.

$$r_{Funding}^{EUR} = r_{Funding}^{GBP} - (r_{rf}^{GBP} - r_{rf}^{EUR})$$

The risk-free rate for GBP was retrieved from the mid yield-to-maturity (0,4720%) observed in the market at the strike date (18/02/2020) of a bond issued by the United Kingdom Government maturing in 3/07/2025 (UKT 5 03/07/25, ISIN: GB0030880693).

From the application of the previous formula, it was achieved a cost of funding in EUR of 0,3319%. This value will be used to discount the expected cash flows.

For the Monte Carlo Simulation model, it was needed to compute the correlation between the 4 underlyings included in the basket of the Structured Product. It was incorporated the 2-year correlation matrix from February 2018 to February 2020 with daily observations (Table 3). This Matrix captures the medium-term relationship between the assets, where it aims to accurately include the market dynamics by observing daily changes in each asset and risks associated with the Structured Product term.

Security	ISP	UCG	ENI	STLAM
ISP	1	0.795	0.552	0.428
UCG	0.795	1	0.47	0.37
ENI	0.552	0.47	1	0.414
STLAM	0.428	0.37	0.414	1

Table 3 - Correlaion matrix

The volatility parameter for each asset was based on the market's implied volatility with options at-the-money recorded on February 18th, 2020. This data was retrieved from a volatility surface provided by the Bloomberg Terminal.

The dividend yield for each underlying was extracted from Bloomberg based on the latest dividend distributed by the companies prior to the issuance of the Structured Product.

4.2 Monte Carlo Simulation

The first step towards the valuation through Monte Carlo Simulation (MCS) was drawing a matrix of 10000 rows by 60 columns, in which there would be 10000 simulations for each time step (60). The next step was computing a series of error numbers and for this it was calculated random numbers according to a normal distribution with mean 0 and variance 1 for each of the 4 assets for each spot in the respective matrix. This resulted in 4 matrices which were named X1, X2, X3 and X4.

$$x_n \sim N(0,1)$$

The 4-assets correlation matrix was subject to the Cholesky decomposition. This decomposition is summarized in a resulting matrix multiplied by its transpose version which results in the original correlation matrix. The Cholesky decomposition results in matrix containing values that will be denominated $a_{n,m}$. The resulting matrix was the following (Table 4):

Cholesky Decomp	L			
	1	0	0	0
	0,795	0,607	0	0
	0,552	0,051	0,832	0
	0,428	0,049	0,211	0,878

Table 4 - Cholesky decomposed matrix

Then to calculate the Error numbers for each asset it was followed these formulas:

$$\varepsilon_1 = a_{1,1}x_1;\ \varepsilon_2 = a_{2,1}x_1 + a_{2,2}x_2;\ \varepsilon_3 = a_{3,1}x_1 + a_{3,2}x_2 + a_{3,3}x_3; \varepsilon_4$$

$$= a_{4,1}x_1 + a_{4,2}x_2 + a_{4,2}x_2 + a_{4,3}x_3 + a_{4,4}x_4$$

Since now all the inputs required for the Monte Carlo Simulations have been acquired, it was used the following formula to calculate the stock price at each observation date:

$$\frac{\delta s}{s} = (\mu - q)\delta t + \sigma\varepsilon\sqrt{\delta t}$$

$$S_t = S_{t-1}e^{\left(\mu - q - \frac{\sigma^2}{2}\right)\delta t + \sigma\varepsilon\sqrt{\delta t}}$$

MCS is based on the foundation of a Geometric Brownian Motion (GBM) within the behavior of a stock price.

MCS considers path dependency of the asset, so the S_t is based on the stock price of the previous date. Furthermore, it assumes a path based on the drift minus the dividend yield. It also implements a volatility assuming an error (ε).

After all, 4 matrices are produced with the corresponding 10000 simulations for each timestep, It is finally outputted the simulated prices which then have to be converted to a performance sheet. This performance sheet can be summarized in each asset returns. After this, all 4 performance matrices need to be compared to find in every simulation the

worst performer in each time step, by using the MIN() function in excel. This outputs a new sheet named Reference Underlying.

5. Product Valuation

As mentioned, the model used to value the Cirdan Phoenix Autocallable Worst of Certificates was the Monte Carlo Simulation model (MCS) due to its specific intrinsic features abling it to price the product's specific features.

From the matrices explained in section 4 where the number numbers were generated, followed by the computations of the errors (where these are also incorporating the correlation between the assets). After all this, it was calculated for each asset the simulated prices for each time step (monthly) and then the performance throughout the 5 years. It was then created a separate excel sheet with all 4 performances, which were then compared against each other so that a reference underlying sheet could be created. In this sheet the MIN() function of excel was used to get the worst performer from the 4 assets in each simulation in the corresponding timestep. This reference underlying sheet will be important for all the rest of the calculations.

In each simulation it was calculated the expected value of the product. This expected value was subdivided in the Automatic Early Redemption (AER) expected value and the Coupons expected value, in the end both were summed to result in a full expectation of value in that simulation. After this, it was calculated the average full expected value of all the simulations.

To get the AER expected value (in the AER sheet in excel), given the value in each simulation (retrieved from the Reference Underlying sheet), it was evaluated whether the reference underlying surpassed the AER barriers throughout the life of the product. If it

were activated, it would be discounted at that time step to the present value and added to a column with the present value of all simulations of AER. After this, the average present value of all AER simulations was calculated.

For the coupon payments, it was once again linked to the Reference Underlying sheet, checking whether at each time step and simulation the reference underlying was at or above the coupon barrier (60%). If it is it would pay the current coupon (0.5% of the investment), plus all the previous unpaid coupons. At each time step and each simulation, the coupon payment was discounted at the corresponding timestep. For each simulation it was summed all the discounted value to get an expected value of coupon payments at the present value. In the end, it was found the average expected value for the 10000 simulations, resulting in

After all computations, the expected value of the note was based on the sum of the average AER present value and the average present value of coupon payments of all simulations. This sum resulted in an expected value of €764.12 for a single certificate note. It's relevant to remind ourselves that a single note could be acquired by €1000 at inception.

It was also calculated the rate of return expected from holding the product until the end of its life and its standard deviation. From the Table 5, it's possible to interpret that on the date of issuance it was expected to lead to a loss of -22.94% to be incurred by the investor; However, this value, has a standard deviation of 32.41%, meaning that there is some amount of variability in the dataset of returns.

Note Expected Value at Inception (Present Value)	€ 764.12
Note Expected Value at Inception	€ 770.59
Note Expected Rate of Return	-22.94%
Note Rate of Return Std Deviation	32.41%
Sharpe Ratio	(0.69)

Table 5 - Expected values of the note

Furthermore, it was studied the aggregate result of the 10000 simulations regarding their autocall events.

Firstly, it was studied the percentage of simulations where the investor recovered his/her initial investment registered in the table below: autocalls per year or if at maturity the product was redeemed at par (reference underlying was above the 60% performance level). It is possible to interpret an annual decline in the autocall probability, meaning that less simulations are being autocalled as time progresses (Figure 2). It is also possible to observe that after 5 years, more than half of the simulations (55.50%) have not been autocalled nor matured at par, leading to losses to the investors (Figure 2).

