

Quantitative Equities
**Forecasting stock crash risk
with machine learning**

Sustainable Investing Expertise by
ROBECOSAM



White paper
For professional investors
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Introduction

Significant developments in big data and machine learning (ML) are pushing back the frontier of quant investing.

This has been facilitated by the increase in computational power, which enables the deployment and use of ML models.¹ In contrast to rule-based models, these adopt a fully data-driven approach and are capable of modelling complex, nonlinear relationships. They can potentially uncover systematic and repeating patterns that simple linear models do not capture.

‘Certain variables might only be able to predict returns when they cross a certain threshold, or when they are combined with other variables, or they might only be able to predict negative performance’

For example, certain variables might only be able to predict returns when they cross a certain threshold, or when they are combined with other variables, or they might only be able to predict negative performance. In this white paper, we delve into how the use of ML techniques can propel quant modelling to the next level. We also look at a concrete example of how they can be used to forecast individual stock price crashes.

The different uses of ML techniques in quantitative investing are increasingly being recognized in the academic literature. These range from relatively simple variable selection models to ones able to identify lead-lag relationships between the returns of different assets. ML techniques are also used in complex deep learning models for statistical arbitrage.^{2,3} Overfitting has always been a key concern for quantitative strategies. It is an even bigger issue when the amount of data and the number of possible relationships between variables increases.

The risk here is that one can uncover a coincidental relationship between variables that has been observed in the past and use it as a signal to construct a portfolio, when in fact it will not repeat in the future as there is no real underlying phenomenon.⁴ The ML toolbox, however, contains solutions to avoid overfitting, such as regularization (i.e., variable selection), model averaging and cross-validation.

¹ See: Van Vliet, P., and Zhou, W., August 2021, “[Moore’s Law is disrupting the world of quant investing](#)”, Robeco article.

² For example, LASSO is a frequently used machine learning method that selects explanatory variables when many are available in a statistical regression model. LASSO is the abbreviation for Least Absolute Shrinkage and Selection Operator.

³ See: Rapach, D. E., Strauss, J. K., and Zhou, G., March 2013, “[International stock return predictability: what is the role of the United States?](#)” Journal of Finance; and Fisher, T., and Kraus, C., October 2018, “[Deep learning with long short-term memory networks for financial market predictions](#)” European Journal of Operational Research.

⁴ See: Martin, I., and Nagel, S., forthcoming, “[Market efficiency in the age of big data](#)” Journal of Financial Economics.

Forecasting which firms will face financial distress

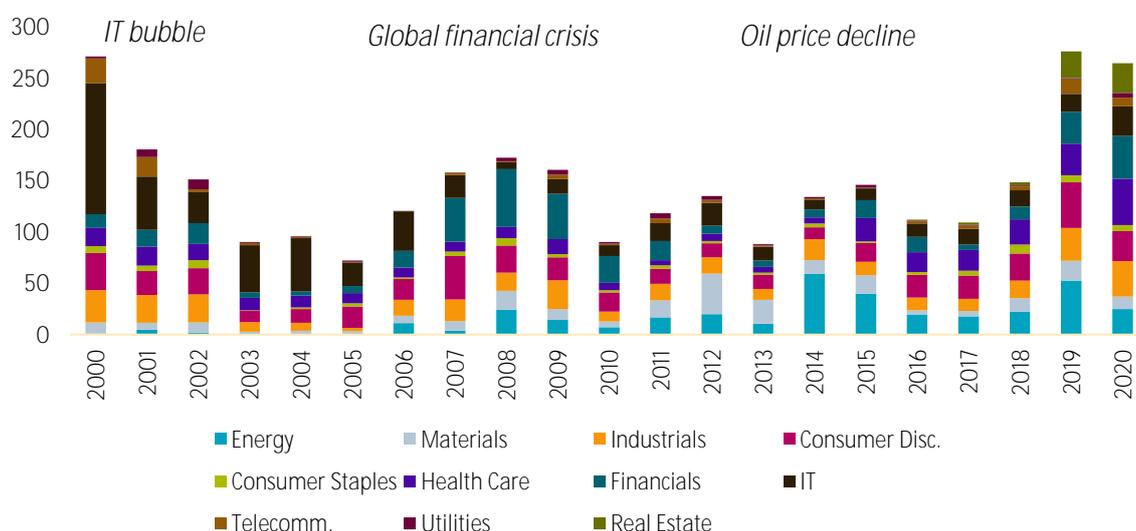
Avoiding investments in companies that will subsequently experience financial distress can help investors outperform the market.

That said, detecting those firms most likely to face distress in the future is far from straightforward. While there are numerous characteristics that can help forecast such outcomes, they perhaps do so most effectively in a nonlinear fashion or in specific combinations. Fortunately, ML techniques are designed to deal with such challenges.

One way to flag distressed firms is by looking at bankruptcy filings or credit downgrades.⁵ However, these events can be preceded by falling stock prices. For an equity investor, predicting a stock price decline is more relevant than correctly forecasting a bankruptcy filing or credit downgrade, as these events could already be priced in by the time they take place. Therefore, we define a crash event as a significant drop in a firm's share price relative to those of other stocks. This measure captures idiosyncratic risk rather than market-wide turmoil, and we believe it lends itself well for use in a stock selection model instead of a market or factor-timing model used for asset allocation.

Based on our definition of financial distress, Figure 1 shows that the identified distress events are not concentrated in a handful of sectors, but across multiple. That said, the more distressed sectors usually have a higher tally of events. Overall, the number of stock price crashes varies over time as cross-sectional volatility is typically higher during crisis periods.

