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Quantitative Model for Assessing Borrower Creditworthiness in Private Debt Transactions

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Abstract
This develops a quantitative model for assessing borrower creditworthiness in private debt transactions, addressing the critical need for systematic, data-driven evaluation in the SME and mid-market financing space. Traditional credit assessment methods often rely heavily on qualitative judgment and historical performance, which can be insufficient in capturing the complex risk profile of private borrowers. The proposed model integrates financial, operational, and market-based indicators into a composite framework that quantifies default probability, expected loss, and overall credit risk. Financial metrics include liquidity ratios, leverage ratios, and profitability measures, providing a foundational assessment of a borrower's capacity to service debt. Operational and strategic factors, such as revenue growth, client concentration, management quality, and governance structures, capture qualitative elements that influence long-term sustainability and risk exposure. Market and macroeconomic conditions, including interest rate trends, credit cycles, regulatory frameworks, and sector-specific dynamics, are incorporated to contextualize borrower risk within the broader environment. The model employs a weighted scoring system to integrate these multidimensional factors, using statistical and machine learning methods—such as logistic regression and classification algorithms—to estimate the probability of default (PD). Loss given default (LGD) and exposure at default (EAD) parameters are calculated to generate a comprehensive creditworthiness index, facilitating comparative analysis across borrowers and transaction types. Validation is performed through backtesting with historical transaction data, stress testing under various economic scenarios, and benchmarking against external ratings where available. This quantitative framework enhances private debt decision-making by providing objective, replicable, and risk-adjusted insights into borrower creditworthiness. It informs loan structuring, covenant design, pricing strategies, and portfolio risk management, supporting lenders in optimizing capital allocation while mitigating default exposure. By combining financial analytics with operational and market intelligence, the model provides a robust foundation for disciplined, evidence-based lending, contributing to the sustainable growth of SMEs and mid-market enterprises within private debt markets.

Keywords: Quantitative Model, Borrower Creditworthiness, Private Debt Transactions, Risk Scoring, Financial Ratios, Operational Metrics, Default Probability, Credit Risk Assessment, Debt Capacity, Cash Flow Analysis, Collateral Valuation, Market Conditions

1. Introduction

Private debt markets have grown significantly in recent years, driven by the increasing demand for alternative financing solutions by small and medium-sized enterprises (SMEs) and mid-market firms (Eyinade *et al*., 2023 [22]; Oluoha *et al*., 2023). Traditional bank lending has often been constrained by regulatory requirements, limited balance sheet capacity, and risk-averse lending practices, creating a financing gap for borrowers that are otherwise creditworthy but lack access to conventional funding channels (Akinsulire and Ohakawa, 2023 [8]; Filani *et al*., 2023). Private debt transactions, which include direct lending, mezzanine financing, and structured credit instruments, provide a flexible and tailored approach to capital allocation, enabling firms to fund working capital, growth initiatives, and strategic expansion. Within this context, accurate assessment of borrower creditworthiness is critical. Creditworthiness evaluation not only informs the pricing and structuring of debt

instruments but also underpins portfolio risk management, capital allocation, and regulatory compliance (Ilufoye *et al*., 2023; Ashiedu *et al*., 2023 [14]). Inadequate assessment can result in elevated default risk, capital inefficiency, and suboptimal investor returns, highlighting the importance of robust, systematic evaluation frameworks in private debt markets (Odinaka *et al*., 2023; Ayumu and Ohakawa, 2023) [42, 16].

Traditional credit evaluation approaches have historically relied on qualitative judgment, experience-based assessment, and historical financial statement review. While qualitative methods capture valuable insights into management quality, market positioning, and operational capabilities, they are inherently subjective and may be inconsistent across transactions or evaluators (Ilufoye *et al*., 2023; Oluoha *et al*., 2023). Qualitative assessment alone may fail to adequately quantify the probability of default or anticipate idiosyncratic and systemic risks, particularly in the context of SMEs or mid-market firms where financial information may be incomplete or less standardized (Filani *et al*., 2023; Kufile *et al*., 2023). The rationale for adopting quantitative approaches lies in their ability to systematically integrate multiple risk dimensions, apply standardized metrics, and generate objective, data-driven insights. Quantitative models facilitate the incorporation of financial ratios, operational indicators, and market variables into a coherent framework, enabling comparative evaluation across borrowers and portfolios (Nwaimo *et al*., 2023 [40]; Filani *et al*., 2023). Furthermore, statistical and machine learning techniques can enhance predictive accuracy, identify nonlinear relationships, and simulate stress scenarios, which are particularly valuable in dynamic and uncertain market conditions (Favour *et al*., 2023 [28]; Ojika *et al*., 2023).