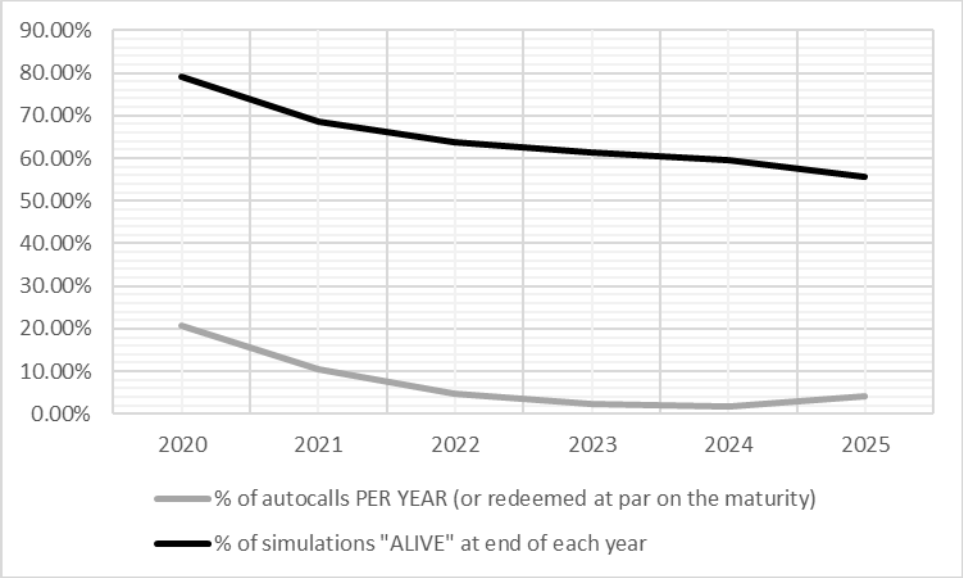

Figure 2 - Probability of autocalling and being "ALIVE" per year

The probability of autocalling per year dependent solely on active simulations is for example on 12/18/202 taking only in account the 7924 active simulations and analyzing how many of those simulations were autocalled up until 12/18/2021. The same process was executed for the following years. It was discovered that the descendent behavior in probability happens as in the non-dependent probability of autocalling. However, in both probabilities it can be seen a rebound in the last period (18/2/2025), where both increase slightly when comparing to the previous month (Table 6).

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	20.76%	10.57%	4.83%	2.42%	1.75%	4.17%
% of simulations "ALIVE" at end of each year	79.24%	68.67%	63.84%	61.42%	59.67%	55.50%
% of cumulative autocalls from ALL SIMULATIONS	20.76%	31.33%	36.16%	38.58%	40.33%	44.50%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	20.76%	13.12%	6.99%	3.78%	2.85%	6.97%

Table 6 - Probabilities of autocalls

The change in the expected value of the note per year also shows the decreasing likelihood of the investor recovering the amount invested (Table 7), as the table below shows. Both the expectation of AER value and the coupon value are decreasing. However, in any scenario, the Coupons Expected Value would decrease as the maturity of product approaches and less coupons are possible to be redeemed.

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	646.45	124.14	770.59	
FY2020	553.83	98.71	652.54	-15.32%
FY2021	485.15	63.59	548.74	-15.91%
FY2022	446.20	35.86	482.06	-12.15%
FY2023	424.38	15.66	440.04	-8.72%
FY2024	407.50	1.72	409.21	-7.01%

Table 7 - Expected values of the note per year

6. Correlations study

The following correlation study was aimed at the objective of finding if there are relevant changes in the expected value of the certificate note when building a basket of assets with different correlations.

This study was conducted using the original product's features, particularly the worst-off feature and a modification to the original by substituting this by a "best-off" feature, where the best performer in a given time step is the reference underlying.

For this it was used 3 different baskets, with each basket containing only 2 underlyings. The first basket has 2 assets with positive correlation, the second one with correlation close to 0 and the final basket has negative correlation. In order to find 2 stocks in the European markets with the demanded correlations, it was used a python code that extracted from multiple stock prices their daily returns from February 2018 to February 2020. It then calculated the Pearson correlation coefficient of all stocks and outputted a list of all correlations in a descending order. It was possible to find that the highest correlation was between BNP Paribas and ING, of 0.799. These are two firms in the same sector (banking) that are subject to mostly the same risks, same regulations and their profits are closely linked since they share the same environment (Europe). The second basket contained KPN and Infineon, two companies in different sectors (telecommunication and semiconductor manufacturer, respectively) being impacted by different factors. The correlation calculated was 0.081. The final basket was based on non-existent stocks, since it was impossible to find a relevant negative correlation between European stocks. It is possible to get accentuated negative correlation between stocks in Europe and other economies, however this approach was not used since the note

is issued in the Euro currency. Despite this, it was still interesting to study the effects of negative correlation and compare them to the remainder results, therefore it was solely used 2 non-existent assets with correlation of -0.799 to keep the symmetry with the positive correlation. This resulted in 6 different products, the 3 baskets for the "worst-off" product and the same 3 baskets but for the "best-off" product.

The next step consisted of executing the Cholesky decomposition to each of the 3 correlation matrices and then inputting them in the same model used in the original product calculation using solely the Monte Carlo Simulation model.

To expunge the product's sensitivities to other asset specific factors, like volatility and dividend yield, it was assumed equal annualized volatility for all assets at 25% and dividend yield of 0%.

In the following analysis it will be only used the expected value of the products and not the present expected value as was used in section 5. Present expected value is useful when trying to get a price for a product, but the expected value (just the nominal payments expected) are more useful from an investor's perspective of possible cash flow returns.

Worst-off

negative

Note Expected Value at Inception (Present Value)	€ 934.61
Note Expected Value at Inception	€ 942.95
Note Expected Rate of Return	-5.71%
Note Rate of Return Std Deviation	28.51%
Sharpe Ratio	(0.18)

10000 Simulations — Date	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	15.38%	17.98%	9.44%	6.20%	4.98%	9.64%
% of simulations "ALIVE" at end of each year	84.62%	66.64%	57.20%	51.00%	46.02%	36.38%
% of cumulative autocalls from ALL SIMULATIONS	15.38%	33.36%	42.80%	49.00%	53.98%	63.62%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	15.38%	20.87%	14.06%	10.75%	9.70%	20.81%

	Expected Value (AER)	Expected Value (Coupons)	Expected Value (NOTE)	% change in Note Expected Value
At Inception	789.11	153.84	942.95	
FY2020	750.78	125.65	876.42	-7.05%
FY2021	683.53	99.26	782.80	-10.68%
FY2022	631.30	66.43	697.73	-10.87%
FY2023	586.48	35.09	621.57	-10.92%
FY2024	541.73	4.46	546.19	-12.13%

neutral

Note Expected Value at Inception (Present Value)	€ 948.90
Note Expected Value at Inception	€ 955.10
Note Expected Rate of Return	-4.49%
Note Rate of Return Std Deviation	25.81%
Sharpe Ratio	(0.15)

10000 Simulations — Date	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	35.77%	17.61%	7.50%	4.50%	3.47%	5.08%
% of simulations "ALIVE" at end of each year	64.23%	46.62%	39.12%	34.62%	31.15%	26.07%
% of cumulative autocalls from ALL SIMULATIONS	35.77%	53.38%	60.88%	65.38%	68.85%	73.93%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	35.77%	26.56%	15.90%	11.40%	9.93%	16.20%