Figure 1 | Average number of stock price crashes according to our definition of financial distress, for the period January 2000 to December 2020



Source: Robeco Quantitative Research. The bars contain the average number of distress events per calendar year split by sector. The developed markets universe consists of the largest 3,000 stocks from the S&P Broad Market Index and MSCI World Index. The emerging markets universe consists of the largest 25% constituents of the S&P Emerging Broad Market Index and MSCI Emerging Markets Index.

⁵ See: Campbell, J Y., Hilscher, J., and Szilagyi, J., November 2008, "[In search of distress risk](#)" Journal of Finance.

If we want to identify firms that will face financial distress through the use of a ML model, we need to feed it a set of variables that may contain predictive information on stock price crashes. In ML terminology, these predictive variables are called features, while the variable that is being predicted is called the target.

Selecting the set of features that serve as inputs for the algorithm that aims to find a predictive relationship with the target is an important modelling step for any predictive model. For our purposes, the variables we chose include classical financial distress indicators such as distance-to-default, volatility, and return on equity.⁶ But since ML models are designed to pick the most important features from a larger set of variables, we also decided to include more granular items from financial statements such as cash flow from operations as well as short and long-term debts.

In our model, we only incorporate features that we believe are potentially relevant to identify firms with stock price crash risk. For instance, features such as the first letter of a company name or the color of its logo are not included, given that we are not able to link them to an economic rationale that could explain why they may be able to forecast crash risk. Since many company characteristics are only a snapshot at a point in time, for example profitability, we have also included several lagged versions for some of the features in our model. In our view, this allows the algorithm to identify how series of events, such as declining profitability, influence distress risk.

Although most ML algorithms are designed to filter out irrelevant predictors from a large set of features, this process is also useful in avoiding overfitting as the number of features is reduced. We believe fewer redundant features lowers the chance of making investment decisions based on noisy data. Furthermore, decreasing the number of features speeds up the training process of the algorithm. For our application, we train three statistical models: a regularized logistic regression, a random forest, and an extreme gradient boosted tree.

A regularized logistic regression is a method based on a classical linear regression model, but through a logistic transformation (where measurements on a linear scale are converted into probabilities) that is adapted to predict the probability of a binary outcome: in our case, whether a company is in financial distress or not. Regularization is ML terminology for model selection, i.e., this technique only selects those variables that help predict this binary outcome.

Meanwhile, the random forest classification is a nonlinear model based on multiple decision trees – hence the term forest – with randomly chosen features as the nodes, where the majority vote decides the classification (determination of which group an observation belongs to), which in our application is a binary decision. Finally, the extreme gradient boosted tree algorithm is also based on decision trees, but instead of relying on majority voting, it changes the weighting of the features in a manner that reduces the number of false predictions.⁷

‘Data leakages lead to better backtested results that cannot be achieved in practice as information that will be accessible in the future will obviously not be available’

These three prediction models are parameterized and retrained each year based on their cross-validation metrics. After retraining the models, we construct the signal for the upcoming year based on previously unseen data. When setting up this training-testing configuration, it is extremely important to ensure there are no data leakages. This refers to the occurrence of overfitting that happens when previously unseen data is leaked in the model training process. Data leakages lead to better backtested results that cannot be achieved in practice as information that will be accessible in the future will obviously not be available.

⁶ Distance-to-default is the number of asset return standard deviations that a firm can handle with its equity before it will default. If the number is high, this means that the firm’s equity buffer is large compared to its business risk. See: Duffie, D., Saita, L., and Wang, K., March 2007, “[Multi-period corporate default prediction with stochastic covariates](#)”, Journal of Financial Economics.

⁷ For more information on machine learning models see: Snow, D., January 2020, “[Machine learning in asset management – part 1: portfolio construction – trading strategies](#)”, Journal of Financial Data Science; and Snow, D., April 2020, “[Machine learning in asset management – part 2: portfolio construction – weight optimization](#)”, Journal of Financial Data Science.

Each of these models make independent predictions, which are then combined as an ensemble prediction. In our view, ensembles are the only free lunch in ML, similar to what diversification is in terms of investing. Figure 2 illustrates the share price of a US financials stock as well as its ensemble forecasted distress risk over time. In this example, we see that its probability of distress increases beyond 75% post mid-2007, and eclipses 90% in the months that follow. What we also observe is that its stock price peaks in January 2007, but only experiences a sharp drop from March 2008 onwards before the company files for bankruptcy in September 2008.

Figure 2 | Illustrative example of a stock price and its forecasted distress risk, for the period January 2002 to August 2008



Source: Robeco Quantitative Research. This is an illustration of the forecast distress probability of a US financials stock (left-hand-side y-axis) and its realized stock price (right-hand-side y-axis).

We applied this methodology to generate financial distress probabilities for separate samples of developed and emerging markets stocks for the period 2000 to 2020. For comparison purposes, we also considered other distress risk predictors such as stock return volatility, equity market beta and distance-to-default. For each sub-sample, we formed 20 portfolios based on the ranking of these stock price crash probabilities and calculated their respective returns in the following period.

Figure 3 depicts the performance of the market as well as the portfolios with the highest financial distress probabilities for each of the four distress risk measures. In terms of developed markets, the average market return over this period was 10.0%. Meanwhile, the bottom portfolio for the strategy based on the ML method only delivered 2.3%. This was considerably lower than the gains achieved by the portfolios constructed on the highest distress predictions based on the other conventional variables, which ranged from 4.2% to 5.0%.

