A selection of company financial ratios, bond terms and conditions information and general market data were selected as estimators (aka features or x-variables) for the machine learning models. The list of items are presented here with detail below. Note that the order of these items reflects the order (or column number) that they were fed into the machine learning algorithms and therefore the order required to make predictions from the machine learning algorithms:

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| **Data Item** | **Data Source** |
| 1.      Bond Time to Maturity | Refinitiv |
| 2.      1 Year Benchmark Government Bond Yield | Bank of England |
| 3.      10 Year Government Yield | Bank of England |
| 4.      5 Year Breakeven Inflation | Bank of England |
| 5.      Bank of England GDP Growth Estimate | Bank of England |
| 6.      FTSE 100 Standard Deviation (22 day rolling) | Refinitiv |
| 7.      FTSE 100 Return (22 day rolling) | Refinitiv |
| 8.      VIX Daily Close Price | Yahoo Finance |
| 9.      Senior Subordination (Y/N) | Refinitiv |
| 10.   Unsecured (Y/N) | Refinitiv |
| 11.   Secured (Y/N) | Refinitiv |
| 12.   Quick Ratio | Refinitiv |
| 13.   Current Ratio | Refinitiv |
| 14.   Interest Coverage Ratio | Refinitiv |
| 15.   Working Capital to Total Assets | Refinitiv |
| 16.   Debt to Asset Ratio | Refinitiv |
| 17.   Debt to Capital Ratio | Refinitiv |
| 18.   Debt to Equity Ratio | Refinitiv |
| 19.   Net Profit Margin | Refinitiv |
| 20.   Operating Cashflow to Debt Ratio | Refinitiv |
| 21.   Return on Equity using EBIT | Refinitiv |
| 22.   Return on Assets using EBIT | Refinitiv |