	Expected Value (AER)	Expected Value (Coupons)	Expected Value (NOTE)	% change in Note Expected Value
At Inception	843.31	111.80	955.10	
FY2020	756.05	105.75	861.80	-9.77%
FY2021	663.90	85.40	749.30	-13.05%
FY2022	599.46	57.38	656.85	-12.34%
FY2023	547.40	30.44	577.84	-12.03%
FY2024	496.98	4.54	501.52	-13.21%

positive

Note Expected Value at Inception (Present Value)	€ 981.21
Note Expected Value at Inception	€ 986.23
Note Expected Rate of Return	-1.38%
Note Rate of Return Std Deviation	21.80%
Sharpe Ratio	(0.03)

10000 Simulations — Date	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	50.24%	16.81%	6.34%	3.69%	2.78%	3.19%
% of simulations "ALIVE" at end of each year	49.76%	32.95%	26.61%	22.92%	20.14%	16.95%
% of cumulative autocalls from ALL SIMULATIONS	50.24%	67.05%	73.39%	77.08%	79.86%	83.05%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	50.24%	32.38%	18.92%	13.72%	11.98%	15.68%

	Expected Value (AER)	Expected Value (Coupons)	Expected Value (NOTE)	% change in Note Expected Value
At Inception	897.11	89.12	986.23	
FY2020	793.23	96.37	889.60	-9.80%
FY2021	687.74	82.74	770.48	-13.39%
FY2022	613.34	57.14	670.48	-12.98%
FY2023	551.09	29.97	581.07	-13.34%
FY2024	489.13	4.18	493.31	-15.10%

Table 8 - Aggregate results from the 3 worst-off products

When analyzing these hypothetical structured notes, particularly those with "Worst-Off" tend to exhibit greater sensitivity to underperformance, as it is very influenced by the weakest asset in the basket (Table 8).

When the underlyings are negatively correlated, they move in opposite directions, theoretically if one rises in price, the other falls. Mixing a “worst-off” feature with assets negatively correlated in the basket creates the lowest expected value out of all 6 notes generated. This is intuitive since the note will always be referencing the worst performer and if one asset increases its value the other one will decrease (and vice versa), this will increase the likelihood of existing a very poor performer within the basket. In this note, the expected value starts at €942.95 with an expected rate return of -5.71% for the whole period that the product is alive. The negative correlation note also denotates higher volatility than the remainder products in the “worst-off” category, reflected in a standard deviation of 28.51%. The likelihood of early redemption (autocall) is low, and by 2024, about 46% of the simulations still remain “alive,” with the note's value declining substantially to €541.73 (if it’s still “alive”). This outcome highlights the difficulty of managing notes from mostly the investor’s perspective when assets are inversely related, creating more unpredictability and risk.

In a neutral correlation scenario, where there is no strong relationship between the assets, the note begins at a slightly higher value of €955.10. However, the expected rate of return is still negative at -4.49%, and volatility remains a concern, however less than the previous note. Autocall rates are initially 35.77%, but by 2024, only 26% of the simulations are active, which can be seen as an improvement since many more simulations are activating an autocall event. However, the expectancy of value for 2024

decreases to €501.52. While slightly better than the negative correlation basket, this scenario still suffers from significant losses and limited upside.

Positive correlation offers a somewhat more favorable outlook for the Worst-Off structure. Here, the assets tend to move in the same direction, providing more stability. The note begins at €986.23, with still expectations of a rate of return of -1.38%. The initial autocall rate is 50.24%, much higher than in the negatively or neutrally correlated scenarios. By 2024, approximately 20.14% of the simulations remain active, with the note's value reduced to €493.31. Though the performance is still negative, the positive correlation provides a degree of protection against extreme declines or sharp increases in value, since all assets in the basket behave in tune.

Best-Off

negative

Note Expected Value at Inception (Present Value)	€ 1,030.83
Note Expected Value at Inception	€ 1,032.69
Note Expected Rate of Return	3.27%
Note Rate of Return Std Deviation	1.04%
Sharpe Ratio	3.75

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	96.22%	3.46%	0.27%	0.04%	0.00%	0.01%
% of simulations "ALIVE" at end of each year	3.78%	0.32%	0.05%	0.01%	0.01%	0.00%
% of cumulative autocalls from ALL SIMULATIONS	96.22%	99.68%	99.95%	99.99%	99.99%	100.00%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	96.22%	73.62%	69.23%	57.14%	0.00%	100.00%

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	1,000.00	32.69	1,032.69	
FY2020	1,000.00	24.63	1,024.63	-0.78%
FY2021	1,000.00	38.44	1,038.44	1.35%
FY2022	1,000.00	40.00	1,040.00	0.15%
FY2023	1,000.00	70.00	1,070.00	2.88%
FY2024	1,000.00	10.00	1,010.00	-5.61%

neutral

Note Expected Value at Inception (Present Value)	€ 1,035.96
Note Expected Value at Inception	€ 1,038.58
Note Expected Rate of Return	3.86%
Note Rate of Return Std Deviation	5.85%
Sharpe Ratio	0.77

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	83.77%	10.13%	2.33%	1.21%	0.63%	0.61%
% of simulations "ALIVE" at end of each year	16.23%	6.10%	3.77%	2.56%	1.93%	1.32%
% of cumulative autocalls from ALL SIMULATIONS	83.77%	93.90%	96.23%	97.44%	98.07%	98.68%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	83.77%	56.25%	36.58%	30.79%	24.05%	30.96%

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	992.94	45.64	1,038.58	
FY2020	956.48	67.84	1,024.32	-1.37%
FY2021	884.21	86.30	970.50	-5.25%
FY2022	812.65	70.72	883.36	-8.98%
FY2023	724.09	44.32	768.41	-13.01%
FY2024	634.03	6.89	640.92	-16.59%

positive

Note Expected Value at Inception (Present Value)	€ 1,026.05
Note Expected Value at Inception	€ 1,029.54
Note Expected Rate of Return	2.95%
Note Rate of Return Std Deviation	12.35%
Sharpe Ratio	0.29

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	71.64%	13.24%	4.24%	2.54%	1.42%	1.52%
% of simulations "ALIVE" at end of each year	28.36%	15.12%	10.88%	8.34%	6.92%	5.40%
% of cumulative autocalls from ALL SIMULATIONS	71.64%	84.88%	89.12%	91.66%	93.08%	94.60%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	71.64%	43.62%	27.25%	22.88%	16.86%	21.78%

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	968.50	61.04	1,029.54	
FY2020	888.93	84.20	973.14	-5.48%
FY2021	791.68	84.35	876.02	-9.98%
FY2022	710.49	61.40	771.89	-11.89%
FY2023	622.32	35.55	657.86	-14.77%
FY2024	544.82	6.09	550.91	-16.26%

Table 9 - Aggregate results from the 3 best-off products

Conversely, the Best-Off structure benefits from the highest-performing asset in the basket (Table 9), offering greater protection and more favorable outcomes across all correlation scenarios. When analyzing in particular the expected value of each of these 3 notes, you can see that there isn't a significant difference between them and all above the invested amount.