The primary objective of this, is to develop a comprehensive, data-driven framework for assessing borrower creditworthiness in private debt transactions. The framework aims to integrate financial, operational, and market-based indicators to generate a composite creditworthiness index that informs lending decisions, loan structuring, and risk management. Specific objectives include: (i) identifying and weighting key financial and operational metrics that influence default probability; (ii) incorporating market and macroeconomic conditions into risk assessment; (iii) employing statistical and computational methods to estimate probability of default, loss given default, and exposure at default; and (iv) validating the model through historical transaction data, sensitivity analysis, and benchmarking. By providing a systematic and transparent methodology, the framework seeks to enhance decision-making for lenders, improve capital allocation efficiency, and mitigate portfolio risk, while supporting sustainable growth in the SME and mid-market sectors.

The evolution of private debt markets and the growing complexity of borrower risk profiles necessitate robust, quantitative approaches to creditworthiness assessment. This study addresses this need by proposing a structured, data-driven model that integrates multiple risk dimensions, enhances predictive accuracy, and provides actionable insights for private debt investors and lenders. The framework establishes a foundation for disciplined, evidence-based lending in SME and mid-market financing, promoting both risk mitigation and sustainable enterprise development (Kufile *et al*., 2023; Okuh *et al*., 2023 [55]).

2. Methodology

The systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to assess quantitative models for evaluating borrower creditworthiness in private debt transactions. A comprehensive literature search was performed across multiple academic databases, including Scopus, Web of Science, and Google Scholar, covering publications from 2000 to 2025. Search terms combined relevant keywords such as “borrower credit assessment,” “private debt,” “quantitative credit models,” “financial ratios,” and “risk scoring.” Inclusion criteria required that studies focus on quantitative approaches for creditworthiness evaluation in non-public or privately held entities, provide empirical or simulation-based validation, and be available in English. Exclusion criteria eliminated studies centered exclusively on public bond markets, theoretical models without empirical testing, or reviews lacking methodological rigor. All retrieved records were screened for duplicates, after which titles and abstracts were independently reviewed by two researchers to identify potentially relevant studies. Full texts of selected articles were then examined to confirm eligibility, with discrepancies resolved through discussion or consultation with a third reviewer. Data extraction captured key information on model type, input variables, statistical or machine learning techniques, predictive performance metrics, and applicability to different SME or corporate contexts. Risk of bias was assessed based on model validation procedures, sample representativeness, and methodological transparency. Quantitative synthesis focused on comparing predictive accuracy, robustness, and scalability of creditworthiness models across varying borrower profiles and market conditions. The PRISMA flow diagram was used to document the identification, screening, eligibility, and inclusion process, ensuring reproducibility and transparency. This structured approach facilitated a rigorous assessment of the evidence base, highlighting best practices, methodological gaps, and areas for further development in the quantitative evaluation of borrower creditworthiness within private debt frameworks.

2.1 Conceptual Framework

Borrower creditworthiness is a multidimensional construct that reflects the likelihood of a borrower fulfilling debt obligations in a timely manner while maintaining operational and financial stability. It encompasses both quantitative and qualitative attributes, providing a holistic measure of risk that informs lending decisions in private debt transactions. At its core, creditworthiness evaluates the borrower’s capacity, willingness, and resilience to meet financial commitments, integrating financial performance, operational efficiency, governance quality, and exposure to external market conditions. Accurate assessment of creditworthiness is crucial for lenders, as it underpins interest rate determination, covenant structuring, portfolio risk management, and capital allocation strategies (Akintobi, 2023 [9]; Okiye *et al*., 2023).

The components of borrower creditworthiness can be broadly categorized into financial, operational, and market dimensions. Financial factors include liquidity, leverage, and profitability, which provide a measurable foundation for

assessing repayment capacity. Liquidity ratios, such as the current ratio and cash flow coverage, indicate the borrower's ability to meet short-term obligations, while leverage ratios, including debt-to-equity and interest coverage, measure the firm's financial structure and reliance on external capital. Profitability metrics, such as net margin, return on assets, and return on equity, capture operational efficiency and the capacity to generate returns from invested capital (Ojika *et al*., 2023; Okiye *et al*., 2023). Collectively, these indicators form the quantitative backbone of creditworthiness assessment, offering objective measures of the firm's financial health and risk exposure.

Operational and strategic factors complement financial analysis by incorporating qualitative dimensions that affect long-term sustainability. Revenue growth trends, customer concentration, product or service diversification, and management quality influence the firm's resilience to market fluctuations and its ability to execute growth strategies effectively. Governance structures, internal controls, and historical performance consistency further reinforce operational reliability and reduce the likelihood of mismanagement or financial misreporting. By including these factors, the conceptual framework ensures that creditworthiness evaluation accounts for both historical performance and forward-looking operational risk (Bankole *et al*., 2023 [18]; Onifade *et al*., 2023).

Market and external factors provide essential context, linking firm-specific risk to broader economic, regulatory, and competitive environments. Macroeconomic conditions, such as interest rate trends, credit cycles, and sector growth, directly affect borrowing costs, revenue projections, and default risk. Regulatory requirements, market volatility, and competitive pressures influence operational sustainability and potential exposure to systemic shocks. Integrating these factors into the creditworthiness framework enables lenders to capture environmental risk that could impact the borrower's ability to service debt, ensuring a more comprehensive evaluation (Ogunnowo *et al*., 2023; Fasasi *et al*., 2023).