1. **Bond Time to Maturity (years)**: The time to maturity is the remaining time until a bond reaches its maturity date. The maturity date is when the loan must be repaid to investors in full. The time to maturity is an important factor in determining the risk of a bond because longer maturity periods expose investors to more risks, such as inflation risk, credit risk, and interest rate risk. Longer time to maturity is associate with higher credit risk and vice versa. So longer times to maturity are associated with higher credit risk and therefore higher credit spreads.
2. **One Year Government Benchmark Yield**: The one year government yield is the interest rate that the government currently pays to borrow money for a period of one year. It is used as a benchmark for the pricing of short-term bonds and as an indicator of the general direction of interest rates. This is because government rates are viewed as ‘risk-free’ and therefore serve as the theoretical minimum rate of return that an investor should demand from an investment. They are risk free because governments can theoretically print money to pay off debts, so their bonds should theoretically have no default risk.
3. **Ten-Year Government Benchmark Yield**: Like the one-year benchmark, the ten-year government benchmark yield is the interest rate that the government pays to borrow money for a period of 10 years. As discussed above, the longer the time to maturity of a bond, the higher perceived risk the bond poses to an investor, so the yield on the government 10-year bond is typically higher than the yield 1-year government yield. The difference between short term interest rates and longer term interest rates is referred to as the ‘Yield Curve’. The shape of the yield curve can also be important in credit analysis. A normal yield curve, where long-term yields are higher than short-term yields, can indicate a healthy economic environment and therefore stable credit risk for corporate bonds with longer maturities. However, an inverted yield curve, where short-term yields are higher than long-term yields, can indicate a potential economic recession and increased credit risk for corporate bonds with longer maturities. By having both 1 year and 10-year government benchmark yields, the hope is to capture the ML algorithm can discover the predictive feature of the yield curve in estimating credit spreads.
4. **Five Year Breakeven Inflation:** The five-year breakeven inflation is the difference between the yield on a five-year inflation-linked government bond and the standard five-year government benchmark. It reflects the market's expectations for inflation over the next five years and is used to gauge the inflation risk associated with a corporate bond. Inflation is an important factor when considering a bond investment because inflation will erode the returns on a bond. Because bonds pay a fixed rate of interest over a period of time, an investor will want that amount to be above the inflation level over that time frame. This is referred to as the ‘real’ rate of return i.e., the return achieved after subtracting inflation. Therefore, as inflation expectations rise, so should yields and therefore potentially also spreads. An interesting element here is whether the inflation expectations are fully captured within the yield of government benchmark yields. Recall the credit spread reflects only the amount above the government yield. If inflation expectations are fully reflected in government yields, then the breakeven inflation should have no impact in predicting credit spreads, because inflation should be fully factored into the model.
5. **Bank of England GDP Growth Estimate**: A measure of the expected growth rate of the United Kingdom's economy as estimated by the economists at the Bank of England. A company's creditworthiness is largely determined by its ability to generate revenue and cash to service its debts. These in turn are influenced by broader economic conditions. If the economy is growing, companies may have more opportunities to increase sales and profits, which can improve their creditworthiness and reduce the credit risk of their bonds. Conversely, if the economy is contracting or experiencing slow growth, companies may struggle to generate revenue and profits, which can increase their credit risk and make it more difficult to repay debt. So the GDP growth estimate provides insight into broader economic conditions in the UK which in turn may be associated with higher or lower credit spreads.
6. **FTSE 100 22-Day Rolling Standard Deviation of Daily Returns:** The Standard deviation is a measure of the volatility of the FTSE 100 index. It is used to assess the overall level of market risk associated with a corporate bond. Volatility may be an important predictor of credit spreads because market volatility is associated with moments of financial distress for companies. Therefore one could expect a positive correlation between stock market volatility and credit spreads. Note that if the bond issuer had a publicly listed stock price, this would almost certainly be a much better predictor of credit spreads than the broad FTSE 100 stock market. However, since not all bond issuers have publicly listed stocks, this estimator would not be available in all situations. In order to make the results of this research as general purpose as possible, no stock specific data was used as a predictor. This was calculated by taking the Refinitiv daily FTSE 100 values and calculating the daily return in excel. Then the rolling 22-day standard deviation was calculated off the daily returns.
7. **FTSE 100 22-Day Rolling Return**: A measure of stock market performance. This may be correlated to credit risk since the performance of the stock market reflects the financial performance of companies, and the general economic climate. Both of these factors should affect the ability of a company to generate revenue and repay debt. Therefore, the assumption here is that positive stock market performance should be associated with lower credit spreads and vice versa.
8. **VIX Daily Close Price**: The Chicago Board Options Exchange (CBOE) Volatility Index, commonly known as the VIX, measures the expected volatility of the S&P 500 index, which is a benchmark index of the US stock market. The VIX is unique in that it extrapolates the forward-looking volatility that is priced into stock options on the underlying index. This estimator is similar to item 7, except it is more forward-looking and it is calculated on US listed companies rather than UK companies. The VIX should theoretically serve as a barometer for global economic conditions.
9. **Senior** **Subordination**: Senior debt refers to the level of subordination for a particular debt instrument. A bond with senior subordination means it has priority over other forms of debt in the event of default or bankruptcy. It is considered less risky than other forms of debt and is therefore associated with a lower credit risk. Here a flag was used with 1 indicating a bond has senior subordination, whereas a 0 was used to reflect a bond that did not.
10. **Unsecured**: Unsecured debt is a type of bond that is not backed by collateral, i.e., assets pledged to secure the bond. This means that in the event of default, the bondholders do not have a specific claim on any particular assets of the company to be repaid. Instead these bonds rely solely on the company's ability to generate sufficient cash flows to repay the bond. It is considered more risky than secured debt and should therefore be associated with a higher credit risk and higher credit spreads
11. **Secured**: Secured debt is backed by collateral. It is therefore considered less risky than unsecured debt and should be associated with a lower credit risk and lower credit spreads.
12. **Quick Ratio**: The quick ratio, also known as the acid-test ratio, is a financial ratio that measures a company's ability to meet its short-term obligations using its most liquid assets, such as cash, marketable securities, and accounts receivable. The quick ratio is calculated by dividing the company's current assets minus its inventory by its current liabilities. This ratio is used to assess a company's ability to pay off its short-term debts without having to sell its inventory or other long-term assets. The ratio is a potential estimator to consider when assessing a company's ability to meet its debt obligations. A company with a high Quick Ratio should generally be considered to have a stronger ability to meet its short-term obligations, which can reduce the credit risk of its bonds. or the purpose of this research the Quick Ratio was taken directly as calculated by Refinitiv.
13. **Current Ratio**: The current ratio is also measure of a company's ability to meet its short-term obligations. It is calculated by dividing a company's current assets by its current liabilities. A company with a high current ratio is generally considered to have a stronger ability to pay off its short-term debts, which may reduce the credit risk of its bonds and therefore credit spreads. For the purpose of this research the Current Ratio was taken directly as calculated by Refinitiv.
14. **Interest Coverage Ratio**: The interest coverage ratio is a financial ratio that measures a company's ability to pay off its debt interest expenses using its earnings before interest and taxes (EBIT). It is calculated by dividing a company's EBIT by its interest expenses. A company with a high interest coverage ratio is generally considered to have a stronger ability to pay off its interest expenses, which can reduce the credit risk of its bonds and should therefore be associated with lower credit spreads. For the purpose of this research the Interest Coverage Ratio was taken directly as calculated by Refinitiv.
15. **Working Capital to Total Assets**: The working capital to total assets ratio is a measure of a company's ability to meet its short-term obligations. It is calculated by dividing a company's working capital (current assets minus current liabilities) by its total assets. A company with a high working capital to total assets ratio is generally considered to have a stronger ability to meet its short-term debt obligations, which can reduce the credit risk of its bonds. This is because a higher working capital to total assets ratio suggests that the company has more liquid assets available to meet its short-term obligations. For the purpose of this research, the ratio was calculated manually from Refinitiv Data as:

1. **Debt to Asset Ratio**: The debt to asset ratio is a financial ratio that measures the proportion of a company's total assets that are financed by its debt. Conversely, the Debt to Asset ratio can be seen as a measure of the burden of a company’s debt relative to its asset base. It is a measure of financial leverage, which is financial industry jargon meaning the debt load a company bears or the amount by which a company is financed by debt. In general, a lower debt to asset ratio may suggest that a company is less risky because it has a lower level of debt relative to its assets, which means it may have a greater ability to repay its debts in case of financial distress. However this may be complicated by the fact that a company that uses debt to generate new business may be more profitable, that a similar company that does not. So, measures of financial leverage should theoretically have non-linear relationships to credit risk and credit spreads. For the purpose of this research, the ratio was calculated manually from Refinitiv data as:

1. **Debt to Capital Ratio**: The debt to capital ratio is also a measure of a company's leverage. It is calculated by dividing a company's total debt by its total debt and equity (assets – liabilities). A higher ratio indicates a higher degree of financial risk and is therefore associated with a higher credit risk. However, like the Debt-to-Asset ratio, it could also suggest that the company has been able to leverage its capital to generate higher returns, so may not entirely be credit negative. For the purpose of this research, the ratio was calculated manually from Refinitiv data as:

1. **Debt to Equity Ratio**: The debt to equity ratio is also a measure of a company's leverage. It is calculated by dividing a company's total debt by its total equity similar to the above two ratios. For the purpose of this research, the ratio was calculated manually from Refinitiv data as:

1. **Profit Margin**: The profit margin is a measure of a company's profitability. It is calculated by dividing a company's income by its revenue. A higher net profit margin indicates a greater ability to generate profits and is therefore associated with a lower credit risk. A company with a high net profit margin is generally considered to be more profitable and financially healthy, which can reduce the credit risk of its bonds. Therefore a higher margin should theoretically be associated with lower spreads. Because taxes are idiosyncratic and depend on factors external to the company, the profit margin here was calculated on earnings before tax. For the purpose of this research, the ratio was calculated manually from Refinitiv data as:

1. **Operating Cashflow to Debt Ratio**: A financial ratio that measures a company's ability to generate enough cash flow to cover its debt obligations. It is calculated by dividing a company's operating cash flow by its total debt. Cash flow is more important than profitability to a credit investor because creditors are only concerned with the company’s ability to pay debt. A firm that generates lots of operating cash flow but is not profitable may still be viewed as low risk to a creditor. A high operating cashflow to debt ratio suggests that a company has sufficient cash flow to cover its debt obligations, which can reduce the credit risk of its bonds and therefore should be associated with lower credit spreads.
2. Return on Equity using EBIT: The return on equity using EBIT is a measure of a company's profitability. It is calculated by dividing a company's earnings before interest and taxes (EBIT) by its total equity. A higher ratio indicates a greater ability to generate profits and is therefore associated with a lower credit risk.

Return on Equity (ROE) is a financial ratio that measures a company's profitability by expressing its net income as a percentage of shareholders' equity. ROE is calculated by dividing a company's net income by its average shareholder's equity.

In credit analysis for corporate bonds, ROE using EBIT (Earnings Before Interest and Taxes) is an important factor to consider when evaluating a company's ability to generate earnings to service its debt. This is because EBIT represents a company's operating earnings before considering the impact of interest and taxes, which can be a significant expense for companies that have high debt levels.