The Best-Off structure performs particularly well in a negative correlation environment. The note begins at €1,032.69, with a positive expected return of 3.27%. Volatility is significantly lower, as seen in a standard deviation of just 1.04%, indicating much less risk compared to the Worst-Off counterpart. Autocall rates are high in the first year alone (96.22%) and by the end of 2022, nearly all the simulations (99.95%) have been autocalled, leaving very few notes still in play. At maturity, we can see that all simulations were either autocalled during the life or redeemed at par at maturity, showing a 100% probability of recovering the initial investment. The note's value remains relatively stable, dipping only slightly to €1010 by 2024, which is a considerably better outcome than in any Worst-Off scenario.

In a neutral correlation scenario, the Best-Off structure continues to deliver solid results. The note begins at €1,038.58 with a favorable expected return of 3.86% and a standard deviation of 5.85%, reflecting some minor fluctuations. Autocall rates are similarly strong, starting at 83.77%, and by 2025, 98.68% of the notes have been redeemed. Although the note's value declines to €640.92 by 2024, representing a big drop when comparing to the expected value of 2024 for the best-off negative correlated basket. But this was expected, since most simulations are maturing with the reference underlying performance being below the 60% barrier. The negatively correlated basket had assets counteracting the others' performance leading to always finishing above the 60% barriers.

This expected value for 2024 of €640.92 also comes from a small number of simulations still “alive” (1.93% of the initial 10000 simulations). (Nonetheless, this is still a significant improvement over the Worst-Off equivalent, illustrating the resilience of the Best-Off structure in a neutral market.

Positive correlation yields the worst outcome out of all Best-Off structures. The note starts at €1,029.54 with an expected return of 2.95%, and while the standard deviation is higher (12.35%), indicating more volatility, the overall performance remains strong. The autocall rate starts at 71.64%, and although it decreases slightly over time, the note retains its value better than in the Worst-Off cases. By 2024, the note’s value stands at €550.91, for the same reasons as mentioned in the neutral best-off product.

A side-by-side comparison of Worst-Off and Best-Off structures clearly demonstrates that the Best-Off option generally provides better performance, reduced volatility, and higher autocall rates across all correlation scenarios. Worst-Off notes, on the other hand, are more prone to significant value erosion, especially when asset correlation is negative or neutral.

The key distinction between these two structures lies in how they respond to asset performance. In the Worst-Off structure, the performance of the weakest asset in the basket weighs heavily on the overall outcome. If one asset underperforms, it can drag down the entire note, leading to greater volatility and reduced returns. In contrast, the Best-Off structure benefits from the highest-performing asset, which provides a buffer against losses, allowing for greater stability and stronger returns, even if some assets underperform.

One common fact shared by both structures was that there was a small pick-up in the % of simulations redeemed at par at the maturity, when looking at the "% of autocalls PER YEAR (or redeemed at par on the maturity)" metric. This is mostly justified due to sharp decrease in the barrier (from autocall barrier of 80% on January of 2025 to 60% on February of 2025 – maturity), when previously there was usually a 5% drop every 12 months.

7. Conclusions

This project started by analyzing the original structure using solely the Monte Carlo Simulation Model due to limitations in the other models. It was found that the Cirdan Phoenix Autocallable Worst of Certificates had a high likelihood of not redeeming at par, making the investor incur losses. The analysis also highlighted a declining probability of autocall over time, with 55.5% of simulations still active after five years. This decline suggests that many investors may face losses, particularly as AER expectations decrease over time, with a slight rebound in autocall probability in the final period. This likely indicates a product structure where the chance of autocalling diminishes the longer the simulation survives, but a certain percentage will still autocall close to or at the maturity date.

When looking at the different baskets with separate correlations studied, it was observed that correlations played a pivotal role in shaping the performance of structured notes. In the Worst-Off structure, negative correlation is particularly detrimental, as assets moving in opposite directions exacerbate volatility and diminish the likelihood of positive returns. Neutral correlation fares slightly better but still lacks a clear upward trend.

Positive correlation offers a more stable environment, but even here, the Worst-Off structure struggles to generate meaningful returns.

In the Best-Off structure, the impact of correlation is less severe. Negative correlation, which often poses challenges in other financial products, can actually be advantageous here, as the strongest asset in the basket can deliver substantial returns, even when others are underperforming, being the best performer out of all 6 products generated, when looking at the combine expected value and standard deviation of returns. Neutral and positive correlation scenarios also showcased great performance, with the Best-Off structure consistently outperforming its Worst-Off counterpart across the board.

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Appendix

Figure A. 1 - Key Information Document

Key Information Document

Phoenix Autocallable Worst of Certificates with Memory

SmartETN

YOU ARE ABOUT TO PURCHASE A PRODUCT THAT IS NOT SIMPLE AND MAY BE DIFFICULT TO UNDERSTAND | **PAGE 1 OF 3**

For further information please contact:
T. +44 (0)203 097 0280 | E. info@cirdancapital.com

1. 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.

2. PRODUCT

Name	Cirdan Phoenix Autocallable Worst of Certificates
Identifier/ISIN	XS2119122948
Distributer	Cirdan Capital Management (Cirdan)
PRIIP manufacturer website	www.cirdancapital.com
Telephone	+44 (0)203 097 0280

Regulated by the U.K. Financial Conduct Authority. The infomation in this Key Information Document is correct as of 10 February 2020.

What is this product?

Type: Senior, Unsecured, Bearer, Medium Term Certificates (English law governed).
Objectives: The product is designed to provide a conditional coupon on a periodical basis. An Automatic Early Redemption Event will occur, and the product will terminate early, if defined conditions are met. If the product does not terminate early, the Final Settlement Amount you will receive on the Maturity Date will be a cash amount linked to the performance of the Reference Underlying. The Reference Underlying is the underlying with the lowest Performance on a Valuation Date. You accept the risk of loss of some or up to 90 per cent. of your investment.
Coupon: On each Coupon Valuation Date, if an Automatic Early Redemption Event has not previously occurred and if the Reference Underlying Performance is greater or equal to the Coupon Barrier, you will receive the Coupon multiplied by the number of periods from the issuance, minus the sum of the Coupons previously paid; otherwise, you will receive no Coupon.
Automatic Early Redemption (AER): If on the AER Valuation Date the Reference Underlying Performance is greater or equal to the AER Barrier, an Automatic Early Redemption Event will occur and you will receive 100 per cent. of the Denomination.
Final Settlement Amount: On the Maturity Date, if an Automatic Early Redemption has not occurred, you will receive a Final Redemption Amount. If the Reference Underlying Performance on the Redemption Valuation Date is greater or equal to the Capital Barrier, the Final Settlement Amount will be equal to 100 per cent. of the Denomination; otherwise, the Final Settlement Amount will be equal to the Reference Underlying Performance on the Redemption Valuation Date multiplied by the Denomination (in this scenario you will incur in a partial loss of the invested capital).
Additional Information: The Performance of each underlying is intended as the the current value as a percentage of the Initial Value; the Initial Value of each underlying is its value on the Strike Date; the Final Performance is the Performance of the Reference Underlying on the Redemption Valuation Date; Coupon is defined as a percentage of the Denomination; if certain exceptional events occur (1) adjustments may be made to the product and/or (2) the product issuer may terminate the product early. The return (if any) you receive on such early termination is likely to be different from the scenarios described above and may be less than the amount you invested.

