A Work Project, presented as part of the requirements for the Award of a Master Degree in Finance from the NOVA –School of Business and Economics.

Field Lab Project Nova SBE | Moody's Analytics

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January 2018

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1. Executive Summary

Moody's Analytics provides valuable tools and services to investors and risk management professionals, helping them better understand and respond to an ever-changing financial environment, by offering credit analysis, advisory services, and financial risk management. A specific service that Moody's provides for investors is a portal for a specific type of products, Structured Products, with several features and advantages further discussed in this report.

The aim of this project is to help Moody's offer a better and more comprehensive service to investors, particularly in the field of Structured Products, whose market still remains relatively unexplored. Our contribution, and thus this resulting project, can be divided into three main points.

First, we started by becoming familiar with the Structured Finance Portal Moody's, which is an efficient tool further described that Moody's offers to investors. At this initial step, we had the opportunity to learn about its specificities, and produce a report analysing its strengths and weaknesses, in order to help Moody's enhance the user experience by providing a more efficient Portal to its users.

Secondly, we have helped Moody's in understanding which metrics would be interesting for investors to have access to, and that could be made available on the portal. To achieve this, we have analysed thoroughly a set of metrics, assessing whether they are appropriate for structured products, and if they are valuable in terms of providing to investors accurate and relevant information on the products. The methodology and conclusions are described in this report; for this purpose, the metrics have been grouped into four categories: Input metrics, Spreads & Returns, Risk measures, and the Greeks. Summarizing, we found that some of the metrics, although very important and widely used in the financial world, were not relevant or properly applicable to this type of products. We consider from our broad analysis that the Option-

Adjusted Spread (OAS), the Yield to Workout date, the yield to next call, the effective spread convexity, the effective spread to duration, the effective duration and the implied volatility are the most relevant and helpful when analysing complex products. These and the remaining metrics are described in this report in a hierarchical order by importance and relevance.

Finally, we have produced a series of research documents on existing and in development regulations, with an emphasis on risk weight calculations for structured products, which is summarized in the final part of this report. This section of our project is also relevant, since regulatory requirements affect directly financial institutions, such as issuers (SPV), banks and insurance companies; consequently, these regulatory changes may affect indirectly investors, as the former may try to pass some of the incremental burden to its holders. By providing Moody's with an overview of how risk weighting must be done to meet regulatory requirements, they can offer better advice to their clients on this matter, and incorporate this information to be displayed on the portal.

2. Introduction

First appearing in the US market in 1987, structured products do not have a formal definition. However, some characteristics are generally present in this type of products. They are designed by modifying and combining traditional securities (such as stocks, bonds, indices), and can be structured to offer income, participation, growth, or a combination of these, linked to the performance of the underlying – consequently, being generally used as satellite investments, as specified by FT Adviser (2013a). Also, derivatives are usually bundled up with these assets to create a new product with specific features and payoffs. These can range from very sophisticated combinations to simpler versions of the primary securities, with the payoff structures also varying in complexity.

Thus, this type of products can facilitate the customization of risk and return strategies according to the investors′ preferences and goals, whilst simplifying the process by allowing them to enter complex positions in options without having to access derivatives exchanges. Another advantage is the fact that investors can enter into positions not available on derivatives exchanges, such as positions with options with a longer than usual time to maturity and exotic options. They can also benefit banks because they can be used to transfer/share risk to/with investors (such as the case of residential mortgage back securities, as will be explained further on).

Given the specificities and customizable particularities of structured products, they are generally traded OTC. They were originated in the US, where they grew immensely in issuance and trading in the 2000s and became one of the fastest growing financial services sector. By the mid-1990s they reached Europe, where they gained popularity in countries like Germany and Switzerland. Nevertheless, the market remains relatively unexplored (especially in terms of regulation), so mispricing and opportunities to make superior returns commonly arise, as analyzed in later sections.

Considering the advantages mentioned above, it is not surprising that structured products became quite popular, and that their market expanded considerably. Not only do these products allow single components (traditional assets) to be "packaged" in a tailored way, but they also enable investors with a low budget and knowledge to enter into derivatives positions without having to invest in them directly (Hens & Rieger, 2008). Additionally, this type of securities could help achieve a certain level of diversification, balance and stability in a portfolio, since they supposedly offer defined outcomes based on defined market conditions, as stated by FT Adviser (2013b).

In addition, their success can be partly attributed to the current market environment. For instance, it has been argued that changes in tax rules might be another reason for their attractiveness, since they can be used in a way that maximizes tax exemptions and allowances. For example, depending on the product, the returns can be classified as capital gains or income, thus being subject to different tax levels, as reported by FT Adviser (2013c)

On the other hand, as interest rates dropped and remained at low levels in the 21st century, investors sought higher returns and incurred higher levels of leverage, encouraging risk transfer and dispersion (Blundell-Wignall, 2007). In fact, investors were attracted by the belief that they were safe investments, guaranteeing minimum payoffs. This narrative was based on two main points: the returns are commonly linked to an index, making structured products seem very safe, almost risk-free investments, like the assets they were associated with; and the fact that they generally had some kind of capital protection, which was sometimes misinterpreted as capital guaranteed (Deverell, 2011).

Nevertheless, structured products also raised some suspicion, being commonly blamed for the financial turmoil and crisis of 2008, because as the underlying mortgages of structured products such as MBS started defaulting, so did the products linked to them. While they had the advantage of allowing risk diversification by pooling several mortgages into one product, these were extremely vulnerable (and volatile), leading to considerable losses when they failed.

Blundell-Wignall (2007) also mentions an important fact regarding the risk management: securitization has given incentives to the issuers of loans (or other underlying assets) to neglect due diligence on borrower quality, considering the repayment risk is no longer only supported by the issuer, but is to a certain extent transferred to the buyers of structured products.

Furthermore, Hens and Rieger (2008) claim that in most cases, the utility gain for investors is merely an illusion, with most structured products not being optimal for rational investors. The authors believe the attractiveness of such products does not comes from rational decisions, but rather from behavioral reasons such as loss aversion and probability misestimation.

2.1. Structured Products and their Market

Many structured products are created through a process known as securitization. Asset securitization is a process through which a special purpose vehicle (SPV) creates securities and issues them to investors. Therefore, investors' payments can be backed by the SPV's cash flows originated from a pool of financial assets. Through this process, credit availability increases by transforming the illiquid assets of a lending entity into tradable securities, backed by assets.

Banks developed the securitization to create value from the assets on their balance sheet. So financial institutions have the possibility of improving the liquidity of their balance sheet, because the original loan is substituted by a bond security with a possibility to be sold before maturity. The balance sheet is reduced by transferring part of its assets, thus the equity/asset ratio gets improved, which in turn allows it to release funds and reallocate them to more profitable business. Therefore, they can refinance at an attractive cost, since Asset-Backed securities' (ABS) interests are lower than the interests on the underlying loans (Martellini et al., 2003).

Moreover, this type of assets can be important to markets, as they make them more complete. For instance, when there is a gap in demand-supply, where demand exceeds the supply for debt products rated as AAA and B, this market necessity can be satisfied through the creation of a portfolio of debt products with an average classification of BBB and then issuing AAA and B tranches.

Securitized products have advantages for both investors and borrowers, as good credit rating. However, there are several complexities associated with its products and market, such as the return and product life volatility, which have to be well measured when investing in this market.

There are many different types of structured products available in the securitization market. Nevertheless, in this section we are going to focus on the ones that we had more contact with in the project for Moody's Analytics: Asset-Backed securities, Mortgage-Backed securities, and Collateralized Debt Obligations.

An Asset-Backed Security (ABS) is exclusively collateralized by a pool of underlying assets. The assets underlying an ABS can be either consumer financial assets (automobile loans, student loans and credit card receivables), or commercial financial assets (small business administration loans, agricultural machinery loans and trade receivables). When ABS are compared with corporate bonds, they have a highest claim on a pool of specific assets, so they are isolated from all other assets of the company, which gives them a secured status.

ABS consist of several tranches with different ratings, which correspond to priority ranks in receiving cash flow payments from the trust in case of default. If the default losses are high and the assets' cash flow is not enough to pay all the liabilities, the Senior tranche (highest ranked) is paid first, followed by the lower-rated tranches by order of seniority.

These securities are quoted in yield spread over the Treasury-bond yield curve or the swap yield curve, using the weighted average life (WAL) measure.

A Mortgage-Backed Security (MBS) is a type of ABS that is collateralized by a mortgage or pool of mortgages. The MBS can be of two types: Residential Mortgage-Backed Securities are backed by single-family residential properties; and Commercial Mortgage-Backed Securities are backed by commercial real estate, such as office buildings, hotels, industrial properties and retail shopping centers.

One particularity of MBS is the possibility of prepayment, especially residential mortgages loans, so they are similar to callable bonds. From an investor's point of view, it has a lot of risk, such as prepayment risk, which can be translated into cash-flow uncertainty due to prepayment before MBS' maturity, and reinvestment risk in the case where reinvestments occur when interest rates decrease.

A Collateralized Debt Obligation (CDO) is a structured product backed by portfolios of assets. The assets that may constitute these portfolios are bonds, loans, securitized receivables, ABS, tranches of other CDOs, or credit derivatives referencing any of the former. There are different types of CDOs depending on type of products that back them: Collateralized Loan Obligations (CLO) are backed exclusively by a portfolio of loans; Collateralized Bond Obligations (CBO) are backed by a portfolio of secured or unsecured senior or junior bonds (may be corporate or sovereign bonds); and Collateralized Mortgage Obligations (CMO) are backed by mortgage-backed securities (MBSs), also called mortgage pass through securities.

Some CDOs can be classified as Synthetic: the underlying assets remain in the sponsor's bank balance sheet, so they are not transferred to the SPV. It happens when the sponsor bank buys credit protection as credit default swaps or issues credit-linked notes. The importance of this may be related with customers' relations, because a bank retains the underlying bonds/loans in its balance sheet.

An important feature of structured products market is the fact that that they are generally traded Over-The-Counter (OTC), meaning the securities are traded in a platform different from a formal exchange, such as the New York Stock Exchange (NYSE). Consequently, as defined in Dodd (2017), these platforms are less transparent and operate under fewer rules. For example, the price is not necessarily equal across all customers and dealers. Another aspect that can happens in this type of market is that dealers can simply leave the market, and so liquidity issues may arise and affect the market stability. This characteristic typically implies high transaction costs that may be large enough to discourage investors from entering in transactions, mainly in the secondary market. The issuer will also generally charge a premium for hedging expenses and for the construction and "packaging" of complex products.

There are also less explicit costs, such as the fact that when holding a product with a return dependent on an index performance, the investor is not exposed to the dividends return associated with that index. This could easily be translated in a 2 to 5 percentage points lower return – historical dividend data values from the indexes FTSE (FTSE Dividend Data, 2017) and S&P 500 (S&P Dividend Data, 2017) – than if the investor was directly exposed to the index. These characteristics will consequently shape investors strategies when working with these securities.

There are common features in both the primary and secondary markets that will essentially define the way demand, supply and prices work with this type of products. A lot of structured products available in the market have protection guaranteeing the principal payment, leading investors to look to these products as almost risk-free.

Looking to the primary market, it is commonly appointed that products tend to be overpriced. This result is demonstrated in an analysis of the German market, produced by Stoimenov and Wilkens (2005), and of the Swiss market by Grünbichler and Wohlwend (2005). There are justifications that appear to explain this behavior. For instance, this may be due to the hedge costs the issuer has to incur in to protect his position, which are especially high given the combination of different products offered in this type of products. In fact, it was observed that products with more exotic options would imply higher premiums, which aligns with this explanation.

Concerning the secondary market, being underused (Moore, 2014) and lacking in regulation and transparency can at times create an almost quasi-monopolist power that sets the rules. The non-existence of universal price models may also contribute to this effect. In fact, the price models used by each institution might be possibly wrong due to the complexity of each product, given, for instance, the difficulty to incorporate option value, consequently leading to incorrectly priced products.

A relevant point in this market is the fact that issuers or large hedge funds may become the main suppliers of the secondary market and so, due to their size, have the power to set the price and control the quantities available in the market. As mentioned by Grünbichler and Wohlwend (2005), the price in the secondary market could even seem to be underpriced. However, that scenario is in fact a demonstration of the power of those institutions, since the products from the lead managers that seem to be undervalued are the ones in which the valuation is the most time dependent. In other words, the products from these institutions are the ones whose valuation varies more through the life-cycle of the product. Consequently, the undervaluation could be simply a price level that incentivizes investors to hold the products whose valuation varies more according to the life cycle.

Also, the issuer is capable of detecting future demand for the products and consequently adjust prices. These large companies can use their information of the market to make their products more attractive, for instance setting prices below fair value to attract investors to roll-over from other investments that are reaching maturity (Grünbichler & Wohlwend, 2005).

Market characteristics such as the mismatch between demand and supply, and the inexistence of a well-defined pricing model may also imply that when an investor needs or desires to sell a product in the secondary market, the price may be undervalued, and the investor will have to accept the market conditions usually set by the big institutions.

Another important aspect that constrains the way investors interact in the secondary market is, as previously mentioned, the high transaction costs associated with OTC transaction. From the issuer's (seller) perspective, these costs can make operations attractive, even with a less fair valuation; from the investors' perspective, these costs can make the secondary market activity harmful. This is an important aspect that restraints a lot the activity in the secondary market.

However, the tendency of the price to become closer to the fair value as maturity approaches was observed in the secondary market as demonstrated by Stoimenov and Wilkens (2005), in their analysis of the German market.

Nevertheless, this type of products seems to be interesting to investors that intend to follow a buy-and-hold strategy, as the products tend to pay higher coupons comparing to other simpler products. As these products are many times linked to indexes, protected by reserves and by derivatives, they can become very attractive products for loss aversion investors.

However, an investor needs to be warned that a higher return is usually implies higher risk. As the payoff of structured products seems to be complex and dependent on several factors, such as the prepayment rate, this may lead investors to wrong inferences and probabilities misestimation, as suggested by Hens and Rieger (2008). Still, there is a possibility that the extra return could be justified by the market being underexplored and by the asymmetry of information that exists on it.

Indeed, it is always pertinent to remember that even products with principal protection can fail, as it happened with several products from Lehman Brothers, that were capital guaranteed and in the end delivered zero capital. Structured products can offer very good protections and return, but an investor needs to be well aware of their complexity, as returns depend on several market conditions, and consequently are highly time variant. They must always remember that unimaginable scenarios can always happen.

Looking from an investor's perspective, the market characteristics previously referred may allow for speculation to occur. From our research, it was found that the opportunities to make high returns are justified by the unclear market that is an OTC market, where there is not enough public information to lead markets to an efficient interaction between the involved parties. Moreover, this type of platform usually has high transaction costs. There is also the fact that the pricing mechanisms used are not clearly defined and publicly disclosed, which aligns with the fact that different institutions and investors probably have different information, leading to different price levels in the market. This combined with the market underused leads to inefficiency. All the uncertainty associated with OTC markets and the products complexity will create the need for the issuer to make the products more attractive.

The lack of liquidity in this market, mainly justified by the unclear OTC market, the complexity of these type of products, and the difficulty to reach equal and fair prices due to the possible returns being dependent on multiple factors, may contribute to the existence of market opportunities that can be exploited by investors. In other words, there may exist highly speculative opportunities.

On the one hand, the issuer needs to make their products attractive, leading to the higher coupons typically seen in these products when comparing to simpler products, or simply lower, seemingly undervalued prices. In fact, historically, according to Moody's, they have been available on the primary market below par, i.e. the security is being traded below face value, meaning it is at discount.

On the other hand, when playing in the secondary market due to the lack of liquidity, investors intending to sell their products may be forced to sell them at lower prices. Good investment opportunities can also be justified by the different price mechanisms used by the market participants.

In these market circumstances, where there is a lot of uncertainty and suspicion about this type of products, and the existence of opportunities to make superior returns can be exploited by investors, is where Moody´s Analytics operates, aiming to create a basket of services and tools to help investors better understand the market and its products, by combining historical data with the right tools to create projections on how each product can perform.

In order to make the activity in the OTC market clearer and more transparent, several institutions were created, not only to better explain what a structured product is, and the type of products available, but also to increase the regulation and the transparency of this market. Associations as the Deutscher Derivate Verband or the programme created by FINRA (Financial Industry Regulatory Authority), called TRACE transparency project in the market, work with the purpose of making this market less opaque. In Bessembinder, Maxwell and Venkataraman (2006), it was found that with the implementation of TRACE transparency project in the market, transaction costs showed significant decreases, close to 50%, and even bonds that were not under the same requirements showed reductions of 20%.

2.2. Constant Default Rate (CDR) and Constant Prepayment Rate (CPR)

This section aims at introducing the concepts that were the baseline of our analysis and, in several cases, used as inputs. The Constant Default Rate (CDR) and Constant Prepayment rate (CPR) are two important concepts, for both the borrowing and lending party, to consider when entering in a loan agreement.

The CDR is the annualized default rate on a pool of mortgages, typically within a collateralized product, as would be the case of mortgage-backed securities (MBS), described above. This percentage represents the outstanding principal balances on the pool of loans that is in default, which in most of the cases implies that the loan contract is in the foreclosure process (occurring when the borrowers fails on the payments and the lender auctions the property to the highest bidder). Considering this, one could expect a positive relationship between the CDR and the yield on a loan. In other words, the lender would require a premium to hold an asset with default risk, being the premium on the yield an increasing function of the default rate. To test this effect, we ran simulations on Moody´s Structured Finance Portal's (this service is further explained in the next section) set of tranches where the default rate was the varying input. For a specific tranche on a mortgage-backed security, we started the exercise by running the baseline scenario, in which we take the Moody´s Portal's inputs as given, assuming every other variable constant. The following steps consisted on increasing and decreasing the default rate input and observing its impact on the yield for that tranche. To summarize, the results were in line with the expectations, confirming the theoretical introduction to this rate, as we could observe the positive relationship between the CDR and the yield on the loan.

On the other hand, the CPR is a loan prepayment rate equal to the proportion of the principal in group of mortgages that is paid off prematurely in each period. As it will be further explained in a later section, prepayment may arise for several reasons, including lower refinancing rates for the loan, the case where the property ceases to exist or when the borrower experiences an increase in wealth. This action constitutes a risk for the lender (and to the holder of the structured product indexed to the mortgages) because it ceases the loan contract and the associated cash flows, mainly the interest that the lender receives for providing the loan. Therefore, similarly to the CDR, in this case an increase in the prepayment rate will increase the return required on the asset, i.e. a higher yield. To test the effect, we have performed a similar exercise to the one for the CDR based on simulations, but instead of varying the CDR, we varied the CPR and observed the effect on the yield-to-maturity. The results were in line with the previously mentioned expected implications on the return of the fixed income derivative asset. However, contrary to the CDR conclusions, this is not so linear, since in some cases prepayment might actually be beneficial and preferred by the lender, when looking to situations with a high expected default risk associated. If we consider the case where there is a high probability of failure on the payments and the loan is repaid due to an unexpected event that increases the wealth of the borrower, such as inheritance or winning a lottery, this risk is reduced, and the lender becomes better off for not having to account for so many case-scenarios where the counterparty would default. In the case the loan is fully repaid, the risk is reduced to 0% and the lender does not have to consider any default scenarios. However, it is worth considering this as a rare case with an extremely low probability of actually happening.

Considering this, one should be careful when analysing the latter concept, because its effect can be ambiguous: a higher CPR can either correspond to a higher YTM, since higher historical prepayments would result in less expected cash flows in the form of interest payments, or lead to a decrease in the YTM due to the perceived decreased riskiness associated with the full repayment of the loan.