The conceptual framework also establishes the relationship between creditworthiness, default probability, and expected return. High creditworthiness is associated with a lower probability of default (PD) and more predictable cash flows, which enables lenders to offer favorable financing terms while minimizing the risk-adjusted cost of capital. Conversely, lower creditworthiness implies higher default risk, necessitating risk-adjusted pricing, additional covenants, or collateral requirements. Expected return is inherently linked to the credit profile, as instruments issued to higher-risk borrowers typically demand higher yields to compensate for increased exposure (Ojika *et al*., 2023; Ogunnowo *et al*., 2023). By quantifying creditworthiness through a composite score that integrates financial, operational, and market factors, lenders can estimate PD, loss given default (LGD), and exposure at default (EAD), providing a data-driven basis for evaluating risk-adjusted return on private debt investments.

The conceptual framework for assessing borrower creditworthiness provides a multidimensional approach that combines financial, operational, and market risk factors into an integrated model. It defines creditworthiness as a comprehensive measure of the borrower's capacity and willingness to meet obligations, establishes links between risk assessment and expected return, and offers a foundation for quantitative modeling. By operationalizing this framework, private debt investors can enhance decision-making, improve risk-adjusted portfolio performance, and support sustainable SME and mid-market financing through structured, evidence-based credit evaluation (Didi *et al*., 2023; Balogun *et al*., 2023) [19, 17].

2.2 Model Inputs and Data Requirements

Accurate assessment of borrower creditworthiness in private debt transactions requires a comprehensive set of model inputs and high-quality data to capture the multifaceted nature of credit risk. Private debt investors, particularly those financing SMEs and mid-market firms, must evaluate not only historical financial performance but also operational dynamics, strategic positioning, and exposure to macroeconomic and market conditions (Fasasi *et al*., 2023; Ogunnowo *et al*., 2023). The effectiveness of a quantitative creditworthiness model depends on the robustness, relevance, and granularity of the input data, as these elements directly influence the predictive accuracy of probability of default (PD), loss given default (LGD), and exposure at default (EAD) estimations. The model inputs can be broadly categorized into financial metrics, operational and strategic indicators, and market and external conditions as shown in Fig 1 below.

Fig 1: Model Inputs and Data Requirements

Financial metrics form the foundation of credit risk assessment, providing quantifiable measures of a borrower's liquidity, leverage, and profitability. Liquidity indicators, including the current ratio, quick ratio, and cash flow coverage ratio, assess the firm's ability to meet short-term obligations. The current ratio, calculated as current assets divided by current liabilities, evaluates the overall short-term solvency of the business, while the quick ratio excludes inventory to provide a stricter measure of liquid assets. Cash flow coverage ratios, which compare operating cash flows to debt service requirements, indicate the firm's ability to generate sufficient internal funds to meet principal and interest obligations, offering a dynamic perspective beyond static balance sheet measures. Leverage ratios, such as debt-to-equity, interest coverage, and total debt ratios, quantify the firm's financial structure and the degree of dependence

on borrowed capital. The debt-to-equity ratio evaluates relative reliance on external financing, interest coverage assesses the ability to service debt from operating earnings, and total debt ratio measures overall financial risk relative to total assets. Profitability metrics, including net margin, return on assets (ROA), and return on equity (ROE), provide insights into operational efficiency, capital utilization, and value creation capacity (Ojika *et al*., 2023; Onifade *et al*., 2023). Collectively, these financial indicators allow the model to assess both the capacity and sustainability of debt repayment.

Operational and strategic indicators complement financial metrics by capturing qualitative and forward-looking aspects of borrower performance. Revenue growth trends reflect the firm's market traction and scalability potential, while client concentration and diversification highlight the risk of dependence on key customers or market segments. Firms with high client concentration may be more vulnerable to revenue volatility, whereas diversified customer bases enhance resilience. Management quality, governance structures, and historical performance consistency are also critical factors, as they influence decision-making, strategic execution, and risk mitigation. Evaluating the experience, expertise, and track record of management teams provides additional context to quantitative financial measures, while governance practices, such as board oversight, internal controls, and compliance mechanisms, support operational discipline and transparency (Ogunnowo *et al*., 2023; Ojika *et al*., 2023). Historical performance consistency allows the model to distinguish between temporary fluctuations and persistent trends, improving predictive reliability.

Market and external conditions provide context for borrower risk that extends beyond firm-specific factors. Macroeconomic variables, including prevailing interest rates, credit cycles, and industry growth rates, influence the cost of capital, borrowing conditions, and the probability of sector-wide distress. Regulatory environment considerations, such as lending restrictions, tax policies, and compliance obligations, can affect both borrower capacity and lender risk exposure. Market risk factors, including commodity price volatility, currency fluctuations, and competitive pressures, further shape the operational environment and potential cash flow volatility (Abiola-Adams *et al*., 2023; Uzozie *et al*., 2023). Incorporating competitor landscape analysis, such as market share, product differentiation, and pricing dynamics, helps contextualize the firm's relative positioning and resilience against external shocks.