Minimum Investment	EUR 1,000.00	**Denomination**	EUR 1,000.00
Exchange	EuroTLX	**Issue Price**	100%of the Denomination
Capital Barrier	60%	**Capital Protection**	No
Coupon Barrier	60%	**Coupon**	0.5%
AER Barrier	See below	**Product currency**	EUR

Refer to the terms and conditions of the product for a full list of the corresponding information set out in the table above.

Dates

Issue Date	14/02/2020
Strike Date	18/02/2020
Redemption Valuation Date	18/02/2025
Maturity Date	25/02/2025
Coupon Valuation Date(s)	18/03/2020, 20/04/2020, 18/05/2020, 18/06/2020, 20/07/2020, 18/08/2020, 18/09/2020, 19/10/2020, 18/11/2020, 18/12/2020, 18/01/2021, 18/02/2021, 18/03/2021, 19/04/2021, 18/05/2021, 18/06/2021, 19/07/2021, 18/08/2021, 20/09/2021, 18/10/2021, 18/11/2021, 20/12/2021, 18/01/2022, 18/02/2022, 18/03/2022, 19/04/2022, 18/05/2022, 20/06/2022, 18/07/2022, 18/08/2022, 19/09/2022, 18/10/2022, 18/11/2022, 19/12/2022, 18/01/2023, 20/02/2023, 20/03/2023, 18/04/2023, 18/05/2023, 19/06/2023, 18/07/2023, 18/08/2023, 18/09/2023, 18/10/2023, 20/11/2023, 18/12/2023, 18/01/2024, 19/02/2024, 18/03/2024, 18/04/2024, 20/05/2024, 18/06/2024, 18/07/2024, 19/08/2024, 18/09/2024, 18/10/2024, 18/11/2024, 18/12/2024, 20/01/2025, 18/02/2025
AER Valuation Date(s)	18/08/2020, 18/09/2020, 19/10/2020, 18/11/2020, 18/12/2020, 18/01/2021, 18/02/2021, 18/03/2021, 19/04/2021, 18/05/2021, 18/06/2021, 19/07/2021, 18/08/2021, 20/09/2021, 18/10/2021, 18/11/2021, 20/12/2021, 18/01/2022, 18/02/2022, 18/03/2022, 19/04/2022, 18/05/2022, 20/06/2022, 18/07/2022, 18/08/2022, 19/09/2022, 18/10/2022, 18/11/2022, 19/12/2022, 18/01/2023, 20/02/2023, 20/03/2023, 18/04/2023, 18/05/2023, 19/06/2023, 18/07/2023, 18/08/2023, 18/09/2023, 18/10/2023, 20/11/2023, 18/12/2023, 18/01/2024, 19/02/2024, 18/03/2024, 18/04/2024, 20/05/2024, 18/06/2024, 18/07/2024, 19/08/2024, 18/09/2024, 18/10/2024, 18/11/2024, 18/12/2024, 20/01/2025, 18/02/2025
AER Barrier Level for AER Valuation Date	100%, 100%, 100%, 100%, 100%, 100%, 100%, 95%, 95%, 95%, 95%, 95%, 95%, 95%, 95%, 95%, 95%, 95%, 95%, 95%, 90%, 90%, 90%, 90%, 90%, 90%, 90%, 90%, 90%, 90%, 90%, 90%, 85%, 85%, 85%, 85%, 85%, 85%, 85%, 85%, 85%, 85%, 85%, 85%, 85%, 80%, 80%, 80%, 80%, 80%, 80%, 80%, 80%, 80%, 80%, 80%, 80%

Key Information Document

Phoenix Autocallable Worst of Certificates with Memory

SmartETN

For further information please contact:
T. +44 (0)203 097 0280 | E. info@cirdancapital.com

Underlying

Basket of equity shares

	ISIN	Exchange	Currency
Intesa Sanpaolo SpA	IT0000072618	Borsa Italiana	EUR
UniCredit SpA	IT0005239360	Borsa Italiana	EUR
Eni SpA	IT0003132476	Borsa Italiana	EUR
Fiat Chrysler Automobiles NV	NL0010877643	Borsa Italiana	EUR

Intended Retail Investor: The product is intended to be offered to retail investors who fulfill all of the criteria below:

1. they are sophisticated and experienced in trading complex securities;
2. they are looking for an investment opportunity that reflects an expectation that the underlying will slightly decreases in value over time;
3. they are able to bear a total loss of the amount invested; and
4. they have a medium-term investment horizon.

3. WHAT ARE THE RISKS & WHAT COULD I GET IN RETURN?

Risk & Reward Profile

Lower Risk — Higher Risk

1	2	3	4	5	**6**	7

! The risk indicator assumes you keep the product one year. The actual risk can vary significantly if you cash in at an early stage and you may get back less. You may not be able to sell your product easily or you may have to sell at a price that significantly impacts on how much you get back.

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 6 out of 7, which is the second highest risk class. This rates the potential losses from future performance at a high level, and poor market conditions are likely to impact our capacity to pay you. You are entitled to receive back al least 10 per cent. The performance depends on future market movements and is uncertain. If we are not able to pay you what is owed, you could lose your entire investment.

Performance Scenarios

Investment EUR 10,000

Scenario		1 Year	3 Year	5 Year
Stressed Scenario	What you might get back after costs	EUR 2,090.87	EUR 1,217.95	EUR 686.17
	Average return each year %	-78.91%	-50.40%	-41.45%
Unfavourable Scenario	What you might get back after costs	EUR 4,318.95	EUR 2,691.89	EUR 1,694.70
	Average return each year %	-56.61%	-35.41%	-29.86%
Moderate Scenario	What you might get back after costs	EUR 7,062.52	EUR 9,084.62	EUR 10,300.00
	Average return each year %	-29.24%	-3.15%	0.59%
Favourable Scenario	What you might get back after costs	EUR 10,350	EUR 10,800.00	EUR 11,300.00
	Average return each year %	3.48%	2.60%	2.47%

This table shows the money you could get back over the next year, under different scenarios, assuming that you invest EUR 10,000.00. The scenarios shown illustrate how your investment could perform. You can compare them with the scenarios of other products. The scenarios presented are an estimate of future performance based on evidence from the past on how the value of this investment varies, and are not an exact indicator. What you get will vary depending on how the market performs and how long you keep the investment/product. The stress scenario shows what you might get back in extreme market circumstances, and it does not take into account the situation where we are not able to pay you. This product cannot be easily cashed in. This means it is difficult to estimate how much you would get back if you cash in before the end of the recommended holding period. You will either be unable to cash in early or you will have to pay high costs or make a large loss if you do so. 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.

4. WHAT HAPPENS IF CIRDAN IS UNABLE TO PAY OUT?

You are exposed to the risk that Cirdan might be unable to fulfil its obligations in respect of the product e.g. in the event of insolvency or an administrative order. If Cirdan is unable to pay out, you may lose all of your investment. Your loss would not be covered by any investor compensation or guarantee scheme.