3. Moody's Structured Finance Portal and the Interest Payments Project

In this section, we define and describe the Structured Finance Portal, our main tool for this project, where we had access to all tranches and where we have conducted the simulations to obtain our results. At a second point, we introduce and describe briefly an intermediate project we did with Moody's Analytics to correct flaws on an excel file due to a time lapse on interest payments, where we had to consider the day-to-year count on leap years *versus* non-leap years.

3.1. The Portal

The Structured Finance Portal is an online portal designed especially for investors in structured products, such as ABS, MBS and CDO, in order to easily analyze individual products and portfolios. The portal is comprised of three modules, including the monitoring module, used for comparative analytics, the cash flow module for cash flow analytics, and the regulatory module for instant regulatory metrics.

In the first module, investors can consult all the data about each deal and its tranches; for instance, capital structure (that includes currency, original balance, current balance, maturity, spread, interest index, payment frequency, and rating), information about counterparties, and relevant documents, performance, and history of payments are available. All these data allow investors to understand easily how each deal and its tranches are performing, and the data can be exported to Excel to be analysed as each investor prefers.

The second module is composed by dynamic cash flows, where investors can perform different simulations for a chosen deal, and see how it behaves for different values of CPR, CDR, and call assumptions (if it is hold until maturity, or if it is exercised). It is also possible to see the cash flows, and other relevant data, such as yield, discount margin, IRR, loss, and collateral performance.

In the regulatory module, several regulatory documents are available, and investors can perform simulations for their portfolios in order to analyse the different risk weights.

Despite its usefulness, while working on a frequent basis with the Structured Finance Portal, we have found some limitations. First, we believe that a Portal so widely used should be more efficient, as it usually breaks, takes too long to flow from one section to the other, or in some cases, even within the same section. Also, as the Portal is open to clients, the abbreviations of key variables (as is the case of the CPR and CDR) should be disclosed in a complementary note. The same recommendation applies to the formulas used to compute the different metrics presented. On a third point, considering our careful analysis and study on the metrics, we recommend adding some additional metrics to the ones presented in the Portal, as is presented further on. Adding to these, and considering that we have analysed a considerable number of tranches in the Portal, we have noticed that there was a considerable amount of information missing on a wide range of parameters and different sections, mainly on the section comprising the historical performance of the asset. Following on this point, we occasionally found information missing on the graphical representations. Mainly, we found cases where we could select a wide range of parameters to observe on a graphic, but only a few would return values and display the respective graph. Finally, in the cases where we had values, these would not always be consistent, in a sense that they were not within the acceptable range for the metric and did not make theoretical sense. An example of this would be the pool factor, one of the default variables presented on all the tranches of the Structured Finance Portal. The pool factor is simply the current balance of the loan divided by its initial balance. On one hand, we would expect it to decrease over time as the loan is repaid. On the other hand, if the loan is refinanced at some point in time, it may happen that the factor increases and, in the case where the bond is fully refinanced, that it increases to one. However, we have observed in more than one case a factor above one, and the current balance of the bond would not justify that value, which would be inconsistent.

We believe that these recommendations, when applied, would enhance the Portal experience for the end users.

3.2. Interest Payment Project

On a middle project, we also had the chance to work with other Moody's Analytics' tools, namely an Excel file on stress testing, and had the opportunity to correct some flaws. The most relevant one being the fact that annual interest payments that happened after the 28th of February in leap years were inserted as input, so they were not calculated in Excel, and considered that 366 days had passed since the last payment, while simultaneously considering that the year's duration is 365 days, and the other way around in years following the leap year. Since the Excel model considered that a full year had passed between dates, there was a mismatch between the interest as an input and the interest predicted by the model, which would result in the model predicting losses, and as a result would lead to a downgrade in the product's rating.

Downgrades in the ratings of structured products like Asset-Backed Securities are rare and usually followed by consequent negative returns, which also reflects the severity of downgrades based on miscalculation.

4. Metrics Project

4.1. Introduction to metrics

This section of the report aims at describing the metrics that were analysed and tested on a sample of tranches provided by Moody's Analytics. After a careful analysis, we present the main results and conclusions about each metric's relevance, and give a final opinion on whether Moody´s Analytics should add them to the Portal.

In a financial environment that offers a diversified range of financial assets, metrics play an essential role on the decision process. These can be used as the baseline of a score system for each unique investor background, to measure the risk-reward relation, to choose the best assets to meet financial needs or simply to compare different assets with similar requirements. Moreover, metrics assess the different dimensions of risk at a security level and at a portfolio level.

Our analysis focuses on structured fixed income assets, mainly on how each metric behaves within different deals and associated tranches, in terms of seniority, maturity and cash flows. This section aims at understanding how these perform under different scenarios, having as ultimate objective to measure these effects and assess the different types of risk that each involved party bears by entering in the deal with specific contractual conditions.

The metrics were grouped into four main groups: Input metrics, Spreads & Returns, Risk measures, and the Greeks. Within each group, we present them in our perceived order of relevance (from most relevant to least relevant) for structured products, particularly for the type of structured products we dealt with. The analysis starts with a theoretical background on each metric, followed by a practical interpretation reflected by our expectations on their behaviour under different scenarios. The third step involves the metrics calculation on a sample of tranches and inputs from the portal. Finally, we provide the results, the main conclusions based on an expectation *versus* reality matching process, and conclude on the relevancy of each metric.

4.2. Input Metrics

The metrics that constitute this sub-chapter are three metrics that from our view have an enormous impact when analyzing structured products, and consequently lead investors to better decisions. The more accurate projections we have regarding Interest Rates, Prepayment and Call Option exercise (the metrics on this section), the more accurate the results on returns, maturity, and risk for structured products, the subjects assessed in the next sub-chapters, which typically use these three as inputs in the calculations.

4.2.1. Projected Interest rates

Valuable as it reflects current economic conditions and future expectations.

Definition:

Projected interest rates are the forecasted rates for bonds maturing in the future. The methodologies vary widely across different institutions. For this project, the projected interest rates were assumed to be the forward curves for Libor, Euribor and GBP Libor available in the SF Portal. The curve tends to reflect the expectations for the future. Normally, the yield curve is shifted upwards because it reflects inflation, thus positive expectations regarding the future economy.

Interpretation/Results:

We could observe that all three curves show an upward trend, with a flattening of the curve in the longer run. It is also important to note that the Euribor starts out with negative values, denoting the current prospects of interest rates in the Eurozone, which are still dropping.

According to the presented forward curve, the expectations are for them to only become positive in around 2 years.

As a forward curve is computed through the spot rates, the shape of the curve makes sense considering a normal economic scenario, in which economic agents add a premium for the uncertainty of future economic conditions, stabilizing in the more distant future, for which expectations cannot be made completely yet.

Considering this, this metric is useful and relevant for at least one fundamental reason: it reflects current economic conditions and future expectations. To illustrate this, consider the case where there is a credit crash, and nobody is willing to lend money because of fear of not getting paid back. This would invert the normal interest rates curve, since, in this situation, current interest rates would be extremely high, as economic agents would require high premiums to lend money. However, the situation is not expected to hold indefinitely and as the economic outlook is expected to improve, agents demand a lower premium for future dates.

4.2.2. CPR Estimation: Richard and Roll (Goldman Sachs Model)

Valuable, as it is more adaptable to different products than the PSA model.

<u>*Definition:*</u>

One of the most popular ways to replicate the prepayment behavior in a pool of loans is by using the Public Securities Association (PSA) Standard Prepayment Model. The intuition behind this model is that in the beginning, the rate of prepayment on loans is low, linearly growing until it stabilizes. However, Moody's Analytics asked us for an alternative to the PSA Prepayment model, hence we present the Richard and Roll (1989) model. Unlike the PSA Prepayment model (which simply assumes a linear growth of the CPR and then stabilizes it), this model can be adapted to different products, hence having better prepayment prediction power. It considers factors like the current incentive for homeowners to refinance, the maturity of the product, seasonality, and the current pool.

The refinancing incentive can be calculated the following way: $Refinance = 0.28 - 0.14 * \arctan(-8.571 + 430 * incentive)$. With the $incentive$ being the Weighted Average Coupon – Mortgage Rate prevailing at that time.

The seasoning/age of the mortgage variable applies the reasoning behind the PSA model: in the first months, the prepayment is low, increasing until it stabilizes.

The month of the year multiplier considers the month of the year and associates a given multiplier. Starting from January until December we considered: 0.94, 0.76, 0.74, 0.95, 0.98, 0.92, 0.98, 1.1, 1.18, 1.22, 1.23 and 0.98.

The Burnout multiplier which can be calculated the following way:

$$BM(t) = 0.3 + 0.7 * PoolFactor$$

Finally, $CPR = Refinancing * Seasoning * MonthMultiplier * Burnout$

Since this metric was suggested by Moody's Analytics, it was not present on the SF Portal. However, most of the inputs were available, except for the prevailing mortgage rate.

Interpretation/Results:

The downside of this model is the need to estimate and adapt the models that deliver the factors/inputs of the main model.

Moreover, the CPR is an annual measure, since payments are often made monthly, so one should transform the CPR in a Single Monthly Mortality Rate (SMM) the following way: $SMM = 1 - (1 - CPR)^{\frac{1}{12}}$. Both the CPR and the SMM are in percentage of the scheduled principal balance for that month. In order to apply these measures, one should calculate the scheduled principal (regardless of the prepayment) and then subtract the respective percentage given by the SMM, which should result in the actual principal balance.

4.2.2.1. Empirical performance of the Richard & Roll model (Luís Bettencourt Individual report)

In this section we will compare how this model behaves in comparison to the Public Securities Association (PSA) Prepayment Model empirically. The importance of accounting for prepayment risk resides in the fact that the loans backing the MBSs are mortgages, therefore the homeowners (borrowers) have the option to anticipate principal payments. Although one could see that anticipated payments reduce the riskiness of the product, it will also affect the cash flows during its life spam since the interest will be calculated upon a lower principal.

The Richard and Roll (1989) model determines a CPR by calculating the product of the following four multipliers: **Refinancing Incentive**, this multiplier is obtained by modelling a relationship between CPRs and a refinancing incentive that is given by the difference between the Weighted Average Coupon (a weighted average of the rates in a pool of mortgages using the pools as the respective weights) and a refinancing rate which we will assume as the ten year mortgage rate, and fit it in the following equation: $CPR = a + b \arctan(c + d(WAC - r_{10y}))$. This should behave like a call option of a stock in the sense that when the refinancing incentive is below zero the CPR should be low since homeowners don't have an incentive to refinance their mortgages when the new rate (r_{10y}) is higher than their current one (WAC), moreover, from this point onwards there is an incentive for refinancing and the CPR should increase quickly and then reach a flat level; **Month Multiplier**, this factor tries to capture the empirical evidence that prepayments are higher in Summer/Autumn months, Huang (2006) points to the seasonality of house turnover, weather and school schedules as possible factors; **Seasoning Multiplier**, this translates another empirical evidence that prepayments are lower at the inception and then gradually increase, arguing that homeowners are less likely to refinance new loans; and **Burnout Multiplier**, which accounts for the fact that prepayments decrease over time since borrowers who are more likely to refinance do it early, therefore this multiplier takes into account the current balance as percentage of the original balance (Pool Factor), thus decreasing the CPR of older loans.

The PSA prepayment model only follows the logic of the Seasoning Multiplier by assuming the CPR to increase linearly from 0% in the first month to 6% in the 30th month. However, there are variants to the PSA model. The previous one is considered the 100% PSA model, a 200% PSA model would increase linearly until 12% in the 30th month, so one can adjust the model to the expected level of prepayment of the product.

The data used was available in the Moody's SF Portal, besides the mortgage rates which were made available by the Eurosystem. The chosen securities were the ones that were both available to this project and that had all the required data to estimate the CPRs, which resulted in a total of 233 historical payments from 6 different securities as observations. Moreover, the parameters considered for the Richard and Roll (1989) model are: refinancing multiplier $= 0.28 + 0.14\arctan(-8.571 + 430 * (WAC - r_{10y}))$, as suggested by Pachamanova and Fabozzi (2010); month multipliers are, from January to December respectively, 0.94, 0.76, 0.74, 0.95, 0.98, 0.92, 0.98, 1.11, 1.18, 1.22, 1.23 and 0.98, these were taken directly from the Richard and Roll (1989) paper; seasoning multiplier is equal to minimum between the maturity in months divided by 30 and 1; and the burnout multiplier is equal to 0.3 + 0.7 * Pool, these last two factors were also suggested by Pachamanova and Fabozzi (2010).

The following procedure was performed to compare both models: estimate each model's CPR, as described before, and take the absolute of the difference between the results and the reported CPR given by Moody's SF Portal (by taking the absolute, we give the same importance to deviations above and below the reported CPR). While the PSA Model CPRs' deviated 354 basis points on average from empirical data, the Richard and Roll (1989) model deviated on average 402 basis points from reality, and was also empirically closer than the PSA model only 40.77% of the times. We also found which would be the in-sample optimum level for the PSA model, the level that returns the lowest average of deviations from empirical data, which was 124.5% and returned 336 basis points of average deviation. Since it was obtained through an in-sample optimization, it should necessarily return better results than the 100% PSA model.

Although at first sight this should imply that the Richard and Roll (1989) model does not predict efficiently the CPR, we will present arguments that may explain the model's poor performance. Firstly, the data used to model multipliers such as the Refinancing Incentive or Month Multipliers is North American, while in the sample we predicted CPRs for European deals, and since the latter is influenced by seasonality and housing turnover, it should be based on how Europeans react to those factors, moreover it considers data from almost three decades ago. Hence, the parameters should be frequently adjusted with recent and appropriate data, regardless of the theory behind the model which is logical and applicable or adaptable to both North American and European, for example both should behave accordingly when facing lower refinancing rates in comparison to their current mortgage (regarding the refinancing incentive). Another reason that can justify the model's performance is the calculation of the refinancing multiplier. Among the four factors, the refinancing incentive is the preponderant one in determining the CPR while the others just adjust it, hence the concern of having its model estimated properly. The model with the inverse function of tangent becomes flat for both the lowest and highest values, so it only starts to "react" when it reaches refinancing values above 0 (when the homeowner option to refinance is "in the money") and then it starts to become constant afterwards when it reaches values around 3% of refinancing incentive. This is relevant for our analysis since in our data the refinancing incentive was positive only 10 times out of the

233 observations (4.29%), moreover, when calculating the average of the absolute of the deviations while only considering the observations with positive refinancing incentives it goes from the previous 402 basis points to 172 basis points. Although this would suggest that under these circumstances the model performs better, one should consider that the sample is of only 10 observations and that having a negative refinancing incentive is common.

In conclusion, theoretically there is a logical reasoning behind the Richard and Roll (1989) model that can be applied to MBSs regardless of their origin. Although the results suggest that the PSA model outperforms this model, we believe that if one estimates new parameters using data that is recent and geographically or demographically relatable to the respective security, one could get a better performance from the model.

4.2.3. Call Projection

Could be highly valuable, however it is necessary to develop a model to catch the impact of the several factors.

Definition:

There are several factors that matter when deciding whether to exercise a call option. The most famous is changes in interest rates. When issuers have a call option on the outstanding debt, they have the power to redeem securities. In a very simplified world, they will exercise this option when interest rates go down, as they can now access debt at lower prices.

However, several other reasons interfere in the decision. Factors as company risk, extra commissions, extra interest costs, liquidity and even inflation have an important role in the decision.

Interpretation/Results:

When a company's risk increases, debt will become more expensive due to the company profile. Even if general debt cost decreases, it may not compensate the increase in the specific risk profile.

Regarding extra commissions, we have to take into account the fact that going to the market to buy back debt, and then (after it moves) to refund again, will imply extra commission costs that have to be taken into consideration in the final decision.

Inflation is also a relevant factor when exercising an option, since if the nominal interest rates go up, it does not necessarily mean that real interest rates follow that movement. Real interest rates equal the nominal interest rate less inflation; therefore, if a increase in a nominal interest rate is overcome by an increase of inflation, the issuer will decide not to exercise the option.

The decision to buy back debt implies the necessity to have the whole amount of money on hand. In the case you cannot get new funding before the repurchasing, this implies an interest loss as it will be necessary to use reserves that could be gaining interest. Another important point that is highly related to this one is liquidity, as the transaction requires the existence and availability of high quantities of money.

All these factors will interfere in the decision to exercise a call option. It does not depend only on interest rates fluctuations.

This tool can be very useful to investors as these products are typically exposed to the options being exercised; consequently, investors' return and investment life time may be affected. With this metric, investors can create more realistic expectations.

This can be very hard to predict and there is not yet any model to make this projection. In the section "A new approach to project structured products returns", a suggestion on how we can try to predict call date is presented.

4.3. Spreads & Returns

In the following section, we will discuss metrics related to the return of the products. Returns allow investors to be aware of the performance of their investments and if they are being properly rewarded for their level of risk. One of the main characteristics of structured products is the fact that they rarely reach maturity, therefore the prediction of return should take this into account.

This characteristic arises from the fact that the product usually has an embedded call option from the selling side, which is often exercised by the issuer since it may happen that as the product's life moves towards maturity the principal of the product diminishes, such that the costs of maintaining the remaining principal are higher than its return, hence the call is exercised. Also, another factor is the uncertainty of the cash flows, either because of the risk of default of the pool's loans, or the prepayment risk in the case of CDOs and MBSs.

Moreover, some of the metrics are Spreads, which allow investors to evaluate the return from an incremental point of view relative to a benchmark (usually the treasury bill curve or an interest rate swap curve).

These metrics should address the expected returns under different scenarios, mainly considering the different possible maturities the structured product may reach.

4.3.1. Spreads

4.3.1.1. Option-Adjusted Spread for Prepayment

Valuable because it considers the prepayment options and time effect.

Definition:

The OAS for prepayment is calculated as the difference between the Z-spread, explained further on, and the option of prepayment (Pereira, 2017):

$$\text{Z} - \text{spread}(\%) = \text{OAS}(\%) + \text{Option Cost}(\%)(\text{Prepayment})$$

As previously mentioned, prepayment is most common in low interest rates environments, and it might be a risk for the bondholder because once the issuer makes an early payment of the bond, its holder stops receiving the Cash Flows inherent to the asset. However, it may constitute the case where the bond has a substantial risk of default and its holder actually benefits from the fact that it is prepaid, which would happen if for example the borrower suffers an unexpected increase in the wealth. This would not be taken into account in ex-ante expectations, but in the realized return of the bond. Also, it is worth mentioning that this is a rare case with an extremely low probability of happening in reality.

Interpretation/Results:

To obtain the value of the OAS, we have used the results from the simulations ran on the Structured Finance Portal. The scenarios used for the simulations assumed a set of inputs for specific tranches from a given basket of deals given. The main difference between the two scenarios was that the first would assume that the bond was carried until the maturity date, and the second assumed that the bond would be called before reaching the maturity date. Therefore, the option value was obtained as the difference between the first scenario and the one where the bond would be called. Finally, the Z-spread was given directly in the portal. The OAS was calculated as the difference between the Z-spread and the option value, using the relation in the formula described above. However, it is worth noting that this procedure, which was a Moody´s indication, is part of a simple exercise we did in the Portal to illustrate the effect that the existence of the option, has on the bond, and that real options prices are not computed using this methodology as the option value is the result of several different scenarios that may occur.

Regarding the results, in all deals and tranches considered, the prepayment option was negative. This result implies an OAS bigger than the Z-spread meaning that the return received by the investor when removing the return implied with the option exercise, is larger than when accounting with the option. This can be explained by the fact that when there is a considerably high prepayment rate, issuers face the risk of having the sum of the time weighted payments decreased, assuming a constant price, the investor return may end decreasing due to the

We do believe OAS should be included, not only applied to the prepayment option but also to the call option, as this spread denotes the true return from the security itself, without the options, making it more correct for comparisons to products without options.

As previously mentioned, this metric is more reasonable than the Z-spread, as the first one removes the option value from the security making it more correct to compare to other products in particular when looking to portfolios with stripped securities.