The integration of financial, operational, and market inputs requires high-quality, granular data that is accurate, timely, and relevant to the borrower's context. Historical financial statements, audited reports, management accounts, and operational records provide the quantitative foundation, while industry reports, macroeconomic datasets, and regulatory guidance supply external context. Advanced data validation, normalization, and preprocessing are essential to address inconsistencies, missing information, and differences in accounting standards, particularly when assessing SMEs or firms in emerging markets.

Model inputs and data requirements form the core of a robust quantitative framework for assessing borrower creditworthiness. Financial metrics provide a baseline assessment of liquidity, leverage, and profitability, operational and strategic indicators capture forward-looking and qualitative dimensions, and market and external conditions contextualize firm-specific risks within broader environmental factors. By systematically integrating these multidimensional inputs, lenders can develop predictive, data-driven insights that inform loan structuring, risk management, and portfolio allocation, thereby enhancing decision-making in private debt transactions (Ogunnowo *et al*., 2023; Fasasi *et al*., 2023).

2.3 Quantitative Modeling Approach

Quantitative modeling is central to assessing borrower creditworthiness in private debt transactions, enabling lenders and investors to make informed, risk-adjusted lending decisions. Unlike traditional qualitative evaluations, quantitative models provide structured, reproducible frameworks that integrate financial, operational, and external factors to estimate the likelihood and severity of default as shown in Fig 2. These models are particularly valuable in private debt markets, where borrower information is often less transparent and standardized than in public markets (Uzozie *et al*., 2023; Ozobu *et al*., 2023). A rigorous quantitative approach involves four interconnected components; risk scoring and weighting, probability of default (PD) estimation, loss given default (LGD) and exposure at default (EAD) estimation, and the calculation of a composite creditworthiness index.

Risk scoring begins with the identification of relevant financial, operational, and external variables that influence default risk. Financial metrics, including leverage ratios, liquidity indicators, profitability, and cash flow stability, provide insight into a borrower's capacity to meet debt obligations. Operational factors, such as management experience, supply chain reliability, and customer concentration, capture potential vulnerabilities beyond balance sheet data. External factors, including macroeconomic conditions, industry volatility, and regulatory exposure, contextualize the borrower's risk environment. Each factor is assigned a weight based on its relative impact on default probability, informed by historical data analysis, expert judgment, and statistical testing. Weighting mechanisms allow the model to reflect the multidimensional nature of credit risk, ensuring that critical drivers are prioritized while less influential variables contribute proportionally.

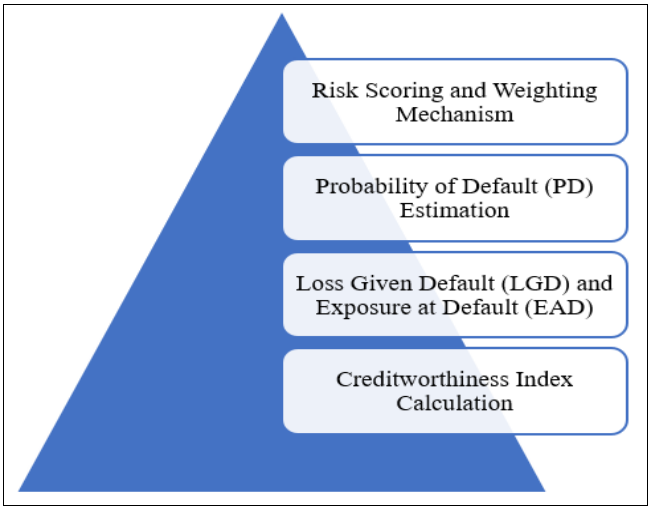

Fig 2: Quantitative Modeling Approach

The estimation of probability of default (PD) is a cornerstone of the quantitative modeling framework. Logistic regression has traditionally been employed to model the binary outcome of default versus non-default, enabling the transformation of predictor variables into estimated default probabilities. In recent years, machine learning classification methods, including random forests, gradient boosting, and support vector machines, have increasingly been applied to capture complex nonlinear relationships and interactions among risk factors. Model calibration relies on historical default data, including both performing and non-performing loans, to ensure accurate predictions. Stress-testing scenarios are incorporated to evaluate the model's robustness under adverse economic conditions, such as recessions, sector-specific downturns, or interest rate shocks. These simulations enhance the model's ability to anticipate potential vulnerabilities and inform proactive risk mitigation measures.

Loss given default (LGD) and exposure at default (EAD) are complementary parameters that quantify the potential severity of loss if a borrower defaults. LGD estimation considers factors such as the value and liquidity of collateral, enforceability of covenants, and the seniority of debt in the capital structure. Higher-quality collateral or stronger covenant protections reduce LGD, while subordinated or unsecured debt increases potential loss. EAD represents the outstanding exposure at the time of default, including drawn and undrawn credit lines, accrued interest, and other contingent obligations. Accurate estimation of LGD and EAD enables lenders to quantify expected losses and to set appropriate pricing, reserve requirements, and risk-adjusted return targets (Fasasi *et al*., 2023; Ogunnowo *et al*., 2023).