Key Information Document

Phoenix Autocallable Worst of Certificates with Memory

For further information please contact:
T. +44 (0)203 097 0280 | E. info@cirdancapital.com

5. WHAT ARE THE COSTS?

The Reduction in Yield (RIY) shows what impact the total costs you pay will have on the investment return you might get. The total costs take into account one-off and ongoing costs. The amounts shown here are the cumulative costs of the product itself, for one holding period. They include potential early exit penalties. The figures assume you invest EUR 10,000.00. The figures are estimates and may change in the future.

Costs Over Time

The person selling you or advising you about this product may charge you other costs. If so, this person will provide you with information about these costs, and show you the impact that all costs will have on your investment over time.

Investment Scenarios EUR 10,000	Year 1	Year 3	Year 5 (Recommended Holding Period)
Total cost	1,553.27 EUR	1,980.65 EUR	2,176.95 EUR
Impact on return (RIY) per year	15.47%	6.58%	3.93%

Composition of Costs

The table below shows:

- the impact each year of the different types of costs on the investment return you might get at the end of the recommended holding period;
- the meaning of the different cost categories.

This table shows the impact on return per year.

One-off costs	Entry costs	3.93%	The impact of costs you pay when entering your investment. This is the most you will pay, and you could pay less.
	Exit costs	0.00%	The impact of the costs of exiting your investment when it matures.
Ongoing costs	Portfolio transaction costs	0.00%	The impact of the costs of us buying and selling underlying investments for the product.
	Other ongoing costs	0.00%	The impact of the costs that we take each year for managing your investments.
Incidental Costs	Performance costs	0.00%	The impact of the costs that we take each year on the positive performance of the product. The performance is considered to be positive if the value of the product is higher than the previous high watermark.

6. HOW LONG SHOULD I HOLD IT AND CAN I TAKE MONEY OUT EARLY?

Recommended holding period: 5 Years

If you wish to exit the product early, the price at which you are able to sell the product may be less than the amount you invested and you may make a loss. In addition, there may be no trading market for the product meaning you are unable to find a buyer. The price at which you are able to sell the product may be impacted by market factors including, but not limited to, movements in interest rates, interest rate volatility and the financial condition of Cirdan. If Cirdan purchases the product, Cirdan may deduct costs from the price it is willing to pay you (including, but not limited to costs relating to its hedging arrangements).

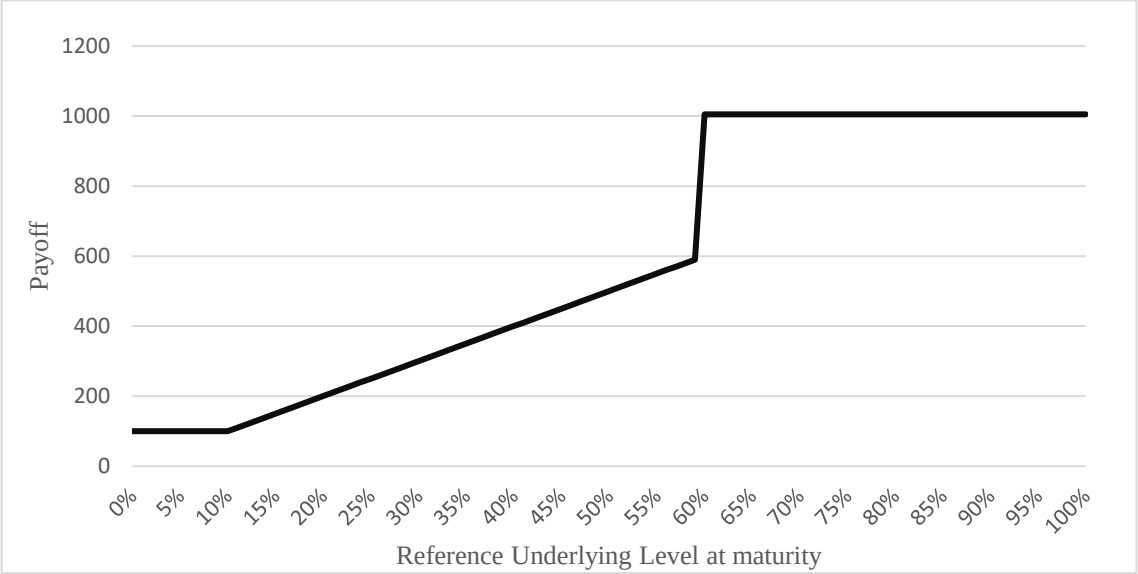
7. HOW CAN I COMPLAIN?

Any complaint regarding the person advising on, or selling, the product can be submitted directly to that person. Any complaint regarding the product or the conduct of Cirdan can be submitted to Cirdan under the following address: 5th Floor, 1 Knightsbridge Green, London SW1X 7NE United Kingdom or at www.cirdancapital.com or to complaints@cirdancapital.com

8. OTHER RELEVANT INFORMATION

The full terms and conditions of the product are set out in Prospectus relating to the issue of the product as supplemented and amended from time to time. The Prospectus can be found here: https://smartetn.com

Valuation Date(s)	3/18/2020	4/18/2020	5/18/2020	6/18/2020	7/18/2020	8/18/2020	9/18/2020	10/19/2020	11/18/2020	12/18/2020		
AER Barrier	NO AER	NO AER	NO AER	NO AER	NO AER	100%	100%	100%	100%	100%		
Valuation Date(s)	**1/18/2021**	**2/18/2021**	**3/18/2021**	**4/19/2021**	**5/18/2021**	**6/18/2021**	**7/19/2021**	**8/18/2021**	**9/20/2021**	**10/18/2021**	**11/18/2021**	**12/20/2021**
AER Barrier	100%	100%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Valuation Date(s)	**1/18/2022**	**2/18/2022**	**3/18/2022**	**4/19/2022**	**5/18/2022**	**6/20/2022**	**7/18/2022**	**8/18/2022**	**9/19/2022**	**10/18/2022**	**11/18/2022**	**12/19/2022**
AER Barrier	95%	95%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Valuation Date(s)	**1/18/2023**	**2/20/2023**	**3/20/2023**	**4/18/2023**	**5/18/2023**	**6/19/2023**	**7/18/2023**	**8/18/2023**	**9/18/2023**	**10/18/2023**	**11/20/2023**	**12/18/2023**
AER Barrier	90%	90%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
Valuation Date(s)	**1/18/2024**	**2/19/2024**	**3/18/2024**	**4/18/2024**	**5/20/2024**	**6/18/2024**	**7/18/2024**	**8/19/2024**	**9/18/2024**	**10/18/2024**	**11/18/2024**	**12/18/2024**
AER Barrier	85%	85%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
Valuation Date(s)	**1/20/2025**	**2/18/2025**										
AER Barrier	80%	60%										