Therefore, when working with structured products, which are typically exposed to prepayment options, OAS is a better metric than the Z-spread. The Z-spread assumes products reach maturity and that its cash-flows are not affected by the option, consequently it gives a spread that it is highly probable to be wrong. Being it more correct to use the OAS that clean the option risk looking to total spread of the security in the best scenario (Z-spread) minus the risk/cost associated with that option.

4.3.1.2. Option-Adjusted Spread Applied to Calls

Valuable because it considers the call option's value and time effect.

Definition:

As mentioned by Pereira (2017a), the option-adjusted spread for callable bonds is the spread of a fixed income security that is adjusted to take into account the embedded option, by removing the option value, on other words by removing the percentage value associated with the specific risk of the option. The call option benefits the issuer of the bond because it gives the option to buy back the bond if rates increase, i.e. if the bond's price goes down. Following this, investor will demand an extra return for holding a bond with this feature. For instance, considering a product with an embedded option, for compensate the extra return the issuer pays a higher coupon. It is not correct to simply do not take into consideration the associate risk to the option and compare the spread in this situation (Z-spread) to the spread of a security with no embedded option and consequently no option risk. In order to do a fair comparison, it should be subtracted to the Z-spread the cost (risk) associated with the option.

The Option-Adjusted Spread (OAS) for a bond with an embedded option is the value that solves:

For a callable bond, or bonds with prepayment options:

$$Z - spread(\%) = OAS(\%) + Option\,Value(\%)$$

On the other hand, if we were looking to calculate a puttable bond, the formula would be:

$$Z - spread(\%) = OAS(\%) - Option\,Value(\%)$$

where the Z-spread is computed as described further in Z-spread) and the embedded Option Value is computed with an option pricing model.

<u>Interpretation/Results:</u>

Regarding factors that affect OAS, let us first observe the implications of a call option. A call option in a bond gives the issuer the right to buy back the bond, meaning that when market conditions are favorable to the issuer – namely lower interest rates –, the option to buy back the bond is available, thus increasing reinvestment risk to investors, who as a result will demand a higher yield to compensate. Therefore, the option adjusted spread of a callable bond should be smaller than the Z-spread.

As OAS removes the option exercise risk, it is a superior measure to compare returns between products with different characteristics, which a normal z-spread and nominal spread do not take into account. As structured products' cash flows may be highly volatile due to the embedded call options, which are typically exercised before maturity, this metric should be a better approach than the Z-spread to compare to other products that may not have embedded options. When working with structured products it should be used the OAS and not the Z-spread as the last does not take into consideration that the product cash-flows may be affected by the embedded option.

4.3.1.3. Spread to Option Adjusted Spread (Prepay)

Valuable as it allows investors to easily analyze the extra reward of holding this type of risk.

Definition:

This metric is commonly used in the market, to understand it, the OAS and Z-Spread concept must be clear. When considering two similar products, with one of them with an embedded option and the other without, it is not fair to compare the total return of these products as captured by the Z-spread. To make the analysis right, the OAS should be used, since it will be adjusted to take into consideration an embedded option, giving a more accurate spread of the product as it removes from the Z-spread the cost that come from the option. And then, it is possible to compare the option return with its risk.

Spread to OAS gives a relation of the extra spread demanded resultant from adding an option to a security. This comparison can be made through a ratio (division) **(Function 1)** or absolute difference (subtraction) **(Function 2) –** the former being a more relative value. Both approaches seem useful and quite similar but capable of different inferences.

$$1)\ Option\ value = \frac{Z - spread}{OAS}$$

$$2)\ Option\ value = Z - spread - OAS$$

In the case of structured products, there is the option of prepayments – consequently, the risk of less interest to an investor when comparing to a product without a prepayment option. Thus, it is expected investors are being rewarded to support the existence of this risk.

Interpretation/Results:

To calculate this metric, we used the Z-spread and the OAS, both calculated as explained in their specific sections.

In our scenarios, a negative return value was always associated with the prepayment option, which makes sense since the prepayment option will decrease investors' interest payment. That way, investors will receive less return when the prepayment option is available comparing to an all equal scenario but with no CFs change due to the existence of the option – in other words, compared to the value given by the Z-spread.

This metric is important as it gives investors the possibility to easily analyze the extra reward that they should demand due to the option exercise risk, and to compare in similar conditions how different tranches within the same deal are rewarded for that risk (since different tranches have a different exposure). Following this, it can be very useful to an investor looking to structured products, as these products typically have a prepayment option and so this option allows the investor to see what is the extra reward that may come from the option and compare it the associated risk.

4.3.1.4. Spread to Weighted Average Life

Valuable as it gives a more accurate value to the possible excess return that could come from each product.

<u>*Definition:*</u>

This metric was designed by us together Moody´s following their expectations on what it should measure, it is something new that is not currently being used in the market or by the institution. It gives the spread of a given security in the case in which the maturity equals the average life. The weighted Average Life concept is widely known and it is the average time to receiving principal payments. It is a weighted average of the time until full repayment of principal, based in each principal repayment value and time lag, as mentioned in Finance Train (2015).

$$WAL = \sum_{i=1}^{\eta} \frac{P_i}{P} \times t_i$$

Where P is the total principal, P_i is the principal repayment included the payment of period i, and t_i is the time lag until payment i.

In the particular case of structured products, this can be very useful due to prepayments and call options, as these particularities tend to affect the security maturity. Consequently, spread to WAL could be a better approach of the observed extra return.

For instance, let us imagine an investment with 3 years but with a WAL of 2 years, with principal divided by the three periods **(Price Function 1)**. In order to reach the yield to WAL it is necessary to distribute the total principal by the 2 periods (WAL) in order to reach a maturity of 2 in this new equation **(Price Function 2)**. With the new principal distribution and with less one period, the yield that equalizes the discounted CFs to market price is the yield to WAL.

$$1) \quad P = \frac{P_1 + C}{(1+YYM)^1} + \frac{P_2 + C}{(1+YYM)^2} + \frac{P_3 + C}{(1+YYM)^3}$$

$$2) \quad P' = \frac{P`_1 + C}{(1+Yield\ to\ WAL)^1} + \frac{P`_2 + C}{(1+Yield\ to\ WAL)^2}$$

Where P_i is the principal payment during period i, C is the Coupon payment and P'_i is the principal payment considering a life time equal to WAL.

Regarding structured products, the security life is typically smaller than the pre-specified maturity. Thus, spread to average life should lead to a more realistic value to investor.

Another relevant point of this metric is that it is used to price MBS, such as CMOs issued by the Federal Home Loan Mortgage Corporation and others issued by private institutions. Usually securities exposed to repurchase and prepayment risk that are trading below par are priced with the yield to average life due to price stability.

<u>Interpretation/Results:</u>

There are three main observations that arise from the analysis that was computed:

1. A trend in the reduction of periods to maturity as CPR increases is usually observed. For example, a 10pp increase in the CPR was usually matched by a reduction of 2 periods of maturity. However, all this impact is conditional on the cash flows distribution within the tranches;
2. Regarding the impact in yield, it has no apparent trend as it goes up and down. It is simply justified by the risk of each security, as sometimes, in the case of risky securities, guaranteeing the payment and paying it back faster is a plus. However, reducing the maturity implies less interest payment and so investors can require a higher yield;
3. A problem observed with this metric was in the case where the principal payments are well-defined and not possible of change. Consequently, changes in CPR do not affect maturity and so this metric has no value in these cases.

A similar metric that could be relevant and interesting to use would be $\frac{Spread}{WAL}$. This metric can be useful as it allows to infer the return per a unit of average invested time, thus being a valuable method of comparison.

4.3.1.5. Spread to next call

Valuable because it allows for a good comparison between different products under the same scenario.

<u>*Definition:*</u>

The Spread to next call was suggested by Moody's Analytics and it uses a spread added to each point of a theoretical spot rate Treasury curve, such that when we apply them to discount the bond's cash-flows we get its market price. The Spread to next call (s) is such that:

$$Price\ of\ Bond = \frac{coupon}{(1 + r(0,1) + s)^1} + \cdots + \frac{coupon}{(1 + r(0,T) + s)^T} + \frac{call\ price}{(1 + r(0,T) + s)^T}$$

Although not available at the SF Portal, one could generate the cash-flows of the bond until the next callable date.

<u>*Interpretation/Results:*</u>

We want the spread(s) that sets the Bond's cash-flows (until it is called in the next callable date) equal to the market price – higher spreads mean higher risk for the Bond.

It is a measure of the credit risk of the product when this is called, hence a higher value should indicate higher risk. This is particularly important since the one with the right to exercise the option is the issuer.

4.3.1.6. Spread to Worst

Valuable because allows investors to compare the excess return in the worst-case scenario across different products.

Definition:

Although not directly present in the Structured Finance Portal, this metric was calculated by running a scenario where the call option on the product is exercised as early as possible and another one where the product goes until maturity, and then choosing the lowest Yield from both scenarios. While in the first scenario the product stops earning interest earlier, in the second the product suffers the losses until the end.

Interpretation/Results:

The worst yield (Spread to Worst) among these scenarios informs the investor of the worst possible outcome. Both scenarios frequently ended up providing the same Yield and DM when ran in the SF Portal.

A product presenting a higher Spread to Worst shows a relatively higher return when compared in these two scenarios.

4.3.1.7. Z-Spread

Not Valuable, although it takes into attention the time effect, it has the option value embedded and it runs until maturity

<u>*Definition:*</u>

Z-spread is the constant spread that gives the price of a bonds, as a sum of the present value of its cash flows when added to the yield at each point on the implied spot rate curve where a cash flow is received, assuming that the security reaches maturity. It is a better mechanism to calculate the spread to maturity than the nominal spread, as it takes into consideration time fluctuation through the use of the implied yield curve. In other words, it measures the spread that an investor will receive over the implied yield curve. (Fabozzi, 2007)

$$P_0 = \sum_{t=1}^{T} \frac{C_i}{[1 + r(0, t) + z]^t}$$

where C_i is the total cash flow paid at time t as a fraction of par value, P_0 stands for price of the bond, Present Value of cash flows, r(0, t) is the spot rate for maturity t, and z stands for the z-spread.

The Z-spread allows to understand if there is any mispricing in a bond. It also represents the additional risk that is taken, such as credit risk, liquidity risk or option risk. As a result, a higher value of the z-spread indicates that a security has more risk, since the return offered must be higher to compensate for the increased risk. In case of bonds that have a call option, the purpose of a higher Z-spread is to cover the possibility of the security being called back. The option can also be a prepay option, which is very common in MBS, as it can have the possibility to prepay the principal.

Interpretation/Results:

This metric is already used by Moody's, although it is mentioned as "spread" and to get the Z-spread we assumed that tranches were run until maturity.

Analysing the values of Z-spread between different tranches over several deals, it is possible to conclude that more senior tranches have a lower Z-spread than junior ones, which is reasonable because more senior tranches are less risky than junior ones.

Nevertheless, when considering a security with an embedded call option, Z-spread is not the best metric to compare this security's return with the one from a security without an option, as it gives the total return of the security, including the option spread. If the objective is to compare the specific return of the products, z-spread is not the correct approach.

This metric is easy to understand in terms of returns when additional risk is taken, although investors should be careful when analysing structured products, therefore the Option-adjusted spread should be preferred, as it gives the specific return of the product without the option.

4.3.1.8. I-Spread

Not valuable because OAS is a better approach when looking to products with embedded options.

Definition:

It is the difference between bond's yield to maturity and interest rate swap, interpolated from the par Interest Rate Swap curve (CFA, 2015). I-spread can be considered as a risk premium. It overcomes the issue of maturity mismatch; however, it does not coincide to the yield to maturity of a traded reference bond.

$$YTM_C = IRS + I\ spread$$

$$Current\ Market\ Price = \frac{C}{(1 + IRS + I\ spread)} + \cdots + \frac{C + P}{(1 + IRS + I\ spread)^n}$$

where YTM_C is the yield to maturity on the corporate bond, IRS stands for the interpolated rate from the par Interest Rate Swap curve, C the coupon payment and P the principal payment.

Interpretation/Results:

This metric is not present on the Moody's structured products portal, and to assess the impact of I-spread, we considered an initial price of 100 and respective yield, and according to its maturity and currency a correspondent Swap rate was used. In the analyzed deals, I-spread was higher than the yield when the interest swap rate was negative. Also, more senior deals have a lower I-Spread, that results from a lower yield.

I-Spread considers the shape of the term structure of interest rates, though only in a very crude way, providing a spread that takes into consideration only a simple/linear benchmark yield. Consequently, the use of the Z-spread, which considers for each period the specific yield of a zero coupon with the right maturity and thus gives the extra return against a benchmark, while taking into consideration the right reinvestment risk, is a better metric when looking to the overall return of holding a product. When comparing different products, Option-Adjusted spread would be a better measure, as it takes into consideration, excluding, the option value.

4.3.1.9. Nominal Spread

Not valuable as structured products do not usually reach maturity. Also, due to time fluctuation, OAS is better for these products.

Definition:

Nominal Spread is an existing metric commonly used. It is the difference between the yield to maturity that sets a security price equal to the current market price and the benchmark yield to maturity, generally the YTM of a similar maturity Treasury bond.

In simple words it is how much more or less is the market willing to spend in that security against the benchmark yield to maturity.

$$Nominal\ Yield\ Spread = Security\ YTM - Benchmark\ YTM$$

This spread only takes into consideration a single moment in time, as it only needs the benchmark YTM – that is the YTM, at that time, of a treasury bill with a similar maturity as the product in analysis. It is consequently exposed to time volatility and also ignores the effect of options, as the market price and the coupon correspond to the product as a whole. It is possible to infer this by looking at the following function:

$$Current\ Market\ Price = \frac{C}{(1 + R_f + S)} + \frac{C + P}{(1 + R_f + S)^n}$$

where C is the coupon payment, P the principal, R_f stands for benchmark yield to maturity and S for nominal spread.

Interpretation/Results:

This metric is broadly used, and it comes from the YTM that is frequently used to price products, mainly due to the fact that it is easily computed. This metric is not displayed in Moody´s portal yet, as the spread given by the portal is adjusting the benchmark for each period.

However, there are two relevant main aspects: the fact it does not incorporate time variation, as it is fixed to a single point; and the fact it gives a return with the option embedded. Consequently, there are other metrics, such as the z-spread and the OAS, that are relatively better than this one.

Concluding, we do not believe nominal spread is a relevant metric when dealing with structured products (which usually are not held until maturity), rendering this metric an inaccurate measure of the possible returns. Also, as this metric is not exposed to time

4.3.2. Returns

4.3.2.1. A new approach to project structured products returns (João Correia Individual Report)

Introduction: Moody´s plays an important role supporting investors in their decisions to invest in structured products. However, the classic framework that are used or suggested by Moody´s do not allow to capture the complexity of this type of product and market conditions.

Example of these products´ complexity is the fact that these products are usually dependent on call options, on underlying assets´ performance such as mortgages or assets performance, that can default or prepay, and they also depend on market conditions that define the collateral principal prepayment. Thus, a simple change in the market interest rate may imply a change in the prepayment rate or even imply the exercise of a call option, and change the expected CF´s distribution, with implication on the expected returns and maturity.

Focusing on some of the proposed metrics, the yield to maturity is not correct as these products do not usually reach maturity. The yield to average life (WAL) may be a better approach, as the investment horizon is possibly more accurate this way. However, it still is it is not the best approach as the average life manipulates the CF´s distribution to reach a maturity equal to WAL. As shown in the following formula $WAL = \sum t * \frac{P_t}{P}$, where t refers to payment period, Pt is the principal payment done at each period and P is the total principal, WAL takes only into account pre-defined principal distribution, not taking into account the market condition that could lead to change in prepayment rate nor the exercise of a call option. Another two analysis tools on this subject are the yield to next call and the yield to workout date. These metrics have limitations on forecasting the return and the security maturity, as they do not account for changes in principal distribution. Instead, they simply assume a date where the call will be exercised and force the call at that date, doing a principal balloon payment (example of this metric problem in appendix 1).

Approach: In this section we suggest a new approach, that can be easily added to Moody´s portal, to project cash-flows distribution and consequently returns and maturity for structured products, particularly concerning mortgage backed securities (MBS). Taking into account the products´ complexity, namely the market condition and different factor that may affect CF´s distribution, we will focus on three aspects: a) Unscheduled Principal distribution, using the Richard and Roll (1989) model; b) Coupon payment- no changes suggested to Moody´s approach; c) Call-Option exercise date, defined in a rational way and based on historical data.

a) Prepayment will affect all the principal distribution of these products and consequently the interest payments and so affecting return and maturity of investments.

To project the unscheduled principal payment associated to each period it should be used the following formula $Unscheduled\ Principal = Beg.\ Poll\ Balace \times \Big[1 - (1 -$

$CPR)^{\frac{1}{Frequency}}\Big]$. This formula combines the remaining principal available at the beginning of each period with the Constant Prepayment Rate (CPR) value and with the frequency associated to principal payment (e.g. monthly, quarterly, yearly). Please note the importance of the CPR, making it a necessary input that we need to project for each of the following periods of the product lifetime.

To forecast the prepayment rate we suggest to do an adaption of the Richard and Roll (1989) model, which has the objective to create projection about prepayment rate for each period given the economic conditions observed at each period. With it we can create predictions today on how product cash-flows distribution may be affected. Being clear that this model was developed for MBS, we are currently focusing on these particular type of structured products.

The model is based on four main factors: the tendency to refinance, seasonality, seasoning and burnout. The refinance incentive is the one which needs a deeper look. This factor compare what people are actually paying, in the form of weighted average coupon (WAC), to what they could be paying each period, being necessary to project these two inputs.

Pachamanova and Fabozzi (2010) suggest using a 10 years' mortgage rate to define what people could be paying. Following their suggestion, several mechanisms can be used to project the 10 years rate in the next periods ($\mathrm{r}\ (\mathrm{t}; \mathrm{t}+10)$). Some methods more complex could be used such as econometrics models or a Monte Carlo simulation. We suggest a simpler way in order to make easier for Moody´s to implement the proposed approach to their portal. Our proposal follows the formula, $r(t;10+t) = \left[\frac{(1+r(0;10+t))^{10+t}}{\left(1+r(0;t)\right)^{t}}\right]^{\frac{1}{10}} - 1$, where the inputs r(0;t) and r(0;10+t) can be projected using several approaches. The inputs can be calculated using a linear interpolation or the Nelson and Siegel (1987) model. The model allows to construct an equation for mortgage rate and so reaching the necessary inputs directly, not requiring to produce an interpolation, to calculate the future rate in place at time t, $r\ (t; t+10)$. We believe this is the best approach.

This model follows a parameterized structure: $r(t) = a + b \times \frac{\left[1-e^{\left(-\frac{t}{\gamma}\right)}\right]}{\frac{t}{\gamma}} + c \times \left[\frac{\left[1-e^{\left(-\frac{t}{\gamma}\right)}\right]}{\frac{t}{\gamma}} - e^{\left(-\frac{t}{\gamma}\right)}\right]$ where t is the maturity and a, b, c and γ are parameters to be estimated based on the following optimization process: minimize subject to a, b, c and γ of the $\sum_{i=1}^{I}(Bond\ i\ market\ price - \ Bond\ i\ price\ based\ on\ NS\ model)$, where the $Bond\ i\ price\ based\ on\ NS\ model$ follows the rate proposed above by Nelson and Siegel (1987), being it equal to $\frac{coupon}{coupon\ frequency}\sum_{j=1}^{m} e^{-r(tj)tj} + e^{-r(Tm)Tm}$. What we are doing is finding the more accurate values for a, b, c and γ that minimize the error between the bonds market prices and the bond prices based on the rates that are estimated based on what is proposed by Nelson and Siegel (1987). Based on this it is necessary to define which type of bonds should be used to follow the optimization. As previously mentioned we pretend to use mortgage rates. As it is previously explained the model needs data on bonds with different maturities available in the market. We suggest using government/agency bonds such as the issued by Government Sponsored Enterprises, for example by Freddie Mac or Fannie Mae, which are entities created with the objective to develop the home ownership in the USA.