The final step in the quantitative modeling approach is the calculation of a composite creditworthiness index. This index integrates PD, LGD, and EAD into a single, standardized metric that facilitates comparability across borrowers of varying sizes, sectors, and geographies. A weighted aggregation of these parameters produces a score reflecting both the likelihood and magnitude of potential credit losses. Normalization and scaling techniques are applied to ensure that the index is interpretable and consistent across portfolios, allowing lenders to rank borrowers, prioritize due diligence efforts, and structure debt instruments accordingly. The creditworthiness index also serves as a foundation for portfolio-level risk management, enabling the aggregation of individual borrower risks into sectoral, geographic, or strategic risk profiles.

The quantitative modeling approach offers several practical advantages for private debt lending. It enhances objectivity, transparency, and reproducibility in credit decision-making, while enabling sophisticated risk-adjusted pricing and capital allocation. By integrating PD, LGD, and EAD into a unified framework, lenders can better anticipate potential losses, optimize covenant structures, and design financing solutions tailored to borrower-specific risk profiles. Furthermore, the approach provides a platform for ongoing monitoring and model refinement, incorporating new data and evolving market conditions to maintain predictive accuracy.

A rigorous quantitative modeling approach represents a critical tool for assessing borrower creditworthiness in private debt transactions. By combining risk scoring, probability of default estimation, loss quantification, and composite index calculation, the methodology enables lenders to evaluate credit risk comprehensively, structure debt instruments prudently, and support sustainable SME and corporate financing. As private debt markets continue to expand, the integration of advanced statistical and machine learning techniques promises to further enhance predictive precision, portfolio resilience, and investor confidence (Giwah *et al*., 2023; Ozobu *et al*., 2023).

2.4 Model Validation and Calibration

The robustness of quantitative models for assessing borrower creditworthiness in private debt transactions relies not only on their initial design but also on rigorous validation and calibration processes. Validation ensures that the model accurately reflects the risk profile of borrowers, while calibration aligns model outputs with empirical observations and industry benchmarks. Together, these processes provide confidence that the model can reliably inform lending decisions, portfolio management, and risk mitigation strategies (Adanigbo *et al*., 2023; Komi *et al*., 2023). Three critical components of model validation and calibration include backtesting with historical transaction data, sensitivity analysis of key assumptions, and benchmarking against external ratings or industry standards.

Backtesting represents a foundational approach to model validation. This process involves applying the credit assessment model retrospectively to historical private debt transaction data to determine how accurately predicted outcomes align with actual borrower performance. For instance, historical defaults, late payments, covenant breaches, and recoveries are compared to the model's predicted probability of default (PD), loss given default (LGD), and exposure at default (EAD) values. The discrepancies between predicted and observed outcomes provide insight into model bias, overfitting, or underestimation of risk. Metrics such as the Brier score, receiver operating characteristic (ROC) curves, or mean squared error are commonly used to quantify predictive accuracy. Backtesting not only validates the model's predictive power but also identifies specific borrower or sector segments where the model may underperform, informing adjustments to weighting schemes, covariate selection, or functional forms. In private debt markets, where borrower data can be heterogeneous and less standardized than public markets, backtesting is particularly valuable for capturing idiosyncratic risks and sector-specific performance patterns.

Sensitivity analysis constitutes a complementary approach to model validation, focusing on the model's responsiveness to changes in key financial, operational, or market assumptions. SMEs and private borrowers are inherently exposed to fluctuations in revenue, cash flow, input costs, and macroeconomic conditions. Sensitivity analysis systematically adjusts these input variables to assess how the probability of default, LGD, or EAD changes under alternative scenarios. For example, increasing leverage ratios, declining profitability, or rising interest rates may be simulated to evaluate the model's stability and to identify thresholds beyond which default risk escalates significantly. Such analysis allows lenders to understand which factors have the greatest influence on credit outcomes and to stress-test portfolios under adverse economic or sector-specific conditions. Sensitivity analysis is critical for designing robust debt instruments and covenants, as it highlights

potential vulnerabilities and informs contingency planning to mitigate unexpected losses (Obuse *et al*., 2023; Ayanbode *et al*., 2023) [41, 15].

Benchmarking against external ratings and industry standards provides an additional layer of model validation and ensures alignment with broader market expectations. While private debt borrowers often lack publicly available credit ratings, comparative analysis can be conducted using ratings from analogous firms, sectoral default studies, or standardized scoring systems employed by development finance institutions. Benchmarking allows model developers to evaluate whether their internal risk assessments are consistent with recognized external measures, facilitating credibility with investors, regulators, and other stakeholders. Discrepancies between model outputs and external benchmarks can reveal areas for recalibration, including adjustment of risk weights, incorporation of additional covariates, or refinement of scoring algorithms (Abiola-Adams *et al*., 2023; Evans-Uzosike and Okatta, 2023). Moreover, benchmarking promotes transparency and comparability across private debt portfolios, enabling lenders to communicate risk assessments effectively to investors and to support risk-adjusted pricing strategies.