We saw an even larger improvement in terms of emerging markets. The average market return was 11.6%, while the portfolios built on the other conventional distress predictors delivered gains between 4.5% to 7.0%. On the other hand, the portfolio based on the ML method generated a loss of 1.5%, thus producing a substantially better result than the other three alternatives.

Figure 3 | Performance of developed and emerging markets portfolios with highest distress probability, for the period January 2000 to December 2020



Source: MSCI, S&P and Robeco Quantitative Research. The developed markets universe consists of the largest 3,000 stocks from the S&P Broad Market Index and MSCI World Index. The emerging markets universe consists of the largest 25% constituents of the S&P Emerging Broad Market Index and MSCI Emerging Markets Index. The solid colors represent developed markets and the diagonally striped colors represent emerging markets. The portfolios are sorted based on historical volatility, market beta, distance-to-default and machine learning (plum) distress probabilities. The holding period is 1 month and the returns are annualized in USD.

Figure 4 incorporates the findings from Figure 3 and illustrates the potential gains for an investor using these predictive methods for financial distress. Just by excluding 5% of the stocks with the highest ML-based distress probabilities, while keeping the remaining 95% of the universe, we saw an improvement of 33 and 66 basis points for developed markets and emerging markets respectively over our sample period.

Figure 4 | Performance of the market portfolio excluding 5% of stocks with highest distress probability, for the period January 2000 to December 2020



Source: MSCI, S&P and Robeco Quantitative Research. The developed markets universe consists of the largest 3,000 stocks from the S&P Broad Market Index and MSCI World Index. The emerging markets universe consists of the largest 25% constituents of the S&P Emerging Broad Market Index and MSCI Emerging Markets Index. The market returns exclude 5% of the stocks with the highest distress risk probabilities. The portfolios are sorted based on historical volatility, market beta, distance-to-default and machine learning (plum) distress probabilities. The holding period is 1 month and the returns are annualized in USD.

This indicates that advanced ML techniques can potentially help us to identify stocks with elevated distress risk. Put differently, we can potentially enhance the returns of our quantitative equity portfolios if we avoid investing in these stocks.

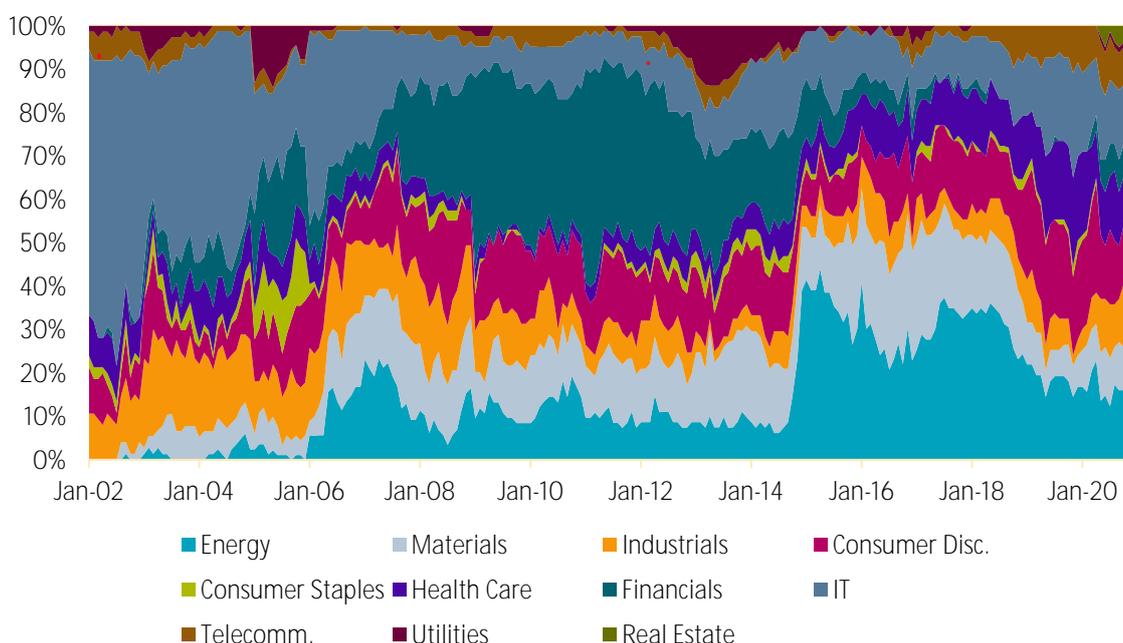
Uncovering how ML helps to forecast financial distress

To get a better understanding of how ML helps to forecast financial distress, we started by examining the sector breakdown of the 5% of stocks with the highest distress probability.

While we would like the ML methodology to automatically recognize the sectors that are likely to experience distress, we do not want it to be dominated by sector selection. In terms of our ML model, we have not placed such restrictions on it as we have not included sector information in its set of features.

Figure 5 shows the sector distribution of this subset of stocks over time. We observed that most of the financially distressed stocks were found in the information technology sector in the early 2000s, then the financials sector during the 2008 to 2010 period, followed by the energy sector during the 2015 to 2019 interval. Although there have been clear tilts towards these distressed sectors over time, we did note that the identified distress events are not concentrated only in a few sectors. Therefore, we believe this makes our ML technique a good candidate for use within stock selection processes.