With the needed mortgage rate projection defined, we can focus on the weighted average coupon (WAC), which is a weighted average return that is paid by the collateral pool in each period. To make an accurate projection on this input it would be necessary to have more detailed information on the composition of the pool. We can use several ways to define the WAC level to be used. For simplification and when historical data on pool performance exists, it can be assumed that the WAC remains constant over time and equal to the last value that we have information. We may also want to build a projection based on the pool consistency and on its characteristics- information available at Moody´s portal- for the following cases: being in the beginning of the product life, not having historical collateral performance, or in the case the product is not in the beginning, but we intend to perform a complex projection on WAC value. From our experience the mortgage payment can depend on Euribor plus a spread, if we can project the future Euribor rates and get a more accurate WAC forecast.

With the WAC and mortgage projection created it is possible to reach a projection on the CPR for the following periods and consequently the unscheduled principal payments, and so reaching what should be a more accurate projection on what should be the total principal payment distribution adding the scheduled and the unscheduled.

b) On the Coupon payment projection theme, we follow the Moody´s approach that is through a linear interpolation. If the coupon payment is a spread plus a rate performance, for instance the Euribor 3 months, the forecast for the next months is done using the 3 and 6 months Euribor.

c) Call option which may affect the cash-flows distribution. Focusing on clean-up call options, a type that is very common in MBS, the issuer has the right to call back a security when it reaches a balance level below a threshold. They allow the issuer to clean this product from their balance sheet when market conditions are interesting but at the same time protect the investor as the threshold cannot be greater than 10%, as defined in Basel. Equally, this type of option is very useful to the issuer as it allows to eliminate the expenses of servicing a very small pool of loans. As mentioned in Fabozzi (2002), the collateral “quality” plays an important role, as different levels of collateral quality have associated different probabilities of credit-impairment or delinquency for market conditions faced. For instance, when exercising the option while still receiving payments from collateral the issuer may be put in a risk position as the collateral may default after the option exercise, and so the issuer would need to support the default. Based on

Fabozzi (2002) we suggest developing a probabilistic model to create a relationship between clean-up call exercise, securities collateral rating and market conditions.

Also, it is necessary to understand under which market conditions a company may have interest in exercising an option. We define it as the rate difference between what companies can pay at period t and what were the rates at the product creation, being this difference subject to the need of being larger than the costs of going to markets again. To define what companies can be paying in the next periods we would need to project market rate. We suggest to do it using the Nelson and Siegel (1987) model and current market information on debt products with different rating. Following Lee et al. (1996) research, the bond issue has a total direct cost of 2.22% of the involved amount. Therefore, the rate available at product creation and the project rate would need to differ in at least 2.22%.

Summing up, we consider an option will be exercised when fulfilling two conditions: the current balance is smaller than the defined threshold (at least 10%) of the original balance and when there is a difference of at least 2.22% between the interest rate at period t and period zero. Moreover, we should add the suggested probabilistic model to take into account the incentives to accelerate the option exercise that may exist depended on market and collateral conditions.

Conclusion: We faced a difficulty to perform a test in real data due to the lack of information available, but we believe that with this rational method and using data available at Moody´s to update the regression behind the Richard and Roll (1989) model (consequently getting better CPR projection than what was found in section 4.2.2.1) we can project Mortgage Backed Securities returns and maturity more accurately than using the methods that are currently used by Moody´s providing investors with better tools to help them make their investment decisions.

4.3.2.2. Yield to Workout Date

Valuable as it could be a better estimation due to call options, however it is highly dependable on the chosen date.

Definition:

Although not available in the portal, it is a popular metric in the industry. To understand it is essential to comprehend the workout date concept to comprehend the yield to workout metric. Workout date is the date that a bond is more likely to be called or redeemed taking into consideration the actual price, future expectations about the bond and the call schedule, that is, the list of dates a bond can be redeemed prior to the maturity and the corresponding prices by which it can be exercised.

The yield to workout date is the expected return until the bond is expected to be called or redeemed (Marshall, 2000).

Interpretation/Results:

From the portal, we can get the yield for several different scenarios. For example, by forcing the call at a specific date, or letting it run until maturity. Although information/advice on the workout date is not available, this metric can be achieved using investors' perspective on what is the workout date. Still, we would like Moody´s to use the suggestion on section "A new approach to project structured products returns" to add information on their expectations to call options exercise.

To study this metric, random dates from 3, 6, 9, 12, 24 months apart were selected, and used as call dates. The objective was to see how yields varied for each case.

An expected and observed result is the increase in the yield as maturity increases, for a given price. In other words, as the period of time considered increases, there are consequently more cash flows to discount, implying a higher discount rate for a constant price of 100. Another inference from this metric is the fact that returns can change a lot for small maturities differences.

Concluding, when working with structured products, investors are highly exposed to the call option, and so the maturity date that was defined at the beginning may not correspond to the true one. This metric is a valuable mechanism to help investors as it can give a more accurate value of what should be the achieved return. However, the result is extremely volatile on date changes, making it highly dependent on the workout date, which is a simple perception of what is the most probable call date. Also, this metric has a problem since it does not account for prepayment across the product life.

4.3.2.3. Yield to Call (YTC)

Valuable as it provides the return on a bond with a call option embedded, which is very common with structured products.

Definition:

The yield to call is the return an investor requires to hold a callable bond bought at its market price and held until the next callable date, and it is computed using the yield to maturity formula but adjusting the maturity and consequently the cash flows distribution in this scenario.

Interpretation/Results:

This yield can be higher or lower than YTM, as when calculating this metric, it is assumed that the call will be exercised in the next possible date, independently if the product is being traded at, in or out of the money. Consequently, a lower yield than the YTM can be expected when the product is in the money, and a higher yield when the product is out of the money.

This metric could be useful, since structured products do not usually run until maturity due to the call option, commonly exercised. Thus, this metric gives a more realistic return of what should be the true return when comparing to YTM. Similarly to the Yield to Workout Date, this metric does not account for the existence of prepayment.

4.3.2.4. Yield to Worst (YTW)

Valuable as it provides the return on a bond given the worst-case scenario.

Definition:

The yield to worst is the lowest yield that can be received between letting it simply run until maturity or force a call in the next possible date. Basically, it defines as the worst scenario the lowest yield case between receiving all the cash flows or be exposed as little time as possible to market uncertainty.

It is a tool used to evaluate the worst-case scenario for the yield, helping investors to manage risk and to meet specific income requirements. For example, when a bond is callable or has other specific features, the yield to worst is the lowest of the previously mentioned yields (yield to maturity and yield to call).

Interpretation/Results on the YTM, YTC and YTW:

Applying the three concepts defined above to these metrics on the analysed tranches, we have observed that in several cases, the forced call would not have any effect on the yield of the bond. Supposedly, the holder of the bond would require a premium for the risk of having the bond called. One possible explanation for this is that there would be the fact that when comparing the cash flow distribution of the two scenarios, assuming a constant price, there is no change in the yield received by the investor.

However, we have also seen that in some cases the yield to maturity would be higher than the yield to call, being the latest the worst in this case. This might be explained by the fact that assuming a constant price when running until maturity we receive more interest payments than when the call is exercised, and consequently we will receive a higher yield.

On the importance of the metrics, we conclude that these are of extreme importance, but may not be so relevant for some cases (in cases similar to the described in the second conclusion) and one needs to be extremely careful when analyzing and taking conclusions on these metrics individually, or even when comparing them.

4.3.2.5. Yield to Maturity (YTM)

Valuable as it is easy to calculate, to interpret and is used to price some products, but can lead to wrong inferences as most structured products do not usually reach maturity.

Definition:

The Yield to Maturity is the rate of return that an investor buying a bond today at the market price earns, assuming the bond will be held until maturity and that all coupon payments are made. It can be interpreted as the total return earned by investors under the specified conditions. This relation is expressed as:

$$\mathrm{YTM}: \mathrm{B}(\mathrm{t}) = \Sigma \frac{\frac{\mathrm{c}}{\mathrm{n}}}{\left(1+\frac{\mathrm{y_s}}{\mathrm{s}}\right)^{\mathrm{s}(\mathrm{T}-\mathrm{t})}} + \frac{\mathrm{P}}{\left(1+\frac{\mathrm{y_s}}{\mathrm{s}}\right)^{\mathrm{s}(\mathrm{T}-\mathrm{t})}}$$

where y_s is the annual YTM with compounding frequency s, c is the annual coupon rate with frequency n P is the principal payment, T are the coupon payment dates and t is the starting date.

Interpretation/Results:

As it was previously mentioned, most of these products do not reach maturity. Consequently, the importance of this metric is mostly related with its ease to calculate, and with the fact that it is widely used to price a lot of products.

4.4. Risk measures

Structured products depend on interest rate fluctuations, because its prices and coupons vary along all the time until maturity or the call. For investors in structured products it is very important to evaluate the risk of each security or tranche, riskier securities should require higher returns, so not only the interest rate fluctuations are important but also the changes in spread which is usually linked to the risk premium of the security. In order to provide better tools for Moody's Analytics clients several metrics were analyzed and two were specially developed for their future needs (Effective Spread Duration and Effective Spread Convexity).

4.4.1. Effective Spread convexity

Valuable because it helps assess the change in bond prices in response to a change in spread only (excluding benchmarks' changes), while also considering cash flow variability.

Definition:

Spread convexity is a measure of the non-linear relationship of bond prices to changes in spread, the second derivative of the price of the bond with respect to spread:

$$C = \frac{1}{P}\frac{d^2P}{ds^2} = \frac{1}{P(1+r(0,t_i)+s)^2}\sum_{t=1}^{T}(t^2+t)\frac{CF_t}{(1+r(0,t_i)+s)^t}$$

where P is the Bond price, $r(0,t_i)$ is the spot rate, s is the yield spread, and CF_t is the cash flow of period t.

However, for bonds with an embedded option, it is not possible to consider convexity as a second derivative regarding variability of cash flows and value. Effective spread convexity is a metric specially developed by us for Moody's in order to allow the investor to analyse the price sensitivity to spread changes (Note: The deduction of this metric will be explained in section 4.4.3.1). In order to study spread convexity, the Effective Spread Convexity was computed by us as an approximation, and not as the second derivative of bond's price to the spread:

$$\text{Effective Spread Convexity} = \frac{\mathrm{P}_{+} + \mathrm{P}_{-} - 2 \times \mathrm{P}_0}{2 * \mathrm{P}_0 \times \Delta\text{spread}^2}$$

where P_0 is the bond's initial price, P_{-} is the bond's price if its spread decreases, P_{+} is the bond's price if its spread increases Δspread stands for the change in spread.

The difference between spread convexity and effective spread convexity lies in the fact that the latter takes into consideration possible cash flows changes for spread movements, while the former simply assumes an unchanged cash flow distribution for yield changes. This can be seen in the formulas of the metrics: the spread convexity function is computed using the cash flows, when bond is run until maturity, while the effective spread convexity uses the price that arises from the spread change, letting the cash flows distribution change, if necessary, which is then reflected on the price.

As mentioned by Fabozzi (2007), callable bonds may have negative effective convexity. This happens when the bond has more value for the issuer and a possibility to call it back is high, for instance when the rates fall the risk is higher, or when they increase the risk becomes lower.

Callable bonds are less sensitive to yield increases than to yield decreases, which creates negative convexity, as there is a change in the cash flows distribution that could overcome the interest change effect; whereas non-callable options are more sensitive to yield decreases than to yield increases.

Interpretation/Results:

This metric is not used by Moody's so to calculate it, we encountered the same issues as with the Effective Spread Duration. Therefore, we could not vary the spread itself, and had to instead calculate the Effective Convexity – which would take into account a variation of the yield, not the spread. To calculate it, the prices were taken from the portal as for the Effective Duration.

Analysing the values of the calculated Effective Convexity between different tranches over several deals, it is possible to conclude that more senior tranches have a lower Effective Convexity than junior ones, so its change in price will be lower. Bonds with lower convexity are less sensitive to changes in yield. Therefore, for the same change in spread, senior tranches have a lower change in prices, which makes them less sensitive to yield changes.

Both Effective Spread Convexity and Effective Convexity can be valuable metrics, as they are important to take conclusions on different issues.

On the one hand, Effective convexity considers the non-linear relation between prices and changes in yield, thus better capturing the sensitivity of the bond compared to the Effective Duration, and even better than simple Duration since it considers the cash flow variability. The practical results obtained led us to conclude that the more senior the tranche, the lower the convexity and thus the less sensitive to yield changes.

On the other hand, while we could not calculate the Effective Spread Convexity, it would most likely be valuable because it would not only be an improvement to the Effective Spread

Duration as well (by considering non-linear relations as mentioned), but it would provide conclusions on how the price of the bond reacts to a change in the spread only, not including the possible changes in the index benchmark which would affect the yield.

Effective spread convexity is not easy to understand for investors as effective spread duration or effective duration. However, it may be valuable as structured products are quoted at a specific spread, so this metric will allow investors to analyse price changes when higher changes in spread occur. Before including it in the portal, it is necessary to verify if all data for its calculation is available.

4.4.2. Effective spread duration

Valuable because it captures the change in price for a change in spread, while also taking into account cash flow structure.

Definition:

Effective spread duration is a metric specially developed by us for Moody's in order to allow the investor analyse the price sensitivity to spread (Note: The deduction of this metric will be explained later in section 4.4.3.1). Effective spread duration is an estimate of how much the price of a specific bond will move when the spread of that bond changes.

$$\text{Effective Spread Duration} = \frac{P_{-} - P_{+}}{2 \times P_0 \times \Delta\text{spread}}$$

where P_0 is the bond's initial price, P_{-} is the bond's price if its spread decreases, P_{+} is the bond's price if its spread increases Δspread stands for the change in spread.

Bonds with longer maturity have a larger effective spread duration. However, it will always be lower than the maturity of the bond. The interest rates have a high impact on the cash-flow structure of a bond with an embedded option, so duration or modified duration, which do not take this into account cash flow and value changes, are not a relevant measure of bond sensitivity to yield changes for this type of complex products.

Interpretation/Results:

Moody's does not use it, as the Moody's portal allows us to get the price fluctuation associated to yield change at a given price level. So, to assess the impact of effective spread duration, we considered an initial price of 100 and the respective yield, and then increased and decreased the initial yield by adding 0,5 percentage points to get the respective prices. Due to its limitations, it was not possible to vary just the spread, so only a total variation of yield was performed. This ultimately corresponds to the Effective Duration, therefore no conclusions on the application and practical results of the Effective Spread Duration could be taken.

However, in theoretical terms, this metric could add value since when working with structured products that usually have a floating component, the term discount margin is frequently used, which simply corresponds to the spread over the benchmark index, such that $Yield\ to\ Maturity = DM + Benchmark.$ Consequently, Effective spread duration is theoretically an interesting metric as it allows the spot rate to adjust (following the change in cash flows' structure), while also just focusing on the spread component, to try to see how the price fluctuates with a spread change. Meanwhile, the normal effective duration looks to the whole shift of the yield, without specifying if the change originates in the spread or in the benchmark index.

Mathematically speaking,

$$Yield = spot\ rate + Spread$$

$$\Delta \text{Yield} = \Delta \text{spot rate} + \Delta \text{spread}$$

Effective spread duration may be valuable for investors as structured products are quoted at a specific spread, and may be easier to understand price sensitivity to changes in spread, although before including it in the portal it is necessary to verify if all data for its calculation is available. Effective Spread Duration is equally valuable for investors, when small changes in spread as considered, although for higher changes in spread it is better to analyse Effective Spread Convexity.

4.4.3. Effective Duration

Valuable because it shows the bond's sensitivity to yield changes, given the options and cash flow variability that could happen with a yield change.

<u>*Definition:*</u>

As mentioned by Fabozzi (2007), Effective duration shows the expected price change for a bond when yield rises by 1%. It is a measure of interest rate risk of a bond. This type of duration is particularly important for bonds that have embedded options, because in this case modified duration is not accurate due to the possibility of variability of cash flows and bond value. By considering the prices and the changes when the yield moves, it is assumed that the structure of the cash flows (which in this type of products is commonly not the same as the structure when the bond runs to maturity) is captured and reflected in the price.

$$\text{Effective Duration} = \frac{P_{-} - P_{+}}{2 \times P_0 \times \Delta Y} \qquad \text{(CFA, 2015)}$$

where P_0 is the bond's initial price, P_{-} the bond's price if its yield decreases, P_{+} the bond's price if its yield increases and ΔY is the change in yield.

Bonds with a longer maturity have a larger effective duration. However, it will always be lower than the maturity of the bond. Interest rates have a high impact on the cash-flow structure of a bond with an embedded option, so duration or modified duration are not the most appropriate measures of bond sensitivity to yield changes.

Interpretation/Results:

As this metric is not used by Moody's, but Moody´s structured products portal allows us to get this metric as it gives the price fluctuation associated to yield change at a given price level. So, the same procedure as followed in effective spread duration was taken to get the prices from Moody's structured products portal. In the analysed deals, the effective duration was always lower than its maturity. However, the deal with the highest maturity was not the one with the highest effective duration.

Analysing the values of effective duration between different tranches over several deals, it is possible to conclude that more senior tranches have a lower effective duration than junior ones, hence its change in price will be lower. Additionally, for the same change in yield, senior tranches have lower changes in prices, which makes them less sensitive to yield changes.

Effective Duration is a better measure of price sensitivity than Duration or Modified Duration because it considers the changes in cash flows and value, which might occur when we have a bond that has an embedded option, cash flows that change when interest rates change resulting from prepayments and the exercising of calls. (Fabozzi, 2007)

As other types of durations, effective duration is easier for investors to understand price sensitivity to yield changes; considering this, we believe it should be included in the Moody's structured products portal. Additionally, this metric may be useful to compare price sensitivity of any structured product to a straight bond, as in straight bonds price sensitivity is measured by changes in yield.

4.4.3.1. Effective Spread Duration and Effective Spread Convexity (Lilia Chemetova Individual report)

Interest rate risk is a type of risk that exist in assets, which price depends on fluctuations of interest rates. On investor's decision-making process, it is very important to know how the asset's price will vary with interest rates changes, to evaluate how risky the asset is. Bonds are the securities that depend the most on changes in interest rates and have a particularity: there exists an inverse relationship between bond prices and yields.

In order to easily understand the interdependence between bond price changes and from interest rate fluctuations, there exist metrics such as Macaulay Duration or Convexity. Duration measures the percentage change in the market value of a bond for a given change in yield, when small changes in yield are considered, once in higher changes in interest rates, duration can overestimate or underestimate the price approximation (Dunetz and Mahoney, 1988). Convexity is more useful for higher changes in yield, but we should be more careful since it is the curvature of the price-yield function.

However, for structured products it is not possible to use these metrics to evaluate their sensitivity to yield changes. Since for callable bonds it is almost impossible to have any certainty regarding the cash flows and value, as mentioned previously these securities are not hold until maturity and have other risks associated like prepayment risk, reinvestment risk.