The integration of backtesting, sensitivity analysis, and benchmarking provides a holistic framework for model validation and calibration. Iterative feedback loops between these components ensure that models remain adaptive to evolving borrower characteristics, sectoral trends, and macroeconomic conditions. Calibration techniques may include statistical adjustments to PD estimates, reweighting of covariates, or scaling LGD and EAD parameters to reflect observed recovery rates. Regular recalibration is especially important in private debt markets, where limited data availability, heterogeneous borrowers, and changing regulatory environments can introduce structural shifts that affect model performance (Oladimeji *et al*., 2022; Asata *et al*., 2023). By continuously validating and calibrating the model, lenders can maintain confidence in its predictive accuracy, improve risk-adjusted decision-making, and enhance the resilience of private debt portfolios.

Model validation and calibration are essential processes for ensuring that quantitative credit assessment tools provide reliable, accurate, and actionable insights in private debt markets. Backtesting with historical transaction data evaluates predictive performance, sensitivity analysis examines the impact of variable assumptions, and benchmarking against external ratings or industry standards ensures alignment with market norms. Together, these practices enhance model credibility, support prudent lending decisions, and facilitate effective portfolio management, ultimately contributing to the sustainable growth and stability of private debt financing for SMEs and other private borrowers (Komi *et al*., 2023; Giwah *et al*., 2023).

2.5 Application in Transaction Decision-Making

The practical application of borrower creditworthiness assessment plays a central role in transaction decision-making within private debt markets. By transforming financial, operational, and market data into a structured credit scoring framework, lenders can systematically evaluate borrower risk and make informed decisions regarding loan structuring, pricing, and covenant design. Credit scores derived from quantitative models allow for objective, data-driven comparisons across borrowers, facilitating tailored financing arrangements that align risk exposure with expected return (Evans-Uzosike and Okatta, 2023; Adanigbo *et al*., 2023). For instance, borrowers with high credit scores may qualify for lower interest rates, reduced collateral requirements, or more flexible repayment terms, while those with lower scores may require additional safeguards, higher yields, or stricter covenants. This approach enables lenders to optimize debt instrument structures to reflect borrower-specific risk profiles, enhancing both portfolio performance and borrower alignment with financial obligations.

At the portfolio level, credit scoring supports risk management and diversification strategies by providing insights into the aggregate risk profile of private debt investments. By quantifying default probability (PD), loss given default (LGD), and exposure at default (EAD) for each borrower, lenders can identify concentrations of risk across industries, geographies, or borrower types. Portfolio construction can then be informed by diversification objectives, ensuring that exposure is distributed to minimize correlated losses while maximizing risk-adjusted returns. For example, lenders may limit aggregate exposure to a single sector or region or balance high-yield, higher-risk borrowers with low-risk, stable borrowers to achieve an optimal risk-return profile. This systematic integration of credit scoring into portfolio management allows private debt investors to proactively manage potential vulnerabilities and maintain capital efficiency across diverse holdings.

Scenario analysis further enhances transaction decision-making by assessing the resilience of individual borrowers and portfolios under varying macroeconomic and sectoral conditions. By modeling interest rate fluctuations, credit cycle shifts, or industry-specific downturns, lenders can simulate potential stress scenarios and evaluate the impact on borrower repayment capacity and overall portfolio stability. Scenario analysis informs proactive measures, such as adjusting loan covenants, hedging exposure, or restructuring debt arrangements, thereby mitigating the risk of unexpected defaults. It also supports forward-looking capital planning, enabling lenders to allocate resources strategically and maintain sufficient liquidity buffers to absorb potential shocks.

The integration of credit scoring, portfolio-level analysis, and scenario-based stress testing provides a comprehensive framework for evidence-based transaction decision-making. It allows lenders to balance risk and reward, optimize loan terms, and maintain portfolio resilience in dynamic market environments. Moreover, this approach promotes transparency, accountability, and consistency in credit evaluation, enabling private debt investors to standardize processes across transactions while remaining responsive to borrower-specific and external risk factors (Adepoju *et al*., 2023; Asata *et al*., 2023).

The application of quantitative credit assessment in transaction decision-making strengthens the strategic management of private debt investments. Credit scores guide loan structuring, pricing, and covenant design, while portfolio-level risk management ensures diversification and capital efficiency. Scenario analysis further enhances decision-making by evaluating exposure to macroeconomic or sectoral shocks. Collectively, these tools provide a robust, data-driven foundation for informed lending, supporting sustainable SME and mid-market financing while optimizing risk-adjusted returns for investors.