Figure 5 | Sector distribution of the portfolio with the highest distress risk, January 2002 to December 2020



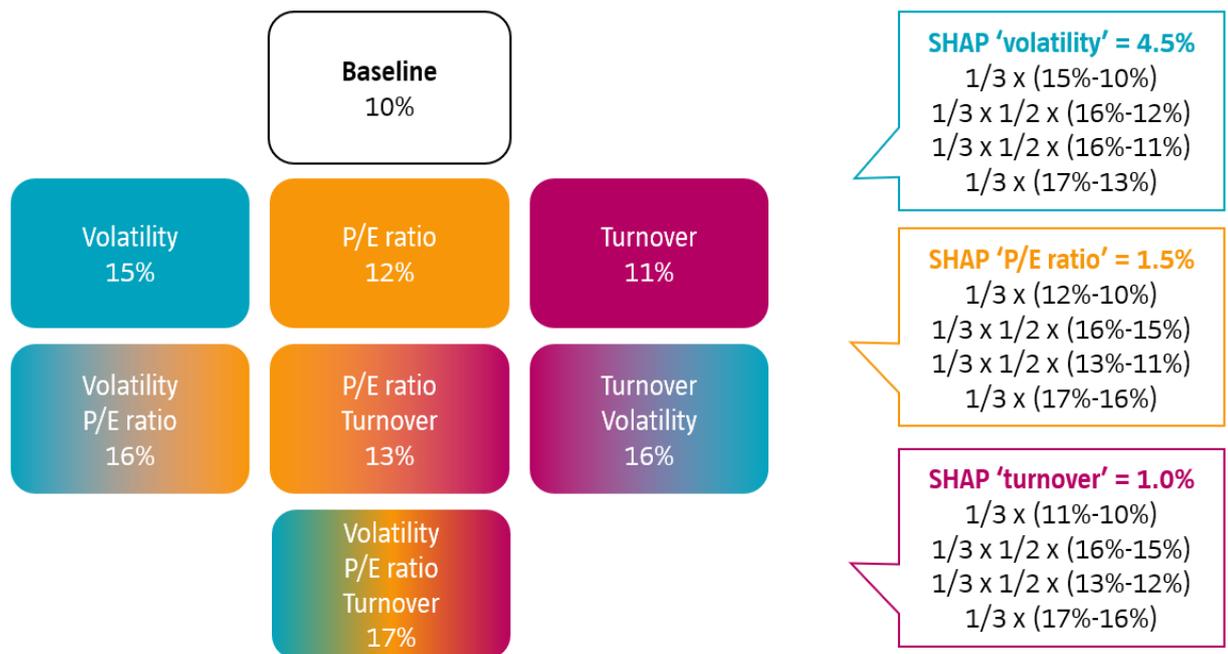
Source: MSCI, S&P and Robeco Quantitative Research. The developed markets universe consists of the largest 3,000 stocks from the S&P Broad Market Index and MSCI World Index. The emerging markets universe consists of the largest 25% constituents of the S&P Emerging Broad Market Index and MSCI Emerging Markets Index. The portfolio is sorted on machine learning distress probabilities and consists of 5% of the stocks with the highest distress risk probabilities.

In our view, it is also crucial to evaluate the importance of each of the selected features, and we did so for a particular year in our sample period. This is indicated by the SHapley Additive exPlanations (SHAP) value.⁸ The SHAP value of each individual prediction is the average of the marginal contribution of the feature when predicting the target. This methodology allows us to understand the economic rationale behind our predictions.

In Figure 6, we illustrate this with a stylized example, in which our predictive model consists of only three features: volatility, price/earnings (PE) ratio, and share turnover. Without taking any feature into account, let us say the model would predict the average distress probability of the training sample to be 10%. Then, with the inclusion of only volatility, PE ratio or share turnover information, we would see the distress probability of a stock increase to 15%, 12% or 11% respectively. Furthermore, we show the changes in the predicted probability when two variables are simultaneously included in the second row, as well as when all three features are taken into account in the bottom one.

The average marginal contribution of each feature, or SHAP value, is calculated on the right-hand side. In this example, the stock's volatility has the highest contribution at 4.5%. This consists of the average of the 5% increase when it is added to the baseline, the 4.5% average increase when it is added as a second feature on the next row,⁹ and the 4% increase when it is added as a third variable on the bottom one. Similarly, the SHAP value for the PE ratio is 1.5%, while the marginal contribution of turnover is the least important with a SHAP value of 1.0%. Altogether, the SHAP values add up to 7% and constitute the difference between the model's prediction of 17% versus the baseline of 10%. Through this method, we can deconstruct the importance of each feature for each observation.

Figure 6 | Stylized example to calculate SHAP values



Source: Robeco Quantitative Research.