In case of these complex products, metrics as Effective Duration or Effective Convexity are used, because they capture cash flow variations and reflect them in respective prices. Effective Duration shows the expected price change for a bond when yield rises by 1%. In callable bonds, when interest rates are low comparing to coupon and a call option is in the money, then it is more likely to be called and so callable bond's Effective Duration is reduced. Effective Convexity is also a good measure of bond's price sensitivity to interest rate changes, as this relationship is not linear. For high interest rates, it is almost impossible for the callable bond to be exercised so its sensitivity to interest rate changes is similar to a straight bond. However, there is a particularity with these products, they may have a negative convexity. Effective convexity turns negative when options value is close to in the money, so when interest rates decline the bond value is capped by the price of the call option if it is near the exercise date. More specifically, most MBS have negative convexity because the mortgage borrowers can prepay their loans. As interest rates fall, the incentive to prepay increases, generally resulting in an increase in prepayments to MBS holders. This effect causes the duration of MBS to fall as interest rates decline (Gagnon et al., 2011). During the last years MBS market has become more negatively convex. This particularity has resulted from the huge market growth, advances in information technology and enhanced competition in mortgage banking (reduction of refinancing costs) (Hanson, 2014). Callable bonds are less sensitive to interest rate increases than to interest rate decreases, which creates negative convexity – price appreciation is less than price decline when huge changes in rates occur; whereas non-callable bonds are more sensitive to interest rate decreases than to interest rate increases.

For investors in structured products it very important to consider not only the yield of the security but the spread over the benchmark index as well. The reasoning behind the heightened importance of this spread comes from the fact that different spreads are commonly used in valuation of these product. For instance, MBS, ABS and CDO are traded at nominal yield spread, Discount Margin, Z-spread, or even OAS when they have embedded options (Nielsen, 2017). When these products have a floating component, discount margin is a frequently used concept, which corresponds to the spread over the benchmark index, expressed as $Yield\ to\ Maturity = DM + Benchmark$, usually in this products with floating component Moody’s compute the yield to maturity by estimation considering that it is run until maturity. Assuming there are many different types of spread used to explain price fluctuations of these securities, it could be interesting to provide the investor a different tool to evaluate risk of structured products. Measure as spread duration was already proposed by Fabozzi (1999), although it is not guaranteed its usefulness for structured products. For this reason, two different metrics, effective spread duration and effective spread convexity, were specially developed for Moody’s Analytics. The purpose of these metrics is to evaluate price sensitivity to a change in spread, assuming there is no change in reference rate. In these metrics any specific spread will not be considered. Therefore, in order to make it easier to understand price sensitivity to changes in spread, a more general expression will be considered. Mathematically speaking, the change in yield will be represented as:

$$\text{Yield} = \text{reference rate} + \text{spread}$$

$$\Delta\text{Yield} = \Delta\text{reference rate} + \Delta\text{spread}$$

The Effective Spread Duration and Effective Spread Convexity expressions derive from the original formulas where yield is the independent variable.

$$\text{Effective Duration} = \frac{P_- - P_+}{2 \times P_0 \times \Delta Y} \text{ (CFA, 2015)}$$

$$\text{Effective Convexity} = \frac{P_+ + P_- - 2 * P_0}{2 \times P_0 \times \Delta Y^2} \text{ (CFA, 2015)}$$

where P_0 is the bond's initial price, P_- the bond's price if its yield decreases, P_+ the bond's price if its yield increases and ΔY is the change in yield.

So, to get the respective expressions a simple substitution was made according to previous assumptions about yield.

$$\text{Effective Spread Duration} = \frac{P_- - P_+}{2 \times P_0 \times \Delta\text{spread}}$$

$$\text{Effective Spread Convexity} = \frac{P_+ + P_- - 2 \times P_0}{2 * P_0 \times \Delta\text{spread}^2}$$

where P_0 is the bond's initial price, P_- is the bond's price if its spread decreases, P_+ is the bond's price if its spread increases Δspread stands for the change in spread.

Assuming there is no change in the reference rate, $\Delta reference\ rate = 0$, it will be possible to study price sensitivity accordingly just to spread changes. Effective Spread Duration and Effective Spread Convexity would be very useful metrics for investors, since they will be able to analyze risk based on spread between different securities.

For instance, considering a random chosen spot rates and spread, for a 4% coupon bond, face value of 100, a spread of 0,12% and applying an increase/decrease in spread of 0.1%:

Maturity	Spot Rate
1	4,09%
2	5,54%
3	6,03%
4	7,55%

$$P0 = \frac{4}{1 + 4.09\% + 0.12\%} + \frac{4}{(1 + 5.54\% + 0.12\%)^2} + \frac{4}{(1 + 6.03\% + 0.12\%)^3} + \frac{104}{(1 + 7.55\% + 0.12\%)^4}$$

$$P_+ = \frac{4}{1 + 4.09\% + 0.22\%} + \frac{4}{(1 + 5.54\% + 0.22\%)^2} + \frac{4}{(1 + 6.03\% + 0.22\%)^3} + \frac{104}{(1 + 7.55\% + 0.22\%)^4}$$

$$P_- = \frac{4}{1 + 4.09\% + 0.02\%} + \frac{4}{(1 + 5.54\% + 0.02\%)^2} + \frac{4}{(1 + 6.03\% + 0.02\%)^3} + \frac{104}{(1 + 7.55\% + 0.02\%)^4}$$

The following prices were obtained: the initial price of this bond, P0, is 88,15%, then varying the spread of it, increasing by 0.1% the price, P_+, will be 87,84%. and decreasing by 0.1% the price, P_- will be 88,46%. Then applying previously obtained formulas I get:

$$Effective\ spread\ duration = \frac{88.46\% - 87.84\%}{2 \times 88.15\% \times 0.1} = 3.49$$

$$Effective\ spread\ convexity = \frac{88.46\% + 87.84\% - 2 * 88.15\%}{2 \times 88.15\% \times (0.1\%)^2} = 7.92$$

Note: just the change in spread was considered as the reference rates remain constant.

It is possible to interpret that a duration of 3.49 represents an approximate change in price of 3.49% for a 100bp change in spread. Supposing that there is a change in spread of 200bp for the previously mentioned hypothetical bond, and the duration adjustment is given by $Duration\ adjustment\ in\ price = -D \times \Delta spread \times 100$, then the duration adjustment for a Δspread=0.02 will be is $Duration\ adjustment\ in\ price = -3.49 \times 0.02 \times 100 = -6.97$. On the other hand, when considering a change in spread of 200bp for the previously mentioned hypothetical bond, where the convexity adjustment is given by $Convexity\ adjustment\ in\ price = C \times \Delta spread^2 \times 100$, then the convexity adjustment for a Δspread=0.02 will be $Convexity\ adjustment\ in\ price = 7.92 \times 0.02^2 \times 100 = 0.32$. Finally, considering the impact on the bond price is given by $\frac{\Delta P}{P} = -D \times \Delta spread + \frac{\Delta spread^2}{2} \times C$, so $\frac{\Delta P}{P} = -3.49 \times 0.02 + \frac{0.02^2}{2} \times 7.92 = 0.07$.

The main advantage of the developed metrics is that they look at changes originated in the spread, whereas the normal Effective Duration and Effective Convexity look only to the whole shift of the yield.

Similarly to Effective Duration, Effective Spread Duration can be easier for investors to understand because it will show the expected price change for a bond when spread changes, which is relevant for small changes. Although Effective Spread Convexity is not so simple to interpret as Effective Spread Duration, it could be relevant as it is a more accurate metric to describe price sensitivity to higher changes in spread. So, a more deepen study must be done in order to understand how useful Effective Spread Duration and Effective Spread Convexity are as risk measures for investor in structured products. Thus, for investors in structured products these metrics can be interesting to analyse when there is available information regarding spread used for trading purposes.

4.4.4. Partial Duration

Valuable since it allows for a more detailed analysis of market risk.

<u>*Definition:*</u>

While Duration measures the sensitivity of the price to changes in the Yield curve, Partial Duration measures the sensitivity of the price for changes in a specific maturity in the Yield Curve. It is calculated as:

$$\frac{\text{Bond Price after a 1\% decrease in a specific maturity} - \text{Bond Price after a 1\% increase in a specific maturity}}{2 \times 1\% \times Original\ Bond\ Price}$$

This metrics was suggested by Moody's Analytics and we believe it should be added to the SF Portal.

<u>*Interpretation/Results:*</u>

Unlike Modified Duration, this allows to check the sensitivity of the product in specific maturities and not in all at the same time (vertical shifts in the curve). This allows investors to know in more detail to what risks they are being exposed to – the maturities of cash-flows with higher partial duration are the ones that expose the product the most. The metric can also be used between different products to know which are the most sensible to a specific maturity.

4.4.5. Implied Volatility

Could be valuable because it represents the market expected fluctuations of the option.

<u>Definition:</u>

It is the estimated volatility of an option's price. It is a method used to estimate the future fluctuations of an option's value considering certain predictive factors.

Implied volatility is different from historical volatility, which represents the realized returns, measuring past changes of market performance. When the two measures have similar values, options premiums are generally considered to be fairly valued.

Implied volatility changes according to investors expectation, so it tends to be higher when investors expect a decrease in the option's price over time, and lower when investors expect an increase in the option's price over time.

There are some factors that affect implied volatility such as supply and demand of a security, and time value of the option. Higher demand rises the price and so does implied volatility, which leads to a higher option premium, due to the risky nature of the option.

Additionally, maturity should be considered, so an option with longer maturity tends to have a higher implied volatility than an option with shorter maturity, since time is an additional variable and a longer period of time is considered into the option (Martellini *et al*., 2003).

<u>Interpretation/Results:</u>

In theory, this metric could be useful as it represents the market expected fluctuations embedded in the security price, and consequently may help investors making decisions as they can adjust their expectations considering the market's. However, to estimate, it would require considering option pricing models as Black-Scholes or Binomial Model, that due to characteristics of analysed products are difficult to be applied.

4.4.6. Standard Deviation/Volatility

Valuable since it is the simplest measure of volatility and can be used as input for other metrics or models.

Definition:

Although a commonly used metric in Finance, this was not present in the Structured Finance Portal, hence we were suggested to calculate it.

When working with Bonds this measure is less reliable since, by definition, the bond price will converge to its Face Value. Therefore, we apply this method to the returns of a Zero-Coupon Bond calculated through the respective spot rates of the bond's coupons, as in decomposing a coupon bond in many zero-coupon bonds, and calculate the value for the whole bond through the following matrix multiplication: $\sqrt{w'\sum w}$, where $\sum$ is the variance-covariance matrix of the spot rates and w is a column vector with the weights of the present values of the coupons on the price of the bond.

A problem that may arise is not having matching coupon's maturities and spot rates, which leads to problems when calculating the w vector. Hence, we can use "Volatility Bucketing", that is, having a "bucket" corresponding to each spot rate in the w vector and partly assign the present value of the coupons to the buckets with the closest maturities. This way, when a coupon's maturity falls between two spot rates, we split it between the bucket with the closest maturity on the downside and the upside:

$$w_1^2\sigma_1^2 + (1-w_1)^2\sigma_2^2 + 2w_1(1-w_1)\sigma_{1,2} = \sigma_k^2,$$

where w_1 is the weight given to the bucket with lower maturity (the remaining goes to the bucket with higher maturity); σ_1^2, the variance of the lower bucket; σ_2^2, the variance of the higher bucket; $\sigma_{1,2}$, the covariance between buckets; and σ_k^2 is the variance got from interpolating the other two variances in respect the cash-flow's maturity. This formula comes from the fact that: $Variance(aX + bY) = a^2Variance(X) + b^2Variance(Y) + 2abCovariance(X, Y)$.

Interpretation/Results:

The Standard Deviation is the most basic way to measure the market risk that may arise from changes in the relevant interest rates. It can be applied to the product to get its overall risk, but also to specific components of the product. For example, by looking to specific interest rates we can find for which maturities and respective cash-flows the product is the most sensitive to. This metric is also used as an input for other metrics and relevant computations (VaR, Pricing Options…).

One negative observation about this metric is the fact that it was calculated with historical data, which may not be the best to predict the future. However, there are more sophisticated models that can be applied (GARCH, EGARCH, EWMA…), but require information that may not be available for this kind of products. The standard deviation calculated also considered the correlation between interest rates regarding different maturities, which can underestimate the real risk since these correlations are not always the same.

4.4.7. Value at Risk

Valuable to show the monetary value of possible losses and the minimum loss that can be expected α% of the times.

Definition:

As defined in Jorion (2001), "Value-at-Risk estimates how much a set of investments might lose, given normal market conditions, in a set time period such as a day. p VaR is defined such that the probability of a loss greater than VaR is less than or equal to p; while the probability of a loss less than VaR is less than or equal to 1−p. For a given portfolio, time horizon, and probability p, the p VaR can be defined informally as the maximum possible loss during the time if we exclude worse outcomes whose probability is less than p."

VaR can be estimated either parametrically (for example, variance-covariance VaR or delta-gamma VaR) or non-parametrically (for example, through historical simulation VaR or Monte Carlo VaR). The approach taken was the variance-covariance one.

From the daily standard deviations and the market values calculated as described in Standard Deviation, we were able to calculate the daily VaR at a 95% and 99% confidence level. The formula is:

$$Daily\ VaR\ @\ 99\% \ = \ -\sigma_{daily} * Z_{1\%} * Market\ Value$$

where $Z_{1\%}$ is the critical value from the cumulative standardized normal distribution for the 1% level. For the VaR at 95% confidence level, this critical value was computed for the 5% level.

Interpretation/Results:

The value is interpreted as follows: there is a 5% probability that the portfolio will fall in value by more than £ 107 067,25 over a one-day period. Informally, a loss of £ 107 067,25 or more is expected in 1 out of 20 days. For the daily VaR @ 99%, there is a 1% probability it will fall by more than £ 151 427,26 over a one-day period, and this is the minimum loss expected in 1 out of 100 days.

This metric is important and relevant for investors, and would be interesting to be included in the portal, because by taking into account the value of the product or position, it shows the monetary value of a possible loss, as well as the loss that can be expected 1%/5%/… of the times. It is also useful because it can be adjusted according to the level of confidence and time frequency (daily, monthly...).

4.4.8. Expected Shortfall

Could be valuable and more useful than VaR, as it gives the expected (average) loss of the portfolio α% of the times.

<u>Definition:</u> (Hull, 2015)

The Expected Shortfall (or Conditional VaR) at α% level is the expected return of the portfolio in the worst *α*% of cases. That is, the expected loss of the portfolio value assuming a loss is occurring at or below the *α*-quantile. CVaR is calculated as the weighted average between the value at risk and losses exceeding the value at risk. To calculate it, the most common procedure is to estimate it non-parametrically, through Monte Carlo simulations.

<u>Interpretation/Results:</u>

For an α of 5%, the ES at a 5% level of confidence is the expected loss in the worst 5% of cases. The metric can be valuable, especially when confronted with the VaR, because it provides the average expected loss of the worst cases whilst the VaR only provides the threshold at which the worst cases start (thus being the 'best case' of the worst cases). This metric is not provided in the portal yet, and could be an interesting addition if a solid model to calculate it could be developed.

4.4.8.1. A Deeper Look into VaR and ES (Daniela Santos Individual Report)

Value-at-Risk, as discussed previously, can be a valuable metric to represent the loss that will not be exceeded with an α% confidence level, in a certain amount of time. That is, if the monthly 99% VaR is $1M, losses in a month will exceed this with only a 1% chance. The interpretation is straight-forward and intuitive, thus causing it to be a very popular, widely used, valuable tool for financial risk management. However, it also has some inherent disadvantages.

First of all, by definition, VaR ignores what can happen in (following the example above) 1% of the cases: it only tells investors what is the *minimum* loss that will occur 1 out of 100 of the times – it is the best of the worst cases, and any loss beyond the VaR level is disregarded. Two portfolios with identical VaRs could have extremely different levels of risk beyond the threshold, and that would not be reflected in the metric at all. The left tail of the distribution is simply ignored, meaning there is 'tail risk' (Artzner et all, 1997). As a result, there can be an underestimation of the risk, with large unexpected losses. In fact, extreme events, in the form of leptokurtosis ('fat tails'), can occur much more commonly than what is assumed by Gaussian models.

Additionally, VaR is not sub-additive, as was formally proven by Acerbi and Tasche (2002). This property implies that "a portfolio made of sub-portfolios will risk an amount which is at most the sum of the separate amounts risked by its sub-portfolios". In other words, breaking this axiom means the sum of the individual assets' VaR is not necessarily higher than the VaR of a portfolio containing all the same assets. For this reason, the authors consider VaR not to be a risk measure in essence, since joining portfolios and assets results in diversification, and the risk, as assessed by the metric, ought to be no higher than the partial portfolios and assets' risk.

The implications of not being sub-additive are quite significant: not only does this mean that the portfolio VaR would have to be recalculated each time a new asset is introduced or removed from the portfolio (Darbha, 2001), but also that simply summing individual VaRs may in fact lead to a misleadingly conservative estimate of the level of risk. The latter is not a disadvantage in itself; however, it can be undesirable for financial institutions determining risk weights and buffers based on that VaR value, because the level of collateral needed to back that risk will be higher, and capital will be 'tied up' unnecessarily.

In terms of calculations, the VaR of a stock or portfolio of stocks can be estimated through three main approaches: historical simulation, parametrically (variance-covariance VaR), or Monte Carlo simulation. While each method has its merits, they also present drawbacks. Historical simulation looks only at historical data to model potential future movements, thus assuming the past is the best indicator of what will happen in the future. Parametric VaR, while the most appropriate for a portfolio because it can correct for the fact that VaR is not sub-additive, must be calculated using a return distribution, usually the normal, therefore not taking into account kurtosis and skewness. Forward-looking simulations such as Monte Carlo are the preferred approach because it can be tailored to the products (which is particularly important considering the type of products we are focusing on), however doing this properly is extremely costly and requires a lot of time. From this, we can conclude that while the metric itself is extremely valuable, a simple number cannot be trusted completely given the difficulty in finding a way to calculate it as accurately as possible.

Nevertheless, the most common approach is to calculate VaR parametrically – particularly, the variance-covariance VaR. However, while it is relatively straight-forward to compute for a portfolio of stocks (historical returns can be used to compute their standard deviation and covariance), for a fixed income portfolio the calculations become trickier. By using the historical returns of a bond directly, VaR would be overestimated because of the 'pull-to-par' effect in bonds: since as maturity gets closer, the price of the bond converges to par, the volatility of returns varies for different points in time depending on the maturity considered, decreasing as maturity is approaching. (Beleza Sousa et al., 2014).

To overcome this issue, the typical approach (and the approach we followed) is Cash Flow Mapping, which involves treating each cash flow – coupon payments and principal repayment –, as individual zero-coupon bonds, and using the available historical yields for each standard maturity. Nevertheless, it is important to note that studies such as Fernandes (2014) have concluded this method greatly underestimates the bond VaR of a portfolio, with incurred losses larger than the forecasted through the model.

Another possibility is the Pull Price method, which, unlike the CF mapping approach, is not dependent on having the relevant historical yields. However, it is constructed under the assumption that yields to maturity are a good measure of return, incorporating interest rate, credit and liquidity risks (Fernandes, 2014). Thus, under this standard definition, Pull Price cannot be applied correctly to structured products. As explained previously, yield to maturity is not an accurate return measure for structured products, given the fundamental characteristic of them being callable, causing a very high percentage of these products to not reach maturity. The alternative would be using the yield to call, which denotes the return considering only the cash flows until the next callable date.