2.6 Limitations and Considerations

While quantitative models provide a systematic and data-driven approach to assessing borrower creditworthiness, their application in private debt transactions is subject to several important limitations and considerations. These constraints arise primarily from the characteristics of SMEs and private borrowers, the assumptions embedded in modeling techniques, and the need to integrate quantitative outputs with qualitative insights (Adeyelu *et al*., 2023 [7]; Uddoh *et al*., 2023). Understanding these limitations is essential for ensuring that credit assessments remain reliable, actionable, and contextually appropriate for transaction decision-making as shown in Fig 3.

A primary limitation lies in data availability and quality, which is often a significant challenge for SMEs and privately held firms. Unlike publicly listed companies, SMEs may not maintain standardized, audited financial statements, leading to inconsistencies, incomplete information, or delays in reporting. Variations in accounting practices, financial disclosure standards, and record-keeping processes further complicate the comparability and reliability of financial metrics. Operational and strategic data—such as revenue diversification, customer concentration, or governance structures—may also be limited or qualitative in nature, making quantification difficult. The absence of historical default data for private borrowers poses an additional challenge, as predictive models rely on past performance to estimate probability of default (PD) and other risk metrics. These data limitations necessitate careful validation, normalization, and, in some cases, the supplementation of modeled inputs with expert judgment to ensure the robustness of credit assessments.

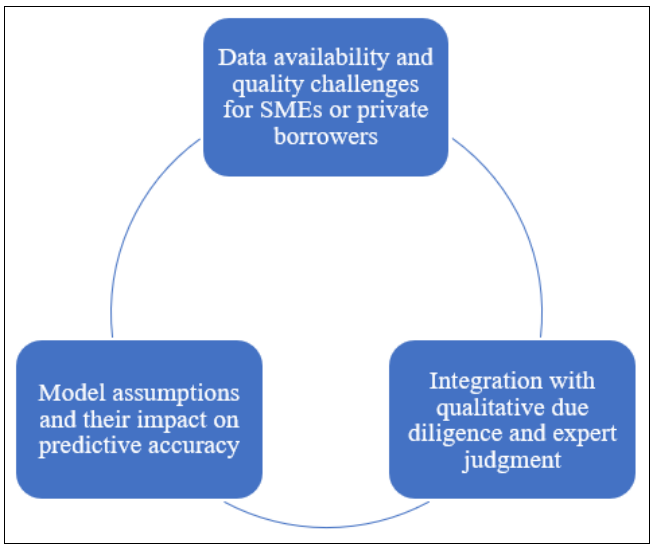

Fig 3: Limitations and Considerations

Model assumptions represent another critical consideration impacting predictive accuracy. Quantitative frameworks typically rely on assumptions regarding linear relationships between financial ratios and default risk, constancy of macroeconomic conditions, or stability in operational performance. While these assumptions simplify modeling, they may fail to capture the non-linear, dynamic, and context-specific nature of SME risk. For example, a firm operating in a highly cyclical industry may experience sudden revenue declines that are not reflected in historical financial ratios, leading to underestimation of default probability. Similarly, correlations among portfolio exposures may vary over time, especially during economic shocks, potentially affecting risk aggregation and scenario analysis. Model sensitivity to these assumptions highlights the importance of stress testing, scenario analysis, and ongoing recalibration to account for changing conditions and maintain predictive relevance.

Integration with qualitative due diligence and expert judgment is therefore essential to complement the quantitative model and address its limitations. While financial ratios, operational indicators, and market variables provide objective measures of risk, they may not fully capture intangible factors such as management competence, strategic vision, competitive advantage, or emerging regulatory risks. Experienced credit officers and industry specialists can provide critical context, interpret anomalous data, and validate model outputs, enhancing the reliability of credit assessments. Structured qualitative assessments—such as management interviews, site visits, and operational reviews—can be systematically combined with model outputs to generate a more holistic view of borrower creditworthiness (Asata *et al*., 2023; Adepoju *et al*., 2023). This hybrid approach ensures that decision-making is informed by both quantitative rigor and contextual expertise, mitigating the risk of overreliance on model outputs.

While quantitative models for assessing borrower creditworthiness offer significant advantages in objectivity, consistency, and predictive capability, their use in private debt transactions is constrained by data availability, model assumptions, and the need for qualitative integration. SMEs and private borrowers often present incomplete or heterogeneous data, necessitating careful preprocessing and supplementation. Model assumptions can influence accuracy, requiring stress testing, scenario analysis, and periodic recalibration. Finally, integration with qualitative due diligence and expert judgment ensures that the assessment captures operational, managerial, and strategic dimensions not reflected in purely numerical inputs. Recognizing and addressing these limitations is crucial for enhancing the reliability, applicability, and practical value of quantitative creditworthiness models, ultimately supporting more informed lending decisions and sustainable SME financing outcomes.