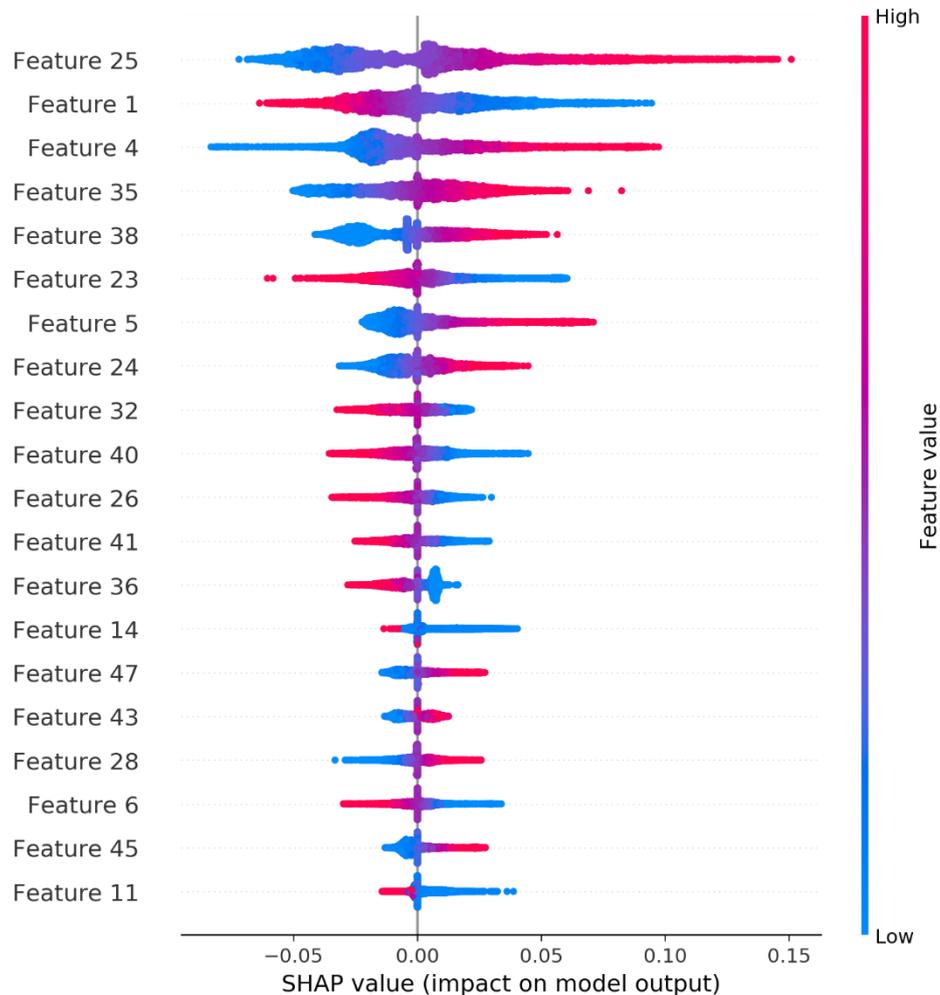
The importance of the anonymized features in our ML model is shown in Figure 7. The color of each dot indicates the sign and magnitude of a feature, where red signals a high feature value and blue denotes a low feature value. The features are ranked from top to bottom in terms of importance. For example, feature 25 is the most important and this is indicated by it having the largest spread in SHAP values.

⁸ This measure was first introduced by Lundberg, S, M., and Lee, S., December 2017, "[A unified approach to interpreting model predictions](#)", NIPS 17: Proceedings of the 31st Conference on Neural Information Processing Systems 4768–4777.

⁹ Adding it to the PE ratio results in an increase of 4%, while adding it to the turnover results in an increase of 5%, leading to an average of 4.5%.

A high value for feature 25, as indicated by the red dots, leads to a large increase in financial distress probability, as these dots are further to the right than for any other feature. On the other hand, a low value, as highlighted by the blue dots, amounts to a decrease in the probability of financial distress, as the blue dots are found in the negative side of the scale. By contrast, the lowest values of feature 4 are furthest to the left, so these can potentially have a larger negative impact on the probability of distress than the low values of feature 25. The effect is nonlinear for feature 5 as high values have a large positive effect on the probability, while low values only have a small negative effect.

Figure 7 | SHAP values of the 20 most important features for prediction of financial distress



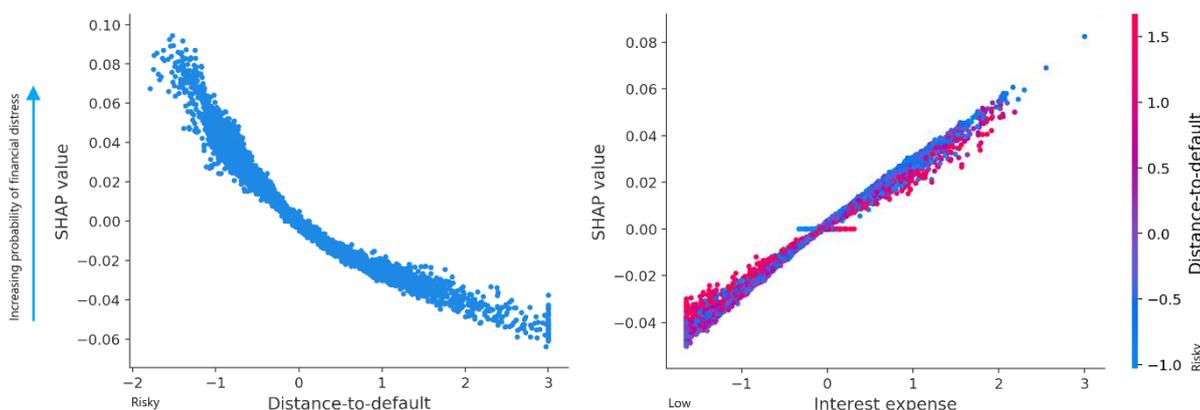
Source: Robeco Quantitative Research. These are SHAP values for a specific year in our sample period. Values to the right indicate increases in the probability of financial distress, while values to the left indicate decreases in the probability. The red dots are high values of the feature, while the blue dots are low values of the feature. The features are ranked in order of importance, from top to bottom. Only the 20 most important features are displayed.

To better understand the nonlinear and interaction effects between features and financial distress probabilities, we looked at partial dependence plots in Figure 8. These plots show the marginal effect of a single feature on predicted distress probabilities.