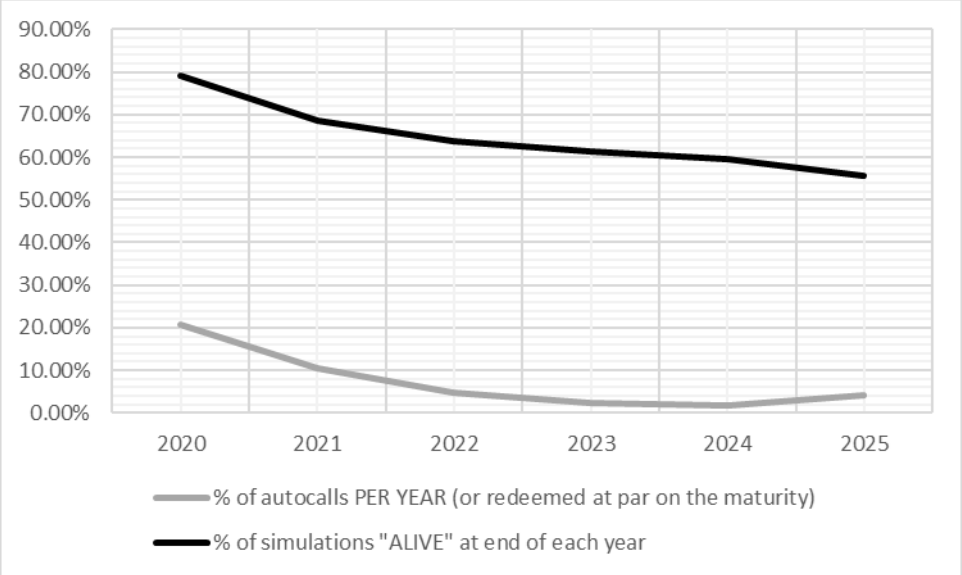


Security	ISP	UCG	ENI	STLAM
ISP	1	0.795	0.552	0.428
UCG	0.795	1	0.47	0.37
ENI	0.552	0.47	1	0.414
STLAM	0.428	0.37	0.414	1

Note Expected Value at Inception (Present Value)	€ 764.12
Note Expected Value at Inception	€ 770.59
Note Expected Rate of Return	-22.94%
Note Rate of Return Std Deviation	32.41%
Sharpe Ratio	(0.69)

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	20.76%	10.57%	4.83%	2.42%	1.75%	4.17%
% of simulations "ALIVE" at end of each year	79.24%	68.67%	63.84%	61.42%	59.67%	55.50%
% of cumulative autocalls from ALL SIMULATIONS	20.76%	31.33%	36.16%	38.58%	40.33%	44.50%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	20.76%	13.12%	6.99%	3.78%	2.85%	6.97%

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	646.45	124.14	770.59	
FY2020	553.83	98.71	652.54	-15.32%
FY2021	485.15	63.59	548.74	-15.91%
FY2022	446.20	35.86	482.06	-12.15%
FY2023	424.38	15.66	440.04	-8.72%
FY2024	407.50	1.72	409.21	-7.01%



Best-Off

negative

Note Expected Value at Inception (Present Value)	€ 1,030.83
Note Expected Value at Inception	€ 1,032.69
Note Expected Rate of Return	3.27%
Note Rate of Return Std Deviation	1.04%
Sharpe Ratio	3.75

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	96.22%	3.46%	0.27%	0.04%	0.00%	0.01%
% of simulations "ALIVE" at end of each year	3.78%	0.32%	0.05%	0.01%	0.01%	0.00%
% of cumulative autocalls from ALL SIMULATIONS	96.22%	99.68%	99.95%	99.99%	99.99%	100.00%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	96.22%	73.62%	69.23%	57.14%	0.00%	100.00%

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	1,000.00	32.69	1,032.69	
FY2020	1,000.00	24.63	1,024.63	-0.78%
FY2021	1,000.00	38.44	1,038.44	1.35%
FY2022	1,000.00	40.00	1,040.00	0.15%
FY2023	1,000.00	70.00	1,070.00	2.88%
FY2024	1,000.00	10.00	1,010.00	-5.61%

neutral

Note Expected Value at Inception (Present Value)	€ 1,035.96
Note Expected Value at Inception	€ 1,038.58
Note Expected Rate of Return	3.86%
Note Rate of Return Std Deviation	5.85%
Sharpe Ratio	0.77

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	83.77%	10.13%	2.33%	1.21%	0.63%	0.61%
% of simulations "ALIVE" at end of each year	16.23%	6.10%	3.77%	2.56%	1.93%	1.32%
% of cumulative autocalls from ALL SIMULATIONS	83.77%	93.90%	96.23%	97.44%	98.07%	98.68%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	83.77%	56.25%	36.58%	30.79%	24.05%	30.96%

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	992.94	45.64	1,038.58	
FY2020	956.48	67.84	1,024.32	-1.37%
FY2021	884.21	86.30	970.50	-5.25%
FY2022	812.65	70.72	883.36	-8.98%
FY2023	724.09	44.32	768.41	-13.01%
FY2024	634.03	6.89	640.92	-16.59%

positive

Note Expected Value at Inception (Present Value)	€ 1,026.05
Note Expected Value at Inception	€ 1,029.54
Note Expected Rate of Return	2.95%
Note Rate of Return Std Deviation	12.35%
Sharpe Ratio	0.29

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	71.64%	13.24%	4.24%	2.54%	1.42%	1.52%
% of simulations "ALIVE" at end of each year	28.36%	15.12%	10.88%	8.34%	6.92%	5.40%
% of cumulative autocalls from ALL SIMULATIONS	71.64%	84.88%	89.12%	91.66%	93.08%	94.60%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	71.64%	43.62%	27.25%	22.88%	16.86%	21.78%

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	968.50	61.04	1,029.54	
FY2020	888.93	84.20	973.14	-5.48%
FY2021	791.68	84.35	876.02	-9.98%
FY2022	710.49	61.40	771.89	-11.89%
FY2023	622.32	35.55	657.86	-14.77%
FY2024	544.82	6.09	550.91	-16.26%

Worst-off

negative

Note Expected Value at Inception (Present Value)	€ 934.61
Note Expected Value at Inception	€ 942.95
Note Expected Rate of Return	-5.71%
Note Rate of Return Std Deviation	28.51%
Sharpe Ratio	(0.18)

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	15.38%	17.98%	9.44%	6.20%	4.98%	9.64%
% of simulations "ALIVE" at end of each year	84.62%	66.64%	57.20%	51.00%	46.02%	36.38%
% of cumulative autocalls from ALL SIMULATIONS	15.38%	33.36%	42.80%	49.00%	53.98%	63.62%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	15.38%	20.87%	14.06%	10.75%	9.70%	20.81%

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	789.11	153.84	942.95	
FY2020	750.78	125.65	876.42	-7.05%
FY2021	683.53	99.26	782.80	-10.68%
FY2022	631.30	66.43	697.73	-10.87%
FY2023	586.48	35.09	621.57	-10.92%
FY2024	541.73	4.46	546.19	-12.13%

neutral

Note Expected Value at Inception (Present Value)	€ 948.90
Note Expected Value at Inception	€ 955.10
Note Expected Rate of Return	-4.49%
Note Rate of Return Std Deviation	25.81%
Sharpe Ratio	(0.15)

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	35.77%	17.61%	7.50%	4.50%	3.47%	5.08%
% of simulations "ALIVE" at end of each year	64.23%	46.62%	39.12%	34.62%	31.15%	26.07%
% of cumulative autocalls from ALL SIMULATIONS	35.77%	53.38%	60.88%	65.38%	68.85%	73.93%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	35.77%	26.56%	15.90%	11.40%	9.93%	16.20%