A specific example of a model that could be developed further under the scope of structured products is a method introduced by Beleza Sousa et al. (2014), involving individual maturity adjustments and removing the 'pull to par' effect from the bond's past prices. By computing Adjusted Historical Returns (AHR), the VaR can then be computed similarly to stocks. For each historical price, it is necessary to take the implied yield to maturity (the suggested adapted model for callable bonds would use the yield to call instead): $r(n, T-n) = \left(\frac{P}{p(n-T)}\right)^{\frac{1}{T-n}} - 1$, where T is the maturity (a proposed alteration is using the workout date, instead of the 'official' maturity of the product), P is the cashflow (this simplified example only considers the principal repayment), and n is the point in time of the historical price. The pulled price to time n_{VaR}, the point in which we are computing VaR (as an example, to calculate the 10-day VaR, we would need to calculate the AHR between dates 10 trading days apart), is between n and T, and given by $f(n_{VaR}, n, T) = \frac{P}{\left(\frac{P}{p(n,T)}\right)^{\frac{T-n_{VaR}}{T-n}}}$. The AHR we want to compute is $R(n, N, n_{VaR}) = \frac{f(n_{VaR}+N,n,T)}{f(n_{VaR},n-N,T)} = \frac{\left(\frac{P}{p(n-N,T)}\right)^{\frac{T-n_{VaR}}{T-(n-N)}}}{\left(\frac{P}{p(n,T)}\right)^{\frac{T-(n_{VaR}+N)}{T-n}}}$; $n = N + 1, \ldots, n_{VaR}$; and N corresponding to the time horizon considered for the VaR (e.g. N=10 for a 10-day VaR). With these Adjusted Historical Returns, the VaR can be computed through the same methods as for stocks, by calculating the potential loss of the 1-α quantile of the bond's specific adjusted empirical distribution of returns. (All the equations regarding this model were taken from Beleza Sousa et al., 2014).

However, there are still limitations to this approach when applied to structured products, despite the suggested modifications. The main one is the difficulty in finding prices. In a prices sample provided by Moody's, there were days with more than one price (corresponding to more than one deal having taken place that day), and several days with no information at all. In addition, the prices were only available until 2015, despite the deal still being 'alive'. While this is expectable given that the products are being traded OTC, and not on a 'traditional' stock exchange, it complicates the calculations of risk measures such as VaR.

Still, these type of risk metrics are important not only at the individual institution's level (for internal risk management), but also at a regulatory level, particularly for collateral determination. VaR used to be the metric chosen in the Basel Accords to be the basis for capital requirements calculations; however, in the revised versions, the risk measure was updated to reflect the Expected Shortfall (ES).

Also known as Conditional VaR (since it is the 'conditional expectation of loss given that the loss is beyond the VaR level' – International Monetary Fund, 2007), ES denotes the average loss in the α% of the cases, to which VaR only sets the threshold. Moreover, unlike VaR, it is indeed a coherent risk measure (Acerbi & Tasche, 2002), by being provably sub-additive (Acerbi, Nordio, & Sirtori, 2001). In addition, by working with averages in the lower quantiles of the distribution, it corrects for the 'fat tails' problem inherent to VaR, which would result in large losses beyond the VaR level, unaccounted for in terms of capital. This is one of the reasons regulation has been updated to replace VaR with ES. As a result, banks must now calibrate the ES to periods of significant market stress, in order to maintain adequate capital during those periods (PWC, 2017).

Regarding its calculation, if we follow the proposed Adjusted Pull Price method described previously, the computation of ES is straightforward, and does not require any additional computational effort. Having the product's returns distribution, ES can be calculated, for example, through Monte Carlo simulation, or it can even be taken directly from the historical simulation, where we simply compute the mean of the α% worst results.

All in all, Value-at-Risk is an essential, widely used metric for risk management. However, it does have some drawbacks, especially when it comes to ignoring what happens beyond the computed VaR level. For that reason, Expected Shortfall is currently starting to replace it as a more adequate risk measure, as confirmed by the regulatory changes taking place in the industry.

4.4.9. DV01 to Worst ($ per 100bps yield change)

Valuable as it allows investors to infer in dollar terms what would be their exposition to interest changes in the worst scenario and so adjust hedge strategies to the worst scenario.

<u>*Definition:*</u>

DV01($ per 100bps yield change) is a metric that is widely used by financial markets participants. It is the monetary variation in the case of 100 basis points change of interest rate, being an interest rate risk metric, as it tells the how much money the security value will change for a percentage point change. It is computed through the following formula:

$$DV01\ (\$\text{ per 100bps yield change}) = \frac{D^{\$}}{100} = -\frac{dP}{dr} \times \frac{1}{100}$$

Where P is referent to the security price function and r to interest rate. It is necessary to divide the dollar duration by 100 (since modified duration is expressed as a 100% change, a unitary price movement, and DV01 ($ per 100bps yield change) is referring to a percentage point change).

The worst-case scenario was defined as the one with the smallest yield between the case the investor does not receive all interest (so if the call is exercised in the next callable date), and the case where the security runs until maturity. Consequently, DV01 to Worst, which is an adaptation from DV01, will refer to the monetary variation a security is exposed to in the worst scenario per a percentage point change.

DV01 is very convenient to produce analysis, as it allows hedge strategies to be developed (which is not possible using duration, as it delivers a value in percentage terms).

Interpretation/Results:

In the conducted analysis we observed, as expected, that senior tranches were less exposed to interest fluctuation, which was matched with a lower yield. Thus, senior tranches presented a smaller DV01 to worst when compared to more junior tranches.

This metric in particular is useful, as structured products' life and payments could differ a lot from the pre-defined maturity, due to its call and prepayment option. As explained before, this metric allows for hedging – a general characteristic of DV01 –, but DV01 to worst is particularly beneficial as it allows to take conclusions and adjust hedge strategies to the worst scenario.

Moody´s structured products portal allows us to get this metric as it gives the price fluctuation associated to yield change at a given price level. However, this is not directly given. We believe Moody´s should add this metric.

4.4.9.1. DV01 as a Hedging Tool (Sofia Oliveira Individual Report)

The case for the U.S. Treasuries Curve

This subchapter aims at exploring the concept of DV01, described in the metrics' section, and to apply it to an investment decision process as a hedging tool. The last part provides a practical example for this concept applied to the U.S. Treasuries Curve.

As previously mentioned DV01 ($ per 1bps yield change) is the dollar value of 0.01% and gives the change in the value of a fixed income security for a 1 basis point decline in interest rates (Tuckman and Serrat, 2012). This metric is widely used in financial markets and it is extremely valuable mainly because it allows investors to determine in dollar terms what would their exposition be to changes in interest rates. Moreover, as highlighted in both DV01 to next call and DV01 to worst, DV01 is very convenient for analysis purposes, as it allows hedge strategies to be developed, and when there is not a closed form for duration, as for the case of callable bonds mentioned in the early sections of this report.. This section will focus on this particularity of DV01, using the concept as the baseline to build hedged spreads in the U.S. Treasuries curve.

Introduction: Every investment requires a risk-return analysis, and the relation will always depend on a predefined set of inputs that vary from investor to investor. These include the risk appetite or risk aversion, the investment horizon and the disposable amount to invest. However, there is something common to (almost) every investor which is the desire to make returns at the lowest, and if possible, at no risk. In any case, the portfolio should be always adjusted to the desired level of risk. Since ceasing the investment activities is not an option in most cases, *hedging* is widely used strategies to achieve the desired level of risk.

At this section, DV01 will be exemplified as a hedging tool for part of the U.S. Treasuries Curve. The set of assumptions for the model include the following:

- Only future contracts are considered;
- DV01 is the only factor that leads to different amplitude movements in the different contracts;
- Floaters are not considered in this analysis.

The U.S. Treasuries Curve: The fixed income market comprises thousands of different securities from every part of the world. Within the most famous are the financial products that form the US Treasuries Curve. The curve is composed by contracts made with the US government, either as the borrowing or the lending party. These contracts have different maturities that when sequentially and timely organized constitute the curve. In simple terms, if an investor buys a 2-Year Treasury contract, she is lending money to the US government, and will be repaid the face value of the loan at maturity, in this specific example, after the two-year period. This would be an active contract. For trading purposes, futures on Treasuries are more commonly used as these are more liquid and easily used as the baseline for a trading strategy. The remaining parts of the U.S. curve include contracts that have maturities from one month to thirty years.

The main idea of using DV01 as a hedging tool applied to the US Treasury curve is simply to find a fair value, and being able to determine which parts of the curve are overvalued and undervalued. The first would trigger a sell signal and the latter would trigger a buy signal. These would ideally lead to more active trades on the contracts and with more confidence, assuming that the contracts will return to their fair value, whenever there is a deviation.

The Fair Value: At this point, it is important to introduce the hedging concept and the fair value idea. A fully hedged investor will make no profit whenever there are price movements on the securities traded. Basically, this investor would gain (lose) on one side and lose (gain) on the other the same amount. The fair value is the price at which the security or strategy (when referring to more than one security) should be trading, considering a set of assumptions. This practical case considers DV01 as the baseline for the fair value. More specifically, for every combination of two or more fixed income products, DV01 will be the main tool to decide which weight each of the securities will have in the strategy. An important assumption is that a security with a higher DV01 is riskier and should react more to events, thus to become fully hedged in terms of DV01 risk, a higher weight should be assign to the other leg. This relation is further explained and exemplified.

Methodology and Application: Applying the concept to the US Treasury Curve, there are several ways of combining every product with each other in strategies of two. By simply combining these securities into spreads and considering a 1:1 ratio, the investor would be exposed, as the two legs involved are impacted differently by events. Therefore, the weight in each leg should be carefully considered to account for this difference and this would be ultimately reflected in the number of contracts, or the ratio for each leg to buy (long) the position. This is necessary because the curve includes contracts with different maturities that cover periods from six months to approximately 30 years. There are two important facts to consider on this point. The first is that different maturities imply different DV01 values and when carrying a two leg strategy where one of the positions has higher DV01, it also has more risk and in theory have larger movements to changes in interest rates than the lower DV01 leg. The second point is that short-term securities are usually more impacted than longer term. This is because a longer time to maturity implies more uncertainty and more time for the markets to incorporate the new information given by the event that led to the movement. This section will focus on the first point.

In every spread of US Treasuries, there will be the lower and higher DV01 leg. To make the strategy tradable, the number of contracts for each leg should be defined such that the investor is fully hedged in terms of DV01. In other words, any movement in the market should return a Profit and Loss of zero. This would be the fair value. Any deviation from this would trigger a signal that would allow the holder to profit from the strategy.

Having now a clear understanding about all the inputs and concepts, the ratios would be simply the minimum tradable ratios that would maintain the DV01 relationship between the two components of the spread. The image below shows the DV01 hedging ratios for the 2-year, 5-year, 10-year and 30-year Treasuries futures considered in this example, extracted from a Bloomberg terminal. All the contracts are March 2018 futures.

Number Contracts Long		SHORT NUMBER OF CONTRACTS			
		TUH8	FVH8	TYH8	WNH8
1	TUH8	....	0.862	0.539	0.146
1	FVH8	1.160	....	0.625	0.169
1	TYH8	1.856	1.600	....	0.270
1	WNH8	6.866	5.920	3.699	....

Assuming a hypothetical strategy, being the spread between the 5-Year Treasury March 2018 future (leg 1, FVH8) and the 10-Year Treasury future for the same month (leg 2, TYH8), 1 unit of DV01 of leg 1 is to 0.625 units of DV01 of leg 2, or as it can be seen from the matrix above, 1 unit of leg 2 is to 1.6 of leg 1. In other words, if one buys one 5-year future, she should also sell (short) 0.625 contracts of the 10-year future contract to become DV01 hedged.

As previously mentioned, this relation makes sense because the higher DV01 leg is riskier, thus is expected to move more that the lower DV01 leg. To compensate for these larger movements, a higher weight should be considered for the latter, In order to replicate the higher amplitude of movements expected for the higher DV01 leg, in this case, the 10-Year Treasury. Practically, these would imply that a loss (gain) on 10-Year Treasury 1 contract would be fully matched with the gain (loss) on the 5-Year Treasury 1.6 contracts. The DV01 relationship derived in the beginning of the paragraph is the baseline of the hedging ratios, which would be 1:0.625 or 1.6:1. However, these are not tradable ratios, as it is impossible to buy/sell 1.6 or 0.625 contracts, i.e. any number that is not an integer. Therefore, the final ratios would be the minimum multiple that would keep this relationship, which in this case would be 8:5. The difference between the original relationship and the adjusted (tradable) ratios is called the tail, and represents usually a small exposure or in other words, a deviation from being fully hedged in terms of DV01.

Conclusions: DV01 is a widely used measure of risk. Its definition itself has several interpretations and can be used as a tool to serve different purposes. This section aimed at introducing DV01 as a hedging tool.

As the strategies were not tested in the live market, it is not possible to conclude about its efficiency. However, in theory, assuming that DV01 would be the only relevant factor affecting the amplitude of the movements of the securities involved which in the example were futures contracts on US Treasuries, the holder of the strategy would reduce her risk by adjusting the weight on each contract by its DV01 risk. In reality, hedging is a difficult task and becoming fully hedged is barely feasible. First because there are other internal factors affecting the markets besides DV01 and there are also external factors and market anomalies that may go against the model. Second, the DV01 relationship as the baseline for the ratios is hard to maintain when transforming this into a tradable number of contracts.

4.4.10. DV01 to Next Call ($ per 100bps yield change)

Valuable to analyze hedge adjustments in case of next call. However, DV01 to Workout date could be more valuable.

<u>*Definition:*</u>

DV01($ per 100bps yield change) is the monetary variation in the case of a 100 basis points change of interest rate. It is an interest rate risk metric, as it tells how much money the security value will change for a percentage point change. It is computed through the following formula:

$$DV01\ (\$\text{ per 100bps yield change}) = \frac{D^{\$}}{100} = -\frac{dP}{dr} \times \frac{1}{100}$$

Where P is referent to the security price function and r to interest rate. It is necessary to divide the dollar duration by 100 (since modified duration is expressed as a 100% change, a unitary price movement, and ($ per 100bps yield change) is referring to a percentage point change).

The metric DV01 to Next Call, is an adjustment of the commonly used DV01, it will refer to the monetary variation a security is exposed to, per a percentage point interest rates change, assuming that a security's call option will be exercised in the next callable date.

As mentioned before, DV01 is very convenient to produce analysis, as it allows hedge strategies to be developed (which is not possible using duration, as it delivers a value in percentage terms).

Interpretation/Results:

As discussed, structured products are highly exposed to call risk. Consequently, this metric is useful as it helps develop hedging strategies, as well as compare the exposition of different securities to interest changes in absolute value, in the case the call option is being exercised in the next callable date.

This value can be more accurate than the DV01 to Maturity, depending on the expectations about the security life. In the particular case of structured products, we have to remember that there are very few products from this market that reach the maturity. Consequently, metrics like this are very useful to investors depending on their expectation about the product life. In this case, this metric is very interesting if the investors believe the call will be exercised in the next possible period, or at least for them to study the implication on the portfolio if this possible scenario happens.

Also, a metric as DV01 to Workout date can be more valuable, as it uses the most probable date to an option being exercised, as it is possibly different than the next call date. In case the workout date is the next callable date, this suggested metric (DV01 to Workout Date) will also incorporate that scenario.

As mentioned before, we can indirectly reach this metric, through an adaptation of the scenarios, however we suggest Moody´s to provide this directly.

4.4.11. Convexity to Worst

In our calculation the results were inconclusive. However, it may be valuable to define risk calculating models as it corrects the inaccuracies of a linear duration, in the worst scenario.

<u>*Definition:*</u>

This metric was developed by us together with Moody´s following their expectations on what it should measure, it is something new that is not currently being used in the market or by the institution. Convexity, the change in duration to worst when interest rates change by 1%, can also be seen as the rate of sensitivity of an asset to interest rates. A bond with greater convexity is less affected by interest rate changes than a bond with a lower convexity. Therefore, as the price for high convexity bonds is not as easily impacted, these will also have higher prices than lower convexity ones (irrespective of a rise or fall in interest rates). Mathematically, it is calculated through the following formula:

$$C = \frac{1}{P} * \frac{d^2P}{dr} = \frac{1}{P(1+y)^2} \sum_{t=1}^{T} (t^2 + t) \frac{CF_t}{(1+y)^t}$$

where P is the bond price, y is the yield and CF_t stands for the cash flow at period t.

Convexity to worst is the convexity given the worst-case scenario. In other words, instead of using the yield to maturity of the bond as given, it considers the worst-case scenario yield. Using a callable bond as an example, convexity to worst is computed using the lowest between the yield to maturity and the yield to call of the bond. (As explained previously, the worst-case was determined by assessing which one of the two scenarios – run to maturity or forced call at the next callable date – yielded the lower return).

Interpretation/Results:

In the tranches where we could observe changing durations, we could observe some values of negative convexity. However, in roughly 90% of the times, the convexity would be equal to zero, as the duration would not change with small changes in yield. Considering this, the analysis we made on our sample of tranches was inconclusive on this metric, as was its importance and relevance for this sample.

4.4.12. Duration to Worst

Valuable as it returns the sensitivity of the price relatively to interest rates in the worst-case, but inconclusive results on the analysis.

Definition:

This metric was designed by us, especially for Moody's and it is not currently being used in the market or by the institution. Duration by itself is an extremely important measure to consider, especially on Fixed Income securities. It is the sensitivity of a security price to a change in the level of interest rates, and is calculated as:

$$\text{Macauley Duration} = \sum_{t=1}^{T} t * w_t \quad \text{with} \quad w_t = \frac{CF_t/(1+y)^t}{P}$$

where the numerator is the present value of the cash flow occurring at time t and P is the bond price. It is also commonly calculated as the percentage change in a bond's price given a 1% change in its YTM (modified duration):

$$\text{Modified Duration} = \frac{\text{Macauley Duration}}{(1 + \frac{YTM}{n})}$$

Intuitively, one can think of duration as the number of years to receive the price paid for the bond when payments are fixed. The same would not be true for floaters, since the coupon resets every period. Therefore, this is used as a measure of risk, because the longer the time to maturity, as duration also increases with time, the higher the uncertainty and the risk associated. Also, a higher duration implies a higher loss on the asset's price when interest rates rise by 1%.

If a bond is callable, puttable, or has other exchangeable features, its duration to worst uses the lowest of these yields instead of the yield to maturity. Considering the case of a callable bond, duration to worst is the percentage change in the bond's price given the lowest yield between its YTM and its yield-to-call, if lower. Mainly, it assumes that bond will or will not be called, without allowing for uncertainty, such as changes in the interest rate environment. Considering this, duration to worst would be the worst-case scenario of duration for a certain fixed income asset.

Interpretation/Results:

Having a clear understanding about the definition of this metric, we have conducted the simulations on a specified set of tranches provided on the Structured Finance Portal. These simulations were applied to two different scenarios; in the first we would consider the YTM, and in the second the bond would be called, referring to the yield-to-call; from these scenarios, the one with the lower yield is defined as the worst case. In the simulations we would change the interest rates by 1 percentage point and observe the effect on both prices. The scenario with the highest duration should suffer the biggest change in price.

An important point that we have considered while analyzing the results is that a callable bond may not be desirable by the holder of the asset, because once the bond is called by the issuer, its holder stops receiving the cash flows, i.e. the returns. For example, if the economy enters a rate cut cycle, there would be attractive refinancing opportunities due to the lower rates, which leads us to the prepayment. At this stage of the economy, borrowers would simply repay their debt and refinance it at a lower interest rate. Also, as lower interest rates have a positive impact on a fixed income asset, high duration would be desirable at this phase. However, sometimes exercising the call in the next possible period could have value to the investor, depending on future cash flows and on the call strike. In other words, the impact of a call exercise could be beneficial or harmful to investor and issuer: it will depend on whether the option is in or out of the money. When testing this metric, we are forcing a call in the next possible date, implying that it will be exercised independently of it harming or not the issuer. It is important to remember that in a normal and real market situation the issuer will only exercise in the case where it creates value to him.

Considering this, one would expect a lower yield to return a higher duration, because if the bond is yielding lower returns, then the repayment of the amount invested on the assets would take longer to be received through its cash flows. For example, a higher yield would be implying that the bondholder would receive repayment for the security at a higher rate. However, this does not apply for most of the cases we have analyzed. First, in roughly 60% of the cases, duration would be the same for all the scenarios, which might be explained by the fact that one of the scenarios was a forced call on a callable bond happening very close to or at maturity. Also, whenever there was a lower duration on one of the scenarios, it was on the callable bond, obviously because calling a bond before the maturity dates forcibly reduces the maturity of the asset, and thus its duration.