The left-hand side chart in Figure 8 shows that a lower distance-to-default value (DtD, left on the horizontal axis) increases the distress probability (up on the vertical axis). The impact of DtD on distress probability accelerates for lower DtD, amounting to a nonlinear effect. This is a clear example of why nonlinear models are useful as the entire range of the cross-sectional values is not equally informative.

The distress probability increases faster at lower DtD than for higher DtD. This means that a single unit rise in the DtD barely reduces the distress probability when a stock has a high DtD (i.e., it is safe), but a single unit drop in DtD significantly increases the distress probability if a stock has a low DtD (i.e., it is risky).

Figure 8 | Partial dependence plot of features



Source: Robeco Quantitative Research. The horizontal axis contains the distance-to-default (left on the horizontal axis) and interest expense (right on the horizontal axis) and the SHAP value (vertical axis). The added coloring dimension on the right-hand side refers to the distance-to-default, where high values (safe) are in red and low values (risky) in blue.

The right-hand side chart in Figure 8 depicts that a high interest expense increases distress probability, but to a lesser extent if the DtD is elevated. The colors of the dots indicate the DtD levels. The distress probability rises by less for high interest paying companies if the DtD is high (safe, in red) in comparison to when the DtD is low (risky, in blue). This interaction effect can be viewed as the difference between safe and risky leverage, which makes sense and provides an economic understanding of the modelling performed by the algorithm.

So far, we have shown the (possibly nonlinear) relationship between features and the probability of financial distress, which helps us to understand the behavior of the predictive model based on its inputs. However, it is also possible to dive deeper into what appeared to be a black box to explain individual distress predictions. Drilling down to the source data enables us to have a clear understanding of why a particular stock is or is not identified as distressed.

For each observation, we can show precisely what features drive up the distress probability and which ones pull it down. This is depicted in Figure 9 for one specific stock in our investment universe. This example takes into account the January 2021 period; the firm's overall probability of default is 0.15.

For each of the relevant features, we illustrate the input value and the effect it has on the estimated probability of distress. The red bars contain the feature values which push up the distress probability, while the blue bars comprise the feature values which pull down the probability. Through the use of these visualizations, we ensure that our ML application is a glass box rather than a black box, and we can drill down to the source data to better understand the distress probability for each stock in our universe.

Figure 9 | Deconstruction of the probability of distress for a specific stock in January 2021 using a force plot.



Source: Robeco Quantitative Research. The red and blue bars indicate the features that push up or pull down the distress probability respectively. For this example, the overall probability of distress is 15%.

As outlined in this section, we believe ML algorithms that are appropriately chosen to forecast stock price crash risk can indeed lead to economically interpretable results. Furthermore, ML tools are available to analyze the core of the predictive model such as feature importance, nonlinearities, and the interaction between features. Additionally, for each individual stock in our investment universe, we can dissect the source data of each feature to better understand the drivers of its distress probability. This can also help us to explain why a specific stock is either held or not held in our quantitative equity portfolios. In our view, the latter gives us more confidence that our ML model is an effective way of identifying stocks that will face financial distress.

The future of ML for stock selection

Several ML applications have already made their way into our stock selection models.

For example, we use natural language processing techniques to interpret large volumes of news to detect sentiment, or to analyze corporate disclosures to determine the contribution companies may make to the United Nations Sustainable Development Goals. This is in addition to the ML technique used to forecast stock price crash risk as described in this article. We believe these tools can help us to better identify companies that will likely underperform in the future. Avoiding investments in such stocks can potentially enhance investment performance.

In our view, new quantitative research techniques – such as ML – challenge conventional wisdom in the field of quantitative investing and can potentially improve investment results. In this note, we have illustrated how ML can help an investor to spot distressed firms prior to distress events (for example bankruptcy filings or credit downgrades) in both developed and emerging markets. We have assessed the added value from ML models given that they can take into account complexities such as nonlinearities and interactions, especially when compared to simpler conventional linear models.

One key strength of ML algorithms is that we can feed them with economically sensible and well-behaved input parameters and analyze in detail whether their choices are logical over time. As we remain cognizant of the risk of overfitting, we make use of a cross-validation framework that we believe leads to a prudent data-driven variation in predictability over time. Moreover, we have the ability to scrutinize the source data which allows us to explain why a specific stock in our portfolio has a particular distress risk probability. In short, our ML-based distress risk prediction application is consistent with Robeco's quant investment philosophy.

The likelihood that future innovative research projects will uncover complex predictive relationships or lead to better interpretation of unstructured data is high. The drawback of financial markets data is that stock prices may be influenced by many known and unknown factors, while relationships between firm characteristics are complex and unstable over time. This makes it difficult to predict stock returns.

Thus, standard statistical methods may not be able to uncover complex patterns, or complex patterns in the data can turn out to be random, and therefore may not be repeated in the future. Our ML application for distress prediction illustrates that the ML toolbox potentially contains methods to reveal true signals of future financial distress, while ignoring the noisy data present in asset prices and firm characteristics.

'When one moves from rule-based models to ML-based ones, the role of the researcher changes from instructor to orchestrator'

When one moves from rule-based models to ML-based ones, the role of the researcher changes from instructor to orchestrator. With the traditional approach, the researcher instructs the computer to test specific rules on input data to see whether they can help predict the output. In terms of ML, the researcher feeds both the input and output data to the computer for it to assess what the best rule is. This is referred to as supervised learning in ML terminology.

This role change allows researchers to deal with more complexities. But one needs to be cautious and pay attention to model explainability and overfitting. Only then can the quantitative researcher stay in the driver's seat and orchestrate ML processes, rather than instructing an algorithm on how to behave.