2.7 Policy and Regulatory Implications

The adoption of quantitative models for assessing borrower creditworthiness in private debt transactions carries significant policy and regulatory implications. As private debt markets expand, particularly in the SME and mid-market sectors, aligning lending practices with established regulatory frameworks is critical for ensuring financial stability, transparency, and risk containment. Regulatory frameworks such as Basel III and associated risk-weighted asset (RWA) requirements provide formalized standards for capital adequacy, credit risk measurement, and supervisory oversight, shaping both the design and implementation of credit assessment models. Compliance with these standards ensures that lenders maintain sufficient capital buffers relative to portfolio risk, mitigating the potential systemic impact of borrower defaults and fostering a resilient financial ecosystem (Uddoh *et al*., 2023; Umoren *et al*., 2023 [67]).

Basel III emphasizes the quantification and management of credit risk through standardized and internal ratings-based

approaches, which directly inform the application of quantitative creditworthiness models. By systematically estimating probability of default (PD), loss given default (LGD), and exposure at default (EAD), lenders can calculate risk-weighted assets and determine capital requirements in a manner consistent with regulatory expectations. This alignment enhances the credibility of private debt portfolios, providing assurance to regulators, investors, and counterparties that credit risk is rigorously measured, monitored, and managed. Furthermore, regulatory guidance encourages stress testing and scenario analysis to evaluate portfolio resilience under adverse macroeconomic conditions, reinforcing the integration of quantitative modeling into prudent risk governance practices.

Beyond compliance with external regulations, the deployment of quantitative credit assessment frameworks has important implications for internal credit risk governance and reporting standards. Financial institutions and private debt funds are increasingly required to establish formalized risk management processes, including credit committees, approval hierarchies, and documentation standards. Quantitative models provide an objective basis for evaluating borrower risk, supporting consistent decision-making across transactions and enhancing transparency in credit approvals. Reporting standards can incorporate model outputs such as credit scores, PD, LGD, and exposure metrics, enabling systematic monitoring of portfolio health, early warning detection of emerging risk, and periodic disclosure to internal stakeholders. By standardizing credit assessment and reporting practices, lenders can ensure accountability, facilitate internal audits, and align risk management procedures with corporate governance requirements.

Regulatory and policy considerations also extend to data management, model validation, and ongoing oversight. Regulators increasingly emphasize the quality, accuracy, and traceability of data used in credit assessment, highlighting the need for robust data governance frameworks. Institutions are expected to validate model performance periodically, recalibrate assumptions based on evolving market conditions, and document methodologies to satisfy both internal and supervisory review processes. These requirements reinforce the importance of integrating quantitative modeling with rigorous governance and operational controls, ensuring that creditworthiness assessments are not only predictive but also auditable and compliant with regulatory expectations (Asata *et al*., 2023; Oladimeji *et al*., 2022).

The application of quantitative creditworthiness models in private debt transactions carries profound policy and regulatory implications. Alignment with frameworks such as Basel III ensures appropriate capital allocation, risk measurement, and supervisory compliance, while internal governance and reporting standards promote transparency, consistency, and accountability. By integrating quantitative modeling with regulatory guidance, private debt lenders can strengthen risk management practices, enhance portfolio resilience, and support sustainable SME and mid-market financing, fostering a robust and transparent private debt ecosystem that balances innovation with prudential oversight.

3. Conclusion

The development and application of a quantitative model for assessing borrower creditworthiness provides a structured, data-driven foundation for evaluating risk in private debt transactions. By integrating financial metrics, operational indicators, and market conditions, the model enables lenders to quantify the probability of default, loss given default, and exposure at default, offering a comprehensive assessment of borrower capacity and resilience. This multidimensional approach enhances transparency, objectivity, and consistency in credit evaluation, allowing private debt investors to make informed lending decisions and tailor loan structures, pricing, and covenants to individual borrower risk profiles.

The utility of the model extends beyond individual transactions, supporting portfolio-level risk management and strategic allocation of capital. By providing standardized credit scores and risk metrics, lenders can identify concentrations of exposure, optimize diversification strategies, and conduct scenario analyses to evaluate potential impacts of macroeconomic or sectoral shocks. This integration of predictive modeling with portfolio oversight strengthens risk-adjusted decision-making, promoting both capital efficiency and financial stability within private debt markets. Furthermore, the model facilitates alignment with regulatory frameworks and internal governance standards, ensuring compliance with capital adequacy requirements and robust reporting practices.

To maximize its effectiveness, continuous refinement of the quantitative model is essential. Incorporating emerging data analytics tools—such as machine learning algorithms, alternative data sources, and real-time performance monitoring—can improve predictive accuracy, enhance sensitivity to early risk signals, and adapt to evolving market dynamics. Integration with qualitative due diligence and expert judgment remains critical, providing contextual insight and validation to complement quantitative outputs.

The quantitative creditworthiness model serves as a pivotal instrument for enhancing risk-adjusted decision-making in private debt markets. By combining systematic analysis, portfolio-level oversight, and iterative refinement through advanced analytics, the framework supports sustainable SME and mid-market financing, promotes transparency and efficiency, and enables lenders to deploy capital prudently while mitigating risk exposure.

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