ROE using EBIT is a measure of a company's efficiency in generating profits from the resources invested by its shareholders. A high ROE using EBIT indicates that a company is generating significant returns on its equity, which can improve its credit risk profile and reduce the risk of default on its bonds. However, it is important to compare a company's ROE using EBIT to industry averages and benchmarks to get a more accurate picture of its performance.

It is also important to note that a high ROE using EBIT does not necessarily indicate that a company is financially healthy or that its bonds are risk-free. Other factors such as interest rates, market conditions, and competition can also impact a company's credit risk. Therefore, it is important to consider the ratio in conjunction with other financial ratios and metrics, as well as broader market and economic factors when evaluating credit risk.

Overall, ROE using EBIT is an important factor to consider when evaluating the credit risk of corporate bonds. A high ROE using EBIT suggests that a company is generating significant returns on its equity, which can improve its credit risk profile and reduce the risk of default on its bonds. However, it should be evaluated in conjunction with other financial metrics and factors to get a more accurate picture of a company's creditworthiness.

1. Return on Assets using EBIT: The return on assets using EBIT is a measure of a company's profitability. It is calculated by dividing a company's earnings before interest and taxes (EBIT) by its total assets. A higher ratio indicates a greater ability to generate profits and is therefore associated with a lower credit risk.

Return on Assets (ROA) is a financial ratio that measures a company's profitability by expressing its net income as a percentage of its total assets. ROA is calculated by dividing a company's net income by its average total assets.

In credit analysis for corporate bonds, ROA using EBIT (Earnings Before Interest and Taxes) is an important factor to consider when evaluating a company's ability to generate earnings to service its debt. This is because EBIT represents a company's operating earnings before considering the impact of interest and taxes, which can be a significant expense for companies that have high debt levels.

ROA using EBIT is a measure of how efficiently a company uses its assets to generate profits. A high ROA using EBIT indicates that a company is generating significant returns on its assets, which can improve its credit risk profile and reduce the risk of default on its bonds. However, it is important to compare a company's ROA using EBIT to industry averages and benchmarks to get a more accurate picture of its performance.

It is also important to note that a high ROA using EBIT does not necessarily indicate that a company is financially healthy or that its bonds are risk-free. Other factors such as interest rates, market conditions, and competition can also impact a company's credit risk. Therefore, it is important to consider the ratio in conjunction with other financial ratios and metrics, as well as broader market and economic factors when evaluating credit risk.

Overall, ROA using EBIT is an important factor to consider when evaluating the credit risk of corporate bonds. A high ROA using EBIT suggests that a company is generating significant returns on its assets, which can improve its credit risk profile and reduce the risk of default on its bonds. However, it should be evaluated in conjunction with other financial metrics and factors to get a more accurate picture of a company's creditworthiness.

1. Z-spread: The Z-spread is a measure of the credit risk associated with a corporate bond. It is the difference between the yield on a bond and the yield on a Treasury security of the same maturity, adjusted for the bond's optionality and other embedded features. A higher Z-spread indicates a higher credit risk associated with the bond. It is often used in bond pricing models to value corporate bonds and assess their creditworthiness.

Z-spread is a financial term used in credit analysis of corporate bonds that refers to the spread over a benchmark yield curve that would be required to discount a bond's cash flows to its market price. It is a measure of the credit risk premium that investors require to hold a bond over and above the risk-free rate, taking into account factors such as the issuer's creditworthiness, market conditions, and liquidity.

Z-spread is an important metric for credit analysis of corporate bonds because it helps investors and analysts to compare the credit risk of different bonds in the same market segment or sector. By calculating the z-spread of a bond, investors can determine whether the bond is overpriced or under-priced relative to other bonds with similar credit ratings and maturities.

The calculation of z-spread involves using a mathematical model to estimate the future cash flows of the bond and discounting those cash flows back to their present value. The z-spread is then the difference between the yield to maturity on the bond and the yield to maturity on a benchmark bond with the same maturity, adjusted for any differences in credit risk.

Z-spread is useful for credit analysts because it provides a measure of the market's perception of a company's credit risk. A higher z-spread implies that investors perceive the bond to be riskier and require a higher return to compensate for that risk, while a lower z-spread implies that investors perceive the bond to be less risky and require a lower return.

Overall, z-spread is an important metric for credit analysis of corporate bonds because it provides a measure of the credit risk premium that investors require to hold a bond over and above the risk-free rate, taking into account factors such as the issuer's creditworthiness, market conditions, and liquidity. By calculating the z-spread of a bond, investors and analysts can compare the credit risk of different bonds in the same market segment or sector and make more informed investment decisions.