Therefore, we believe ML techniques can propel quant modelling to the next level within the realms of our proven investment philosophy. Indeed, evidence-based research, economic rationale and prudent investing are crucial ingredients to make ML work in the context of investments.

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Neither Robeco nor the Funds have been registered with the *Comisión para el Mercado Financiero* pursuant to Law no. 18.045, the *Ley de Mercado de Valores* and regulations thereunder. This document does not constitute an offer of or an invitation to subscribe for or purchase shares of the Funds in the Republic of Chile, other than to the specific person who individually requested this information on their own initiative. This may therefore be treated as a "private offering" within the meaning of article 4 of the *Ley de Mercado de Valores* (an offer that is not addressed to the public at large or to a certain sector or specific group of the public).

Additional Information for investors with residence or seat in Colombia

This document does not constitute a public offer in the Republic of Colombia. The offer of the Fund is addressed to fewer than one hundred specifically identified investors. The Fund may not be promoted or marketed in Colombia or to Colombian residents, unless such promotion and marketing is made in compliance with Decree 2555 of 2010 and other applicable rules and regulations related to the promotion of foreign Funds in Colombia.

Additional Information for investors with residence or seat in the Dubai International Financial Centre (DIFC), United Arab Emirates

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Additional Information for investors with residence or seat in France

Robeco Institutional Asset Management B.V. is at liberty to provide services in France. Robeco France is a subsidiary of Robeco whose business is based on the promotion and distribution of the group's funds to professional investors in France.

Additional Information for investors with residence or seat in Germany

This information is solely intended for professional investors or eligible counterparties in the meaning of the German Securities Trading Act.

Additional Information for investors with residence or seat in Hong Kong

The contents of this document have not been reviewed by the Securities and Futures Commission ("SFC") in Hong Kong. If there is in any doubt about any of the contents of this document, independent professional advice should be obtained. This document has been distributed by Robeco Hong Kong Limited ("Robeco"). Robeco is regulated by the SFC in Hong Kong.

Additional Information for investors with residence or seat in Indonesia

The Prospectus does not constitute an offer to sell nor a solicitation to buy securities in Indonesia.

Additional Information for investors with residence or seat in Italy

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Additional Information for investors with residence or seat in South Korea

The Management Company is not making any representation with respect to the eligibility of any recipients of the Prospectus to acquire the Shares therein under the laws of South Korea, including but not limited to the Foreign Exchange Transaction Act and Regulations thereunder. The Shares have not been registered under the Financial Investment Services and Capital Markets Act of Korea, and none of the Shares may be offered, sold or delivered, or offered or sold to any person for re-offering or resale, directly or indirectly, in South Korea or to any resident of South Korea except pursuant to applicable laws and regulations of South Korea.

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Additional Information for investors with residence or seat in Malaysia

Generally, no offer or sale of the Shares is permitted in Malaysia unless where a Recognition Exemption or the Prospectus Exemption applies: NO ACTION HAS BEEN, OR WILL BE, TAKEN TO COMPLY WITH MALAYSIAN LAWS FOR MAKING AVAILABLE, OFFERING FOR SUBSCRIPTION OR PURCHASE, OR ISSUING ANY INVITATION TO SUBSCRIBE FOR OR PURCHASE OR SALE OF THE SHARES IN MALAYSIA OR TO PERSONS IN MALAYSIA AS THE SHARES ARE NOT INTENDED BY THE ISSUER TO BE MADE AVAILABLE, OR MADE THE SUBJECT OF ANY OFFER OR INVITATION TO SUBSCRIBE OR PURCHASE, IN MALAYSIA. NEITHER THIS DOCUMENT NOR ANY DOCUMENT OR OTHER MATERIAL IN CONNECTION WITH THE SHARES SHOULD BE DISTRIBUTED, CAUSED TO BE DISTRIBUTED OR CIRCULATED IN MALAYSIA. NO PERSON SHOULD MAKE AVAILABLE OR MAKE ANY INVITATION OR OFFER OR INVITATION TO SELL OR PURCHASE THE SHARES IN MALAYSIA UNLESS SUCH PERSON TAKES THE NECESSARY ACTION TO COMPLY WITH MALAYSIAN LAWS.

Additional Information for investors with residence or seat in Mexico

The funds have not been and will not be registered with the National Registry of Securities, maintained by the Mexican National Banking and Securities Commission and, as a result, may not be offered or sold publicly in Mexico. Robeco and any underwriter or purchaser may offer and sell the funds in Mexico on a private placement basis to Institutional and Accredited Investors, pursuant to Article 8 of the Mexican Securities Market Law.

Additional Information for investors with residence or seat in Peru

The Fund has not been registered with the Superintendencia del Mercado de Valores (SMV) and is being placed by means of a private offer. SMV has not reviewed the information provided to the investor. This document is only for the exclusive use of institutional investors in Peru and is not for public distribution.