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	843.31	111.80	955.10	
FY2020	756.05	105.75	861.80	-9.77%
FY2021	663.90	85.40	749.30	-13.05%
FY2022	599.46	57.38	656.85	-12.34%
FY2023	547.40	30.44	577.84	-12.03%
FY2024	496.98	4.54	501.52	-13.21%

positive

Note Expected Value at Inception (Present Value)	€ 981.21
Note Expected Value at Inception	€ 986.23
Note Expected Rate of Return	-1.38%
Note Rate of Return Std Deviation	21.80%
Sharpe Ratio	(0.03)

10000 Simulations **Date**	12/18/2020	12/18/2021	12/18/2022	12/18/2023	12/18/2024	2/18/2025
% of autocalls PER YEAR (or redeemed at par on the maturity)	50.24%	16.81%	6.34%	3.69%	2.78%	3.19%
% of simulations "ALIVE" at end of each year	49.76%	32.95%	26.61%	22.92%	20.14%	16.95%
% of cumulative autocalls from ALL SIMULATIONS	50.24%	67.05%	73.39%	77.08%	79.86%	83.05%
Probability of Autocalling DEPENDENT ON ALIVE SIMULATIONS	50.24%	32.38%	18.92%	13.72%	11.98%	15.68%

	Expected Value (AER)	**Expected Value (Coupons)**	**Expected Value (NOTE)**	% change in Note Expected Value
At Inception	897.11	89.12	986.23	
FY2020	793.23	96.37	889.60	-9.80%
FY2021	687.74	82.74	770.48	-13.39%
FY2022	613.34	57.14	670.48	-12.98%
FY2023	551.09	29.97	581.07	-13.34%
FY2024	489.13	4.18	493.31	-15.10%

Annex 1 – Python code for discovery of asset's correlations

```
pip install yfinance
import pandas as pd
import yfinance as yf
import numpy as np

# List of European stock tickers (excluding UK-based companies)
tickers = ['ASML.AS', 'SAP.DE', 'IFX.DE', 'NOKIA.HE', 'ERIC-B.ST',
          'SAN.PA', 'NOVO-B.CO',
          'SAN.MC', 'BNP.PA', 'DBK.DE', 'INGA.AS',
          'OR.PA', 'ABI.BR', 'MC.PA', 'HEIA.AS',
          'SHELL.AS', 'TTE.PA', 'ENI.MI', 'REP.MC', 'EQNR.OL',
          'ENEL.MI', 'IBE.MC', 'RWE.DE', 'ENGI.PA',
          'DTE.DE', 'ORA.PA', 'TEF.MC', 'KPN.AS', 'ELISA.HE',
          'SIE.DE', 'AIR.PA', 'SU.PA', 'BAS.DE']

# Download historical data for the past year
data = yf.download(tickers, start='2019-02-14', end='2020-02-14')['Adj Close']

# Calculate daily returns
returns = data.pct_change().dropna()

# Calculate the correlation matrix
correlation_matrix = returns.corr()

# Find pairs with strong negative correlation (less than -0.80)
threshold = 0.0
negative_correlation = []
for i in range(len(correlation_matrix.columns)):
    for j in range(i+1, len(correlation_matrix.columns)):
        if correlation_matrix.iloc[i, j] < threshold:
            negative_correlation.append((correlation_matrix.index[i], correlation_matrix.columns[j],
correlation_matrix.iloc[i, j]))

# Sort by the value of the correlation
negative_correlation_sorted = sorted(negative_correlation, key=lambda x: x[2])
```

```
# Output the pairs with strong negative correlation
for pair in negative_correlation_sorted:
    print(f"Pair: {pair[0]} - {pair[1]}, Correlation: {pair[2]:.4f}")


# List of European stock tickers (excluding UK-based companies)
tickers = ['ASML.AS', 'SAP.DE', 'IFX.DE', 'NOKIA.HE', 'ERIC-B.ST',
           'SAN.PA', 'NOVO-B.CO',
           'SAN.MC', 'BNP.PA', 'DBK.DE', 'INGA.AS',
           'OR.PA', 'ABI.BR', 'MC.PA', 'HEIA.AS',
           'SHELL.AS', 'TTE.PA', 'ENI.MI', 'REP.MC', 'EQNR.OL',
           'ENEL.MI', 'IBE.MC', 'RWE.DE', 'ENGI.PA',
           'DTE.DE', 'ORA.PA', 'TEF.MC', 'KPN.AS', 'ELISA.HE',
           'SIE.DE', 'AIR.PA', 'SU.PA', 'BAS.DE']

# Download historical data for the past year
data = yf.download(tickers, start='2019-02-14', end='2020-02-14')['Adj Close']

# Calculate daily returns
returns = data.pct_change().dropna()

# Calculate the correlation matrix
correlation_matrix = returns.corr()

# Find pairs with strong positive correlation (more than +0.80)
threshold = 0.80
positive_correlation = []
for i in range(len(correlation_matrix.columns)):
    for j in range(i+1, len(correlation_matrix.columns)):
        if correlation_matrix.iloc[i, j] > threshold:
                                    positive_correlation.append((correlation_matrix.index[i],
correlation_matrix.columns[j], correlation_matrix.iloc[i, j]))
```

```
# Sort by the value of the correlation
positive_correlation_sorted = sorted(positive_correlation, key=lambda x: x[2])

# Output the pairs with strong positive correlation
for pair in positive_correlation_sorted:
    print(f"Pair: {pair[0]} - {pair[1]}, Correlation: {pair[2]:.4f}")

# List of European stock tickers (excluding UK-based companies)
tickers = ['ASML.AS', 'SAP.DE', 'IFX.DE', 'NOKIA.HE', 'ERIC-B.ST',
           'SAN.PA', 'NOVO-B.CO',
           'SAN.MC', 'BNP.PA', 'DBK.DE', 'INGA.AS',
           'OR.PA', 'ABI.BR', 'MC.PA', 'HEIA.AS',
           'SHELL.AS', 'TTE.PA', 'ENI.MI', 'REP.MC', 'EQNR.OL',
           'ENEL.MI', 'IBE.MC', 'RWE.DE', 'ENGI.PA',
           'DTE.DE', 'ORA.PA', 'TEF.MC', 'KPN.AS', 'ELISA.HE',
           'SIE.DE', 'AIR.PA', 'SU.PA', 'BAS.DE']

# Download historical data for the past year
data = yf.download(tickers, start='2019-02-14', end='2020-02-14')['Adj Close']

# Calculate daily returns
returns = data.pct_change().dropna()

# Calculate the correlation matrix
correlation_matrix = returns.corr()

# Find pairs with correlation close to 0
threshold = 0.0
zero_correlation = []
for i in range(len(correlation_matrix.columns)):
```

```
    for j in range(i+1, len(correlation_matrix.columns)):
        if correlation_matrix.iloc[i, j] > threshold:
                                        zero_correlation.append((correlation_matrix.index[i],
correlation_matrix.columns[j], correlation_matrix.iloc[i, j]))

# Sort by the value of the correlation
zero_correlation_sorted = sorted(zero_correlation, key=lambda x: x[2])

# Output the pairs with correlation close to 0
for pair in zero_correlation_sorted:
    print(f"Pair: {pair[0]} - {pair[1]}, Correlation: {pair[2]:.4f}")
```

Disclaimer

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

Chat-GPT was used only for English, grammar checking and refinement of syntaxes on parts of the written text.

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

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

Diogo Figueira, 14th of October 2024