Duration to worst is relevant but we should interpret the result carefully, since it may return in some cases inconclusive results – mainly when there is no difference between duration in different scenarios. Additionally, although it has been possible to compute the duration to worst using the Structured Finance Portal, it may be interesting to carry out a more in-depth study on a possible extended metric, such as effective duration to worst. Since the analysed products have variable cash flows and price, this suggested metric could capture price sensitivity in more detail. It is also important to take into account that although duration is easier to calculate and understand for investors, convexity can provide more accurate and exact results.

4.4.13. Return Over Horizon Given Yield Curve Shifts

Valuable because it shows how returns are affected by a change in the yield curve.

Definition:

A parallel shift in the yield curve happens when the slope of the curve remains unchanged; that is, the interest rates on all maturities (short-term, intermediate, and long-term) move, increasing or decreasing, by the same number of basis points. If the slope changes and yields suffer by different amounts, the shift is non-parallel. (Kennon, 2016)

When the yield curve shifts, the price of the bond, which was initially priced based on the initial yield curve, will change. If, for example, a bond is maturing in two years and the correspondent two-year yield decreases, the bond will increase in price due to this yield curve change.

If the yield spread between long- and short-term interest rates narrows, the yield curve is said to flatten, and the price of the bond will be adjusted. If it steepens, on the other hand, the spread between long- and short-term interest rates increases, and prices of longer-term bonds decrease compared to short-term bonds. (Fabozzi & Wickard, 1997).

Interpretation/Results:

To assess the impact of the forward curve in practical terms, we considered 6 scenarios of parallel shifts, by increasing and decreasing the corresponding forward curve (EURIBOR or GBP LIBOR, depending on the deal) by 0.5 percentage points (pp), 1pp, and 2pp.

Comparing the yield changes for a set price of 100, it can be concluded in general terms that when the forward rates increase, so does the yield of the instrument – meaning the corresponding "true" market price would drop in price. The opposite happens with a decrease in interest rates, but to a lesser degree: the change in the bond's yield is smaller with a decrease compared to an increase of equal magnitude. In fact, there are instances where the magnitude of the decrease does not matter, and the yield drops to a certain level and remains the same despite it being a decrease of 0.5pp, 1pp or 2pp.

We also ran this initial scenario against a 2nd scenario with lower prepay rate, and higher default and loss rates. There was not a significant difference in the changes in yield (the magnitude and behavior of the change was pretty similar across scenarios).

Even though the yields react in a fairly predictable direction to forward curve changes, the actual magnitude varied a lot. There are also exceptions to the rule, such as tranches where the yield drops to the exact same level regardless of the magnitude (0.5pp, 1pp or 2pp) or the direction (increase or decrease). This metric could therefore be useful to clearly show how returns would be impacted from a parallel shift in interest rates.

4.4.14. Asset Swap Spread

Not valuable: although it can be used to evaluate credit risk, it has assumptions that only fit regular bonds.

Definition:

An Asset Swap is a package of a Corporate Bond with a fixed coupon and an Interest Rate Swap, where the buyer gets the bond and pays to the Asset Swap Seller a fixed rate (equal to the coupon on the Bond) while receiving a fixed spread plus a variable component (dependent on an index). The Asset Swap Spread on the variable leg is such that the value of the Asset Swap package equals the par value of the respective Corporate Bond at the inception of the deal.

Therefore, mathematically the spread can be calculated the following way:

$$Spread_{AS} = \frac{V - P}{A}$$

Where $V = \frac{c}{[1+r(0;1)]} + \cdots + \frac{100+c}{[1+r(0;T)]^T}$, $A = \frac{1}{[1+r(0;1)]} + \cdots + \frac{1}{[1+r(0;T)]^T}$, c = Coupon Rate, r(0;t) = zero coupon swap rate, and P = market price of bond.

Interpretation/Results:

The Asset Swap Spread is a measure of credit quality, it reflects the risk in the cash-flows while assuming the interest rate risk to be residual. However, since bonds only pay interest until maturity and in these specific products we would use the current balance as principal, this measure must be recalculated after principal payments.

4.4.15. ZVO

Does not add value and cannot be applied to small cashflows.

<u>*Definition:*</u>

Unlike the Z-spread which is added to the whole risk-free spot rate curve, the Zero-Volatility OAS applies to a single interest rate path such that:

$$Price\ of\ Bond = \frac{coupon}{(1+r(0,1))^1} + \cdots + \frac{coupon}{\left(1+r(0,t)+ZVO(t)\right)^t} + \cdots + \frac{coupon+Face\ Value}{(1+r(0,T))^T}.$$

<u>*Interpretation/Results:*</u>

Similar to the Z-spread, a higher ZVO should indicate higher risk on the Bond. Moreover, both these metrics increase with volatility when we are considering a MBS due to the increase in the value of the option embedded along the fact that the MBS holder is going short on the option.

This metric presents various flaws: first, it cannot be applied to relatively small cash-flows (regardless of how high the discount rate is, there is a limit to how much one can discount these cash-flows and achieve the market value); second, higher cash-flows and most recent ones are prone to have a lower ZVO (hence it does not add value when comparing within the cash-flows); and finally, the ZVO's own value in itself is meaningless.

4.5. Greeks

The Greeks are a set of metrics usually applied to call and put options on stocks. They are important to investors holding options because they show how the price of the call or put moves when variables related to the underlying change (such as the price of the underlying asset, volatility, interest rate, and time to maturity).

Callable bonds would be the closest equivalent in structured products. Therefore, the metrics would have to be adapted to bonds; specifically, it would be necessary to know the formula with which the option component would be priced. This is quite tricky regarding the type of products we are dealing with: as this kind of structured products are traded OTC, the valuation method of the product in itself is habitually undisclosed and varying with several factors, such as the lifecycle of the product, and hedging and packaging costs, as described previously. As a result, the specific option pricing formula is extremely hard to determine.

Thus, for our particular project, we were dependent on the specificities of the products and on the information available in the portal, so the Greeks were calculated through simulations in the portal (none of these metrics are available in the portal yet). Since they were not achieved through a specific formula, they might not be as accurate as possible, as they are subject to the assumptions of the portal.

4.5.1. Delta

Valuable to understand how sensitive the call option is to changes in bond price.

<u>*Definition:*</u> (Bodie, Kane & Marcus, 2014; Hull, 2015)

Delta, usually applied to options on stocks and here applied to callable bonds, compares the change in the price of an asset to the change in the price of its derivative:

$$\Delta = \frac{\partial C}{\partial S} = \frac{Change\ in\ option\ value}{Change\ in\ stock\ value}$$

This metric measures the option's exposure and sensitivity to changes in the underlying asset's price, and it can be interpreted as the change in option price for a $1 increase in the stock price.

Assuming a stock option has a delta value of Δ, if the price of the underlying stock increases by $1 per share, the option will rise by $\$\Delta$ per share, ceteris paribus. Having a positive delta means that if the underlying rises, the option/position loses value. Conversely, a negative delta implies that if the underlying rises, the option/position gains value.

Interpretation/Results:

The delta was lower for the most senior tranches of the deals, and was gradually higher the lower the seniority – meaning the more junior the tranche, the higher the exposure and sensitivity to changes in the bond price.

It tended to differ in size between prices, within each tranche. That is, the delta decreases in size (ignoring the sign) as the price considered increases, implying the effect on the price of a change in value of the underlying would be more pronounced for lower prices, compared to higher prices.

In terms of the sign, delta is usually negative, which correlates with the fact that, from the issuer's perspective, the option loses value as the price increases, as it is more likely to be exercised.

This metric can be important to understand how sensitive the call option is to changes in price, for different levels of price. It does seem to follow a predictable path: the call option becomes less valuable (even reaching a negative value) as the price of the product is higher, and the sensitivity is heightened the more junior the tranche. If made available and calculated properly, which could be difficult due to the lack of pricing formulas, it would allow investors to assess the impact of a change in the bond price itself, on the embedded call option.

4.5.2. Vega

Could be valuable since it shows the call value sensitivity to changes in volatility, however we could not test the metric.

<u>Definition:</u> (Bodie, Kane & Marcus, 2014; Hull, 2015)

Vega measures an option's sensitivity to changes in the volatility of the underlying asset. It represents the change in option price for a 1% change in the underlying asset's implied volatility:

$$\nu = \frac{\partial C}{\partial \sigma} = \frac{Change\ in\ option\ value}{Change\ in\ volatility}$$

Vega changes when there are large price movements, resulting in increased volatility, in the underlying asset. It is interpreted as the option/position gaining $\$\nu$ for each percentage-point increase in implied volatility, ceteris paribus.

If the vega value is greater than the bid-ask spread, the options are said to offer a competitive spread. As the option gets closer to expiration (and time to maturity decreases), vega is expected to fall. In addition, both call and put options should gain value with higher volatility. (Folger, 2017)

<u>Interpretation/Results:</u>

To calculate this metric through simulation, as the remaining Greeks were calculated, the portal would need to display the volatility, and allow it to be changed as a user-input. In that case, the metric could, in theory, be useful to assess the call sensitivity to changes in volatility, and predict its value if times of increased uncertainty and volatility are expected. Still, by being calculated through simulations as the other Greeks were, it would be subject to the portal assumptions; for a more solid result, the specific call option formula would be necessary, in order to take its derivative.

4.5.3. Rho

Could be valuable as it gives the sensitivity to changes in interest rate, however it is usually the less used of the Greeks because of the small magnitude of the changes.

Definition: (Hull, 2015)

Rho measures sensitivity to the interest rate: it is the derivative of the option value with respect to the risk-free interest rate. In other words, it is the rate of change in the derivative's price relative to a change in the risk-free interest rate:

$$\rho = \frac{\partial C}{\partial r} = \frac{Change\ in\ option\ value}{Change\ in\ risk\ free\ rate}$$

For a rho of ρ, for an increase in interest rates of 1 percentage point, the option/position gains $\$\rho$, ceteris paribus.

Interpretation/Results:

This metric was calculated by comparing the value of the call option in the current scenario with the value in a scenario with a 1 pp increase in the forward curve (parallel shift). The difference in value gives us the rho, the change in value for a 1 pp increase in interest rates.

The results obtained did not seem to follow any specific rule in terms of sign: some tranches reacted negatively (positively) to an increase in interest rates, with the call losing (gaining) value – for all prices –, while others benefitted for some prices and were negatively affected for other prices (for example, having a positive rho for prices below 100 and negative for above).

Comparing the results of the tranches within each deal, in one of the cases the tranches reacted as the example above – positive rho for prices below 100 and negative otherwise. The other deal, with 7 tranches, yielded either all positive or all negative rho's for the same tranche.

In terms of seniority, no conclusions could be taken, since some of the junior tranches had lower rho's than the most senior ones.

A change in interest rates does not usually have a significant impact on option pricing, rendering this metric the more overlooked of the 'Greeks'. Nevertheless, since the two deals considered reacted in different and seemingly random ways, and the tranches also behaved in different patterns, it could be valuable to have information on this metric, as the movements can be quite unpredictable. More solid results could be studied if a call option pricing formula, specific to each product, could be discerned.

4.5.4. Theta

Could be valuable to assess how the call value changes with the passage of time, however a specific option pricing formula is essential, so that the fact that these products do not usually reach maturity is taken into account.

Definition: (Hull, 2015)

Theta measures the sensitivity of the value of the derivative to the passage of time, also referred to as the time decay on the value of an option, since all else constant, the option loses value as the maturity of the option is closer. Mathematically speaking:

$$\theta = \frac{\partial C}{\partial t} = \frac{Change\ in\ option\ value}{Change\ in\ time\ to\ maturity}$$

Time decay leads to a loss in option value as it approaches its expiration date. In theory, for a theta of Θ, the option loses Θ per day until it reaches expiration, ceteris paribus.
Interpretation/Results:

No conclusions could be taken on the behaviour of theta. There were cases where all thetas were negative/positive for all prices, and decreasing with price – meaning the effect on the call value was worse for higher prices compared to lower prices; and cases where the effect of one less month to maturity was positive for smaller prices but negative for higher ones.

Therefore, the effect of having time to maturity decrease 1 unit, and being closer to maturity, affects the value of the call in very different ways depending on the price considered.

There was also no discernible pattern relatively to the seniority of the tranches. In terms of magnitude, the change in call value was relatively small, with theta denoting values usually below 1 pp.

While we could not take any concluding remarks about this metric, it could be valuable if there is interest in assessing how the call value reacts to the passage of time. Nevertheless, it would need to be calculated through a specific option valuation formula, as simulations ignore the fact that these products usually do not reach maturity and are more likely to be exercised beforehand.

4.5.5. Gamma

Not valuable because conclusions can be taken from analysing delta; gamma does not provide additional insight.

Definition: (Bodie, Kane & Marcus, 2014; Hull, 2015)

Measuring the rate of change in the delta with respect to changes in the underlying price, Gamma is the second derivative of the value function with respect to the underlying price. In other words, it is the rate of change in an option's delta per 1-point move in the underlying asset's price:

$$\Gamma = \frac{\partial^2 C}{\partial S^2} = \frac{\partial \Delta}{\partial S} = \frac{Change\ in\ delta\ value}{Change\ in\ stock\ value}$$

The gamma of an option indicates the sensitivity of an option's delta in relation to a $1 change in the underlying security. Theoretically, it is:

- “highest when the option gets near the money;
- positive for long options and negative for short options;
- smallest for deep out-of-the-money and deep in-the money options.” (Summa, 2014)

Interpretation/Results:

While the sign of the changes (positive/negative) did not seem to follow any predictable move, despite the theoretical expectation of it being negative for short options, it was always fairly constant and close to 0.

Thus, the value of the delta itself does not change that much following changes in the underlying price, and when it does it is in a constant pattern (same increase/decrease across prices). So, the sensitivity of the delta to price changes stays fairly the same regardless of the initial price.

For this reason, it can be argued this metric does not add much value to understanding the different tranches within a deal, since the conclusions derived from this metric can be attained through analysing the delta, which would even give greater insight.

5. Regulation Project

5.1. Introduction to Regulation

In this final section of our report, we focus on existing regulation, namely from Bank for International Settlements (2016), developed with the purpose of calculating the risk weights regulated financial institutions, mainly banks, must consider in order to meet regulatory requirements. This subject is quite relevant not only to the regulated institutions, but also to investors, since the changes in risk weights may affect them indirectly through the products they hold. Moreover, Moody's portal already offers risk weight calculation, under two approaches (SEC-ERBA and SEC-SA), thus changes in regulation will have to be incorporated in order to keep providing the best and most updated advice to their customers.

The Basel Committee was established by the central bank governors of a group of ten countries to enhance financial stability, by improving the banking supervision and the enforcement of regulation rules, and to serve as the head coordinator for regular cooperation between its member countries on banking supervisory matters. Since its jurisdiction, the Basel Committee has expanded from the G10 to 45 institutions and has established several international standards for banking regulation, the most known being the Basel I, Basel II and the most recently published, Basel III.

Basel I, also called the Basel Capital Accord, was established to respond to a capital adequacy need, the main focus of the Committee's activities in the 1980s. One of the main policies of the Accord was setting a minimum capital to risk-weight assets of 8%. An amendment to Basel I, established 9 years after its implementation, aimed at incorporating market risks arising from banks' exposure by allowing banks to use internal models, such as VaR models, to measure their capital risk requirements, subject to specific requirements, both qualitative and quantitative.

Basel II, the New Capital Framework, aimed primarily at assessing financial innovation and is comprised of three main pillars. The first is the minimum capital requirements, mainly to develop and expand the standardised rules set out on the old Basel framework. The second point consists on the supervisory review of an institution's capital adequacy and internal assessment process. Finally, the third pillar intends to strengthen market discipline and encourage the sound banking practices.

The most recent Accord, Basel III, was developed to strengthen the Basel II framework as a response to the credit crisis of 2008. Concerns relating to dependence in external ratings and other gaps from Basel II, that support the 2008 crisis, led to the introduction of new approaches and new restrictions to the previous methodology in Basel III. The main policies outlined were an additional layer of common equity, a countercyclical capital buffer, a leverage ratio, liquidity requirements and additional proposals to target specific financial institutions.

Since the implementation of Basel III, the requirements of the Basel committee have expanded significantly, with the main focus on the risk-weighted assets (RWA), internal ratings and on setting regulatory capital floors. These are the base of Basel IV, which will be implemented within the next years and will certainly cause serious impact on banks, mainly at a capital level. The main goal of the changes to the framework was to enhance risk sensitivity, recalibrate risks in more prudent way, improve consistency with the underlying credit risk framework and enhance simplicity.

From a more general view, the Basel Committee on Banking Supervision (BCBS) has made changes to the previous framework regarding some past experiences of implementation and essentially to strengthen the capital standards for all participants (originators, sponsors and investors) in securitization. The revised framework includes an alternative capital treatment for "simple, transparent and comparable" (STC) securitizations. The main goal of STC criteria is to help all involved parties evaluate more thoroughly the risks and returns of a securitization, and to enable more straightforward comparisons across securitization products within an asset class. These criteria cannot substitute due diligence, although it will be useful for investors in undertaking due diligence on securitisations. The STC will help mitigate uncertainty related to asset risk, structural risk, governance, and operational risk.

Among the proposed changes under Basel IV, the most impactful regards the securitisation's exposures calculations, which are used to calculate a bank's capital requirements. This can be done according to three different approaches under Basel III: SEC-ERBA, SEC-IRBA and SEC-SA.

SEC-SA is the only allowed approach for resecuritisations and comes last in the hierarchy of the approaches, meant to be used by less sophisticated banks. It should only be chosen as a last resort, if none of the other approaches (IRBA and ERBA) can be applied.

Meanwhile, the IRB approach is the most preferred of the three, better for assessing the risks related with the securitisation exposures and thus aimed at more sophisticated banks. This relates to internal models developed by the banks, tailored to their specific characteristics, and therefore are not public knowledge; however, they are still subject to strict rules and must be approved by the supervisory entity. Consequently, the impact of using this approach in comparison to the others is not possible to assess as these models are not publically disclosed.

Both SA and IRBA calculate the risk-weights using SSFA (Simplified Supervisory Formula Approach), the difference lies with how the variables (K, D, A and p, which will be described in the next sub-chapter) are defined; particularly, the K and p for the IRBA approach are much more comprehensive than the SA parameters, since they take into account factors such as Loss Given Default, maturity of the tranches and effective number of loans in the pool, which the SA approach does not consider.

A financial institution that does not have the appropriate data to assign the parameters described below, and thus cannot use SEC-IRBA, SEC-ERBA or SEC-SA, must assign the exposure a risk weight of 1250%.

In the next section of our report, we explore the most updated Basel policies that will be established under Basel IV, focusing on the Standardized Approach (SA) and External Ratings Based Approach (ERBA).

5.2. SEC-SA Methodology

To calculate capital requirements and the specific risk-weighting factor for a securitisation exposure to an SA pool (when the IRB cannot be applied because the bank lacks the approval to apply IRB, the bank's supervisor prohibits it, or the bank simply lacks the data to use IRB) using the SEC-SA, a bank must provide accurate information on the following four inputs:

1. K_{SA}, the SA capital charge for the underlying exposures using the Standardised Approach for credit risk, is the weighted-average capital charge of the entire portfolio of underlying exposures. Calculated according to the total capital requirement of the underlying exposure, using the risk-weighted asset amounts in the SA in Section II of the Basel framework in relation to the sum of the exposure amounts of underlying exposures, multiplied by 8%. It is expressed as a decimal between zero and one, such that a weighted-average risk weight of 100% means K_{SA} is 0.08. The RWA calculation must take into account the effects of any credit risk mitigant applied to the underlying exposures. (Credit risk mitigants can be collateralized transactions, on-balance sheet netting agreements, guarantees and credit derivatives. These techniques are used in calculating capital requirements). A provision or non-refundable purchase price discount on an exposure in the pool is excluded from the calculation, which should consider the gross amount of the exposure (without the specific provisions and discounts).