Additional Information for investors with residence or seat in Singapore

This document has not been registered with the Monetary Authority of Singapore (“MAS”). Accordingly, this document may not be circulated or distributed directly or indirectly to persons in Singapore other than (i) to an institutional investor under Section 304 of the SFA, (ii) to a relevant person pursuant to Section 305(1), or any person pursuant to Section 305(2), and in accordance with the conditions specified in Section 305, of the SFA, or (iii) otherwise pursuant to, and in accordance with the conditions of, any other applicable provision of the SFA. The contents of this document have not been reviewed by the MAS. Any decision to participate in the Fund should be made only after reviewing the sections regarding investment considerations, conflicts of interest, risk factors and the relevant Singapore selling restrictions (as described in the section entitled “Important Information for Singapore Investors”) contained in the prospectus. Investors should consult your professional adviser if you are in doubt about the stringent restrictions applicable to the use of this document, regulatory status of the Fund, applicable regulatory protection, associated risks and suitability of the Fund to your objectives. Investors should note that only the Sub-Funds listed in the appendix to the section entitled “Important Information for Singapore Investors” of the prospectus (“Sub-Funds”) are available to Singapore investors. The Sub-Funds are notified as restricted foreign schemes under the Securities and Futures Act, Chapter 289 of Singapore (“SFA”) and invoke the exemptions from compliance with prospectus registration requirements pursuant to the exemptions under Section 304 and Section 305 of the SFA. The Sub-Funds are not authorized or recognized by the MAS and shares in the Sub-Funds are not allowed to be offered to the retail public in Singapore. The prospectus of the Fund is not a prospectus as defined in the SFA. Accordingly, statutory liability under the SFA in relation to the content of prospectuses does not apply. The Sub-Funds may only be promoted exclusively to persons who are sufficiently experienced and sophisticated to understand the risks involved in investing in such schemes, and who satisfy certain other criteria provided under Section 304, Section 305 or any other applicable provision of the SFA and the subsidiary legislation enacted thereunder. You should consider carefully whether the investment is suitable for you. Robeco Singapore Private Limited holds a capital markets services license for fund management issued by the MAS and is subject to certain clientele restrictions under such license.

Additional Information for investors with residence or seat in Spain

Robeco Institutional Asset Management B.V., Sucursal en España with identification number W0032687F and having its registered office in Madrid at Calle Serrano 47-14º, is registered with the Spanish Commercial Registry in Madrid, in volume 19.957, page 190, section 8, sheet M-351927 and with the National Securities Market Commission (CNMV) in the Official Register of branches of European investment services companies, under number 24. The investment funds or SICAV mentioned in this document are regulated by the corresponding authorities of their country of origin and are registered in the Special Registry of the CNMV of Foreign Collective Investment Institutions marketed in Spain.

Additional Information for investors with residence or seat in South Africa

Robeco Institutional Asset Management B.V. is registered and regulated by the Financial Sector Conduct Authority in South Africa.

Additional Information for investors with residence or seat in Switzerland

The Fund(s) are domiciled in Luxembourg. This document is exclusively distributed in Switzerland to qualified investors as defined in the Swiss Collective Investment Schemes Act (CISA). This material is distributed by Robeco Switzerland Ltd, postal address: Josefstrasse 218, 8005 Zurich. ACOLIN Fund Services AG, postal address: Affolternstrasse 56, 8050 Zürich, acts as the Swiss representative of the Fund(s). UBS Switzerland AG, Bahnhofstrasse 45, 8001 Zurich, postal address: Europastrasse 2, P.O. Box, CH-8152 Opfikon, acts as the Swiss paying agent. The prospectus, the Key Investor Information Documents (KIIDs), the articles of association, the annual and semi-annual reports of the Fund(s), as well as the list of the purchases and sales which the Fund(s) has undertaken during the financial year, may be obtained, on simple request and free of charge, at the office of the Swiss representative ACOLIN Fund Services AG. The prospectuses are also available via the website.

Additional Information relating to RobecoSAM-branded funds/services

Robeco Switzerland Ltd, postal address Josefstrasse 218, 8005 Zurich, Switzerland has a license as asset manager of collective assets from the Swiss Financial Market Supervisory Authority FINMA. RobecoSAM-branded financial instruments and investment strategies referring to such financial instruments are generally managed by Robeco Switzerland Ltd. The RobecoSAM brand is a registered trademark of Robeco Holding B.V. The brand RobecoSAM is used to market services and products which entail Robeco’s expertise on Sustainable Investing (SI). The brand RobecoSAM is not to be considered as a separate legal entity.

Additional Information for investors with residence or seat in Taiwan

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Additional Information for investors with residence or seat in Thailand

The Prospectus has not been approved by the Securities and Exchange Commission which takes no responsibility for its contents. No offer to the public to purchase the Shares will be made in Thailand and the Prospectus is intended to be read by the addressee only and must not be passed to, issued to, or shown to the public generally.

Additional Information for investors with residence or seat in the United Arab Emirates

Some Funds referred to in this marketing material have been registered with the UAE Securities and Commodities Authority (the Authority). Details of all Registered Funds can be found on the Authority’s website. The Authority assumes no liability for the accuracy of the information set out in this material/document, nor for the failure of any persons engaged in the investment Fund in performing their duties and responsibilities.

Additional Information for investors with residence or seat in the United Kingdom

Robeco is temporarily deemed authorized and regulated by the Financial Conduct Authority. Details of the Temporary Permissions Regime, which allows EEA-based firms to operate in the UK for a limited period while seeking full authorization, are available on the Financial Conduct Authority’s website.

Additional Information for investors with residence or seat in Uruguay

The sale of the Fund qualifies as a private placement pursuant to section 2 of Uruguayan law 18,627. The Fund must not be offered or sold to the public in Uruguay, except under circumstances which do not constitute a public offering or distribution under Uruguayan laws and regulations. The Fund is not and will not be registered with the Financial Services Superintendency of the Central Bank of Uruguay. The Fund corresponds to investment funds that are not investment funds regulated by Uruguayan law 16,774 dated September 27, 1996, as amended.