2. W, the delinquency ratio, is the ratio of the sum of the nominal amount of delinquent underlying exposures to the nominal amount of underlying exposures. Delinquent underlying exposures are underlying exposures that are:

a. at least 90 days past due;

b. subject to bankruptcy or insolvency proceedings;

c. in the process of foreclosure;

d. held as real estate owned;

e. or in default (default is defined within the securitisation deal documents).

3. Input A, the tranche attachment point, is the threshold at which credit losses within the underlying pool would first be allocated to the securitisation exposure. It is a decimal value between zero and one, and can found as the maximum between zero and the ratio of the outstanding balance of all underlying assets in the securitisation minus the outstanding balance of all tranches that rank senior or equal to the tranche that contains the securitisation exposure of the bank (including the exposure itself), to the outstanding balance of all underlying assets in the securitisation.

4. Input D, the tranche detachment point, is the threshold at which credit losses, within the underlying pool, result in a total loss of principal for the tranche in which a securitisation exposure exists. It is also a decimal value between zero and one, and can found as the maximum between zero and the ratio of the outstanding balance of all underlying assets in the securitisation minus the outstanding balance of all tranches that rank senior to the tranche that contains the securitisation exposure of the bank, to the outstanding balance of all underlying assets in the securitisation. Thus, parameter D is the parameter A plus the ratio of the current

dollar amount of the securitization positions with an equal or higher seniority than the tranche with the exposure, to the current dollar amount of the underlying exposures.

For inputs A and D, overcollateralization and funded reserve accounts are to be recognised as tranches; and the assets serving as such reserve accounts are to be recognised as underlying assets. Unfunded reserve accounts and assets which do not provide credit enhancement are not to be included in the calculations.

Having defined the aforementioned variables, and knowing that p is defined as

$$\begin{cases} p = 1 \; for \; non-STC \; securitisations \\ p = 1.5 \; for \; resecuritisations \\ p = 0.5 \; for \; STC \; securitisations \end{cases}$$

the remaining factors are calculated as follows:

$K_A = (1 - W) \cdot K_{SA} + W \cdot 0.5$, if delinquency status is known for all underlying exposures;

$K_A = \left(\frac{EAD_{Subpool\,1\,where\,W\,known}}{EAD\;Total} \cdot K_A^{Subpool\,1\,where\,W\,known}\right) + \frac{EAD_{Subpool\,2\,where\,W\,unknown}}{EAD\;Total}$, if delinquency status is not known by the bank for no more than 5% of underlying exposures in the pool; $u = D - K_A$; $a = -\frac{1}{p \cdot K_A}$; $l = \max(A - K_A; 0)$;

and $K_{SSFA(K_A)} = \frac{(e^{a \cdot u} - e^{a \cdot l})}{a(u-l)}$ (capital requirement per unit of the securitisation exposure).

Finally, Risk Weight is calculated as $RW = \left[\frac{K_A - A}{D - A} \cdot 12.5\right] + \left[\frac{D - K_A}{D - A} \cdot 12.5 \cdot K_{SSFA(K_A)}\right]$, if A is less than K_A and D is greater than K_A. If D is lower or equal to K_A, the exposure is assigned a risk weight of 1250%. If A is higher than or equal to K_A, the exposure is calculated as $K_{SSFA(K_A)} \cdot 12.5$. If the delinquency status is unknown for more than 5% of underlying exposures in the pool, the securitisation exposure is risk weighted at 1250%.

A final note: when a bank applies the SEC-SA approach to an unrated junior exposure, for which no rating can be inferred, and the more senior exposures are rated, the risk-weight of the junior tranche cannot be lower than the risk-weight for the next more senior rated exposure.

5.3. SEC-ERBA Methodology

While applying the External Ratings-Based Approach (SEC-ERBA), the risk-weighted assets are determined by the product of the securitization exposure (the sum of the on-balance and off-balance sheet exposure amount) by the appropriate risk weights. In order to be applicable in the securitization framework, one should also verify if the operational requirements (defined and clarified in appendix 2) are met when using external credit assessments and inferred ratings.

Moreover, the risk weights to be applied will depend on many factors, such as if we are considering short-term or long-term ratings.

Before the explanation of how the risk weight is calculated, it is crucial to define tranche maturity (M_T) and how it should be calculated under the Basel's latest regulation that will be incorporated in Basel IV. The tranche maturity is simply the effective maturity that is remaining and is expressed in years.

In order to calculate it, the institution can choose between two possible ways:

1) As the monetary value (e.g. dollar or euro) weighted-average maturity of the contractual remaining cash flows of a tranche, being it calculated using the following formula:

$$M_T = \frac{\sum_t t \times CF_t}{\sum_t CF_t}$$

where CF_t denoted the cash flows (what is the sum of principal, interest and fees) contractually paid in the period t by the borrower.

2) Based on tranche final legal maturity, using the formula:

$$M_T = 1 + (M_L - 1) \times 80\%$$

where M_L stand for the tranche final legal maturity.

When the contractual payments are conditional and/or dependent on the actual performance of securitised assets the first approach cannot be used (for example ABS); the institution must calculate maturity using the final legal maturity method.

Another relevant point regarding the effective maturity is that it assumes a floor of one year and a cap of five years.

5.3.1. Short-term Ratings

When dealing with short-term exposures, it is only needed the short-term rating or the inferred rating, that is based on a short-term rating. Based on the external credit classification, the risk weight is given by Table 1 (Appendix).

5.3.2. Long-term Ratings

For long term-exposures, the risk-weighted calculation depends of more factors than the short-term one. In the long-term case it is necessary not only to access the external rating grade, but also tranche seniority position, tranche maturity (that should be calculated as previously explained), and in the case of a non-senior tranches, it is necessary to calculate the tranche thickness (T) – which is equal to detachment point (D) minus attachment point (A).

Regarding the senior tranche, that is the tranche in the higher seniority position, the risk weight is given by Table 2 (Appendix), being only dependable of tranche maturity and on the external credit assessment directly given or inferred.

When dealing with non-senior tranches, there are no significant changes. Instead of using the table 2 as reference, Table 3 (Appendix) should be used. Using the risk weight from table 3, already adjusted to maturity, and using the tranche thickness, the risk weight should be calculated using the following formula:

$$Risk\ Weight = (risk\ weight\ from\ table\ 3\ \ adjusted\ to\ maturity)\ \times\ (1 - \min(T; 50\%)$$

An observation should be made regarding the tranches that do not have a maturity equal to 1 or 5 years, as in this case the risk weight should be calculated through a linear interpolation. Being also important to warn that the effective maturity has a floor of 1 year and a cap of 5 years; consequently, different maturities are restrained by these effective maturities limits. For instance, an effective maturity of 6 years must follow the 5 years' rules.

$$Risk\ Weight\ for\ a\ Maturity\ equal\ to\ X\ =\ RW_{year\ 1} + (\ X - 1)\ \times\ \frac{RW\ \ _{year\ 5} - RW\ \ _{year\ 1}}{5 - 1}$$

where X is equal to tranche maturity and RW stands for risk weight.

5.3.3. 'Simple, transparent and comparable' (STC) securitisations

The revised framework includes an alternative capital treatment for "simple, transparent and comparable" (STC) securitizations. The main goal of STC criteria is to help all involved parties evaluate more thoroughly the risks and returns of a securitization, and to allow more straightforward comparisons across securitization products within an asset class. These criteria cannot substitute due diligence, although it will be useful for investors in undertaking due diligence on securitisations. The STC will help mitigate uncertainty related to asset risk, structural risk, governance, and operational risk.

Simplicity relates to the fact that there should be homogeneity of underlying assets, with simple characteristics, and a transaction structure should not be overly complex.

The main purpose of Transparency is to provide enough information on the underlying assets, the structure of the transaction and the parties involved in the transaction, thereby promoting a more comprehensive and thorough understanding of the risks involved.

Comparability should support investors in understanding investments and allow more straightforward comparison across securitisation products within an asset class. It is important to take into account differences across jurisdictions.

Whenever a securitisation transaction is assessed as STC-compliant, it should be subject to different capital treatments under the ERBA. Firstly, the new floor for risk weights is 10% for senior tranches and 15% for non-senior ones. For short-term ratings, the risk weights are applied as according to Table 4 (Appendix). In the case of long-term securitisation, the weights are divided between senior and non-senior tranches, being the weights restrained by the floor of 1 year and the cap of 5, and it is necessary to compute an interpolation to get the adequate weight to use. The tables to compute the correct weights are Table 5, for senior tranches, and Table 6 for non-senior tranches.

5.4. Results and Interpretation

In order to compare the External Rating Based Approach (ERBA) to the Securitisation Standardised Approach (SEC-SA), we were given by Moody's Analytics a portfolio consisting of 35 tranches (22 RMBSs, 8 ABSs and 5 Auto loans) to run both approaches using the SF Portal. After confirming if the assumptions regarding the risk weights were consistent with Basel III, we found out that the SF Portal not only did not consider all the tranches (only 29 were considered), but also attributed higher risk weights using the ERBA approach, compared to SEC-SA, for 22 out of the 29 tranches. Moreover, ERBA's risk weights reached higher levels more often, giving the highest possible value (1250%) 5 times, while the highest value under the SEC-SA was 607.33%.

These results are surprising, since the ERBA is higher in the hierarchy of approaches, hence is more restrictive and is based in more detailed information than the SA. Therefore, it should require lower capital requirements for financial institutions. Under these circumstances, we may be under the presence of a Moral Hazard cost, since the institutions will prefer a less demanding and simpler approach (SEC-SA), that also leads to less demanding capital requirements.

6. Conclusions

As this report demonstrates, there are several points that are not fully clear and might be improved as the market becomes more efficient. The market for structured finance products, the main focus of this report, is still growing and becoming more popular every day. However, there are still some aspects that made our analysis more difficult.

First, as for structured finance products the market is not transparent, the lack of information makes it extremely hard to predict the prices and the respective maturities of the securities. The tools provided by Moody's Analytics were developed to facilitate the analysis for these complex products. Still, in several metrics we would need to assume a scenario or a set of different scenarios to compute the value of the metric. It is true that the Portal has made this step easier by providing more information than is available from public sources, but we still found the task very abstract, in the sense that the outcome would be highly dependent on the assumptions made for the scenario. One example that represents this is the Yield to Workout date ("What should be the workout date?") and the Yield-to-Call ("When will the bond be called?"). Having these as inputs, the results will be strongly influenced by the assumption values, or in these cases dates. Adding to this, it is hard to find existing tools, which in our case for the metrics would be predicting models for this type of products to solve these problems. The CPR Estimation: Richard and Roll (1989) model developed in this report is one example of these predicting models.

Secondly, the metrics that are currently being used to analyse structured products are not complete and could be more efficient in capturing and measuring the risk/results. On the different projects, we have analysed several tranches from a wide range of deals, and while applying the metrics to the structured products, we had to assume some inputs, as were the cases of the CPR and/or CDR level, based on historical data rather than on forward looking models, such as the Richard and Roll (1989) model, suggested previously.

Finally, regulation has been changing and is consistently improving over time to better capture the risks implied in every security, and to increase transparency. An example would be the increase in the requirements of the different approaches described on the report, and the STC (simple, transparent and comparable) criteria that was developed to guarantee the credibility and safety of the products.

7. References

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8. Appendix

Appendix 1: Failure of the Yield to Workout date

In this equation we are assuming we bought the product at 100, the initial balance is 100, the scheduled prepayment is 30 per year and the coupon payment is 5 % in the first year, 6% in the second and 7% in the third period. We are also assuming the call will be exercised when there is remaining 10 % from the original balance.

$$P = 100 = \frac{30 + 5}{(1 + yield\ to\ workout\ date)^1} + \frac{30 + 4{,}2}{(1 + yield\ to\ workout\ date)^2} + \frac{30 + 2{,}8}{(1 + yield\ to\ workout\ date)^3} + \frac{10}{(1 + yield\ to\ workout\ date)^3}$$

In this case we would have a maturity of 3 years and a yield of around 5,7%. If we know let the model take into consideration the market conditions, for instance an interest rate decrease that would imply a CPR of 30% we would get a different cash-flows distribution:

$$P = 100 = \frac{30 + 5 + 21}{(1 + yield\ )^1} + \frac{30 + 2{,}94 + 12}{(1 + yield\ )^2} + \frac{7}{(1 + yield)^2}$$

Now taking into consideration the impact of market changes on cash-flows distribution we would have a maturity of 2 years and a yield of around 5,3%.

As it possible to see in the example this metric could lead investors to wrong inferences and consequently to wrong capital allocations, by taking into account the prepayment the security life reduces one year and the yield decrease 0,4%, in a real life situation this could have serial implications has the investor to reach the 3-year maturity will have to incur in transaction costs again and at the time the available product may not delivered return high enough to compensate.

Appendix 2: SEC-ERBA Operational Requirements

The appropriate risk weights will be dependent on if the following operational requirements regarding the use of external credit assessments or for inferred rating (these originate when there is an unrated exposure that is senior to another exposure, this one being rated, within the same transaction) are met.

Use of external credit assessments[1]:

- The external credit assessment must consider and reflect the entire amount of credit risk exposure the bank has regarding all payments owed to it;
- The external credit assessment must be from an eligible external credit assessment institution (ECAI), recognised by the respective national supervisor in accordance with the Basel II framework. To be classified as an ECAI, an institution must meet six requirements:
  - Objectivity (the assessment methodology is rigorous and validated)
  - Independence (the ECAI's ratings are not influenced by any kind of political or economic pressures)
  - International access/transparency (the assessments are available equally to domestic and foreign entities)
  - Disclosure (information on assessment methodologies should be disclosed, particularly the default definition and rates, time horizon, transition matrix, and meaning of each rating)
  - Resources (which should be enough to enable credit assessments to be made with the highest quality)
  - Credibility (measured for example regarding the reliance on the credit assessments by other independent parties, such as investors and insurers)

[1] From paragraph 71 of Basel III Document - Revisions to the securitisation framework

- The ECAI must have demonstrated expertise in assessing securitisations;
- If at least two eligible ECAI assess differently the same exposure, one should apply paragraphs 96 to 98 of the Basel II framework. Therefore, in case more than one ECAIs assessments are chosen by a bank and they lead to different risk weights:
    - If there are two different risk weights' assessments, the higher one must be chosen;
    - If there are three or more, the higher of the two lowest risk weights' assessments must be chosen.
- In the case there is credit risk mitigation (CRM) provided by an eligible guarantor (according to the paragraph 195 in Basel II), the risk weight should be the one calculated according to the respective external credit assessment (so referring to tables 1, 2 and 3). If the guarantor is not eligible, it should be treated as unrated;
- When the credit risk mitigant solely protects a specific securitisation exposure within a given structure (so if, for example, only part of a tranche is protected by a CRM mechanism) and this partial protection was considered in the external credit assessment thus influencing the categorization of the whole structure (i.e. tranche), the bank must treat the exposure as if it is unrated. (Note: In our opinion, an insurance from an external entity is not necessarily what this point is referring to, instead it is referring to internal measures from the bank, such as portfolio diversification and other credit risk mitigation measures that can be taken by an institution trying to ensure payments are always guaranteed);
- If an external credit assessment is at least partly based on unfunded support provided by the bank, it cannot use external credit assessment for risk weighting purposes. Basically, a bank cannot use external credit assessment when it has provided unfunded securitisation exposure to an institution. It is necessary to remember that the exposure

given by the bank has impact on the credit assessment of the institution. As a result, the bank must treat that institution as not rated and so hold capital against the provided securitisation exposure.

Inferred Ratings (as explained before, these originate when there is an unrated exposure that is senior to another exposure, this one being rated, within the same transaction)[2]:

- Reference securitisation exposure and the unrated securitisation exposure should be similar in all respects.
- The maturity of the reference securitisation exposure must be at least as long as the unrated exposure.
- On an ongoing basis, any inferred rating must be updated continuously to reflect any subordination of the unrated position or changes in the external rating of the reference securitisation exposure.
- The external rating of the reference securitisation exposure must satisfy the general requirements for recognition of external ratings as delineated before.

Table 1: ERBA risk weight for short-term exposures

External credit assessment[3]	P-1/A-1	P-2/A-2	P-3/A-3	All other ratings
Risk weight	15%	50%	100%	1250%

Table 2: ERBA risk weight for long-term exposures for senior tranche

Rating[4]	Senior tranche	
	Tranche maturity (M_T)	
	1 year	5 years
Aaa	15%	20%
Aa1	15%	30%
Aa2	25%	40%
Aa3	30%	45%

[2] From paragraph 73 of Basel III Document - Revisions to the securitisation framework

[3] The ratings used are short-term ratings, being P classification is given by Moody´s, while A classification is used by S&P.

[4] The rating grades here exposed are only the Moody´s ones, however this is only illustrative.

A1	40%	50%
A2	50%	65%
A3	60%	70%
Baa1	75%	90%
Baa2	90%	105%
Baa3	120%	140%
Ba1	140%	160%
Ba2	160%	180%
Ba3	200%	225%
B1	250%	280%
B2	310%	340%
B3	380%	420%
Caa1 / Caa2 / Caa3	460%	505%
Bellow Caa3	1250%	1250%

Table 3: ERBA risk weight for long-term exposures for non-senior tranche

Rating[5]	Non-Senior tranche	
	Tranche maturity (M_T)	
	1 year	5 years
Aaa	15%	70%
Aa1	15%	90%
Aa2	30%	120%
Aa3	40%	140%
A1	60%	160%
A2	80%	180%
A3	120%	210%
Baa1	170%	260%
Baa2	220%	310%
Baa3	330%	420%
Ba1	470%	580%
Ba2	620%	760%
Ba3	750%	860%
B1	900%	950%
B2	1050%	1050%
B3	1130%	1130%
Caa1 / Caa2 / Caa3	1250%	1250%
Bellow Caa3	1250%	1250%

Table 4: ERBA risk weight for short-term exposures for STC securitisation

External credit assessment	P-1/A-1	P-2/A-2	P-3/A-3	All other ratings
Risk weight	10%	30%	60%	1250%

[5] The rating grades here exposed are only the Moody´s ones, however this is only illustrative.

Table 5: ERBA risk weight for long-term exposures for senior tranche for STC securitisation

Rating	Senior tranche	
	Tranche maturity (M_T)	
	1 year	5 years
Aaa	10%	10%
Aa1	10%	15%
Aa2	15%	20%
Aa3	15%	25%
A1	20%	30%
A2	30%	40%
A3	35%	40%
Baa1	45%	55%
Baa2	55%	65%
Baa3	70%	85%
Ba1	120%	135%
Ba2	135%	155%
Ba3	170%	195%
B1	225%	250%
B2	280%	305%
B3	340%	380%
Caa1 / Caa2 / Caa3	415%	455%
Bellow Caa3	1250%	1250%

Table 6: ERBA risk weight for long-term exposures for non-senior tranche for STC securitisation

Rating	Non-senior tranche	
	Tranche maturity (M_T)	
	1 year	5 years
Aaa	15%	40%
Aa1	15%	55%
Aa2	15%	70%
Aa3	25%	80%
A1	35%	95%
A2	60%	135%
A3	95%	170%
Baa1	150%	225%
Baa2	180%	255%
Baa3	270%	345%
Ba1	405%	500%
Ba2	535%	655%
Ba3	645%	740%
B1	810%	855%
B2	945%	945%
B3	1015%	1015%
Caa1 / Caa2 / Caa3	1250%	1250%
Bellow Caa3	1250%	1250%