What Impacts the Probability of Firms Becoming Zombies? An Empirical Investigation

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Abstract

This study examines the financial determinants of the probability of firms becoming a zombie firm using a panel data taken from multiple non-financial companies from 2010 to 2023. Zombie firms are defined as being firms that cannot afford to pay interest out of operating earnings over extended periods of time and have sustained financial fragility. The analysis uses logistic and probit regression models for assessing the impact of leverage, profitability, liquidity and firm size on the probability of becoming zombie. The empirical findings show that leverage has a significant effect on the likelihood of financial distress, with the higher the debt levels the higher the odds of zombification by more than twofold. Profitability has the greatest protective effect and decreases predicted zombie probability by more than forty percent per unit increase in return on assets. Liquidity also has a similar effect of reducing distress risk by improving short term solvency and firm size has a small but consistently negative link to zombification. Robustness checks such as alternative specifications of the variables and subsampling estimation to check the stability of results are done. Diagnostic tests suggest no concerns in terms of serial correlation, cross sectional dependence or multicollinearity, so the estimated models are reliable. Overall, the study points to the importance of financial structure and operating performance to firm resilience and staving off long term stagnation.

Keywords: zombie firms, leverage, profitability, liquidity, financial distress

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

1.1 Background

The phenomenon of zombie firms has captured increasing attention from scholars and policymakers alike, particularly in the aftermath of global financial crises and in environments characterized by persistently low interest rates. By definition, "zombie firms" are those firms that are still operating even though they cannot meet the debt servicing costs from core profits for a protracted period (i.e., the interest payments are more than the operating earnings, often for more than two years) (Banerjee & Hofmann, 2018). These firms survive largely because these are companies that usually banks and at times, governments extend their reasons in the form of rollovers of debt or better-than-market refinancing conditions instead of letting them go out of business.

Historically, zombie firms are one of the ideas that has its roots in Japan's "Lost Decade" of the 1990s, which further explains the concept of the zombie firm. zombie Examples (1991) Historically, the idea of zombie firms has its origins in the "Lost Decade" of Japan in the 1990s, when weak banks pursued a credit-based policy of keeping nonviable firms afloat, thereby inhibiting the process of creative destruction. These western forces enter the market to achieve their aspirations. to bring down to Over the years, the researchers have attributed the growth of zombie firms to two key macro-financial dynamics: weak banking sectors unwilling to write off losses, and a secular decline of real interest rates. The former imposes credit forbearance and the latter reduces the cost of debt leading to the persistence of marginal firms instead of bankruptcy (Banerjee & Hofmann, 2018).

The recent prevalence of zombie firms has become particularly relevant as central banks have kept their monetary policies ultra-accommodative thus providing favorable opportunities for weaker firms to persist under central bank policies than they otherwise would.The rise of relevance of zombie firms has taken place against a backdrop of repeated economic shocks and the unconventional monetary policies. After the Global Financial Crisis of 2008, many economies pursued very loose monetary policies, including quantitative easing and very low

rates for extended periods of time, to spur growth. In this setting, the "cleansing effect" that recessions are supposed to have through the failure of weak firms and the reallocation of resources to more productive firms has been easily discounted as those firms that would have failed are kept alive (Baxter, 2022). More recent episodes such as the COVID-19 crisis led to an even larger blurring of the boundary between viable and nonviable firms with massive government support and credit guarantees, increasing zombie dynamics (He et al., 2023). The danger is that the overhang of zombified firms may lead to a depression of aggregate productivity growth and crowd out investment in more-efficient firms commonly referred to as "resource misallocation" or "capital congestion" effects.

Globally, the literature seems to indicate that the prevalence of zombie firms has expanded in both advanced as well as emerging markets. For example, in the IMF's study The Rise of the Walking Dead: Zombie Firms Around the World the theme of zombies surveys both the listed and private nonfinancial firms in advanced and emerging economies show the increased incidence of zombies, especially following monetary easing and liquidity disruptions after 2008 (IMF, 2023). The authors write that in 2021, zombie firms represented more than 10 percent of listed firms, and about 5.3 percent of private firms in the year before. In the United States, the prevalence has raised concern about potential systemic risk particularly with the rates of interest beginning to return to normal (Schivardi et al., 2020).

In the European context, the value of the euro area has come under greater scrutiny in the form of zombie companies at ultra-low interest rates coupled with ongoing bank fragility. Jafarov et al. (2023) emphasize that subsidized credit along with near zero or negative rates make it difficult to identify favorable credit to zombie firms and consequently to formulate an effective policy targeting them. In a comparative analysis of Germany and the Czech Republic, Blažková and colleagues show that in Germany with more vibrant institutions and stronger conservative monetary policy there was a lower zombie firm persistence, whereas the Czech country had higher shares comparable to the European average (Blažková et al., 2022). Post-crisis monetary regimes, in particular prolonged low rate policies, were demonstrated to play a role in cross-country differences in the prevalence of zombies.

In emerging economy, India has also drawn more and more scholarly attention. Rai and Sharma (2025) empirically study the impact of capital structure choices, leverage, and the interaction between firms and the banking sector on firms' likelihood to become zombies in India and find that in an accommodation monetary policy regime experience similar to capital structure choices. Other research studies (e.g.,Adalet McGowan et al., 2018) on the role of recessions and low-interest regimes in raising the risk that a firm will become a zombie, based on a very broad sample.

In sum, the background and evolution of zombie firms raises the suspicion that they are not rare or isolated anomalies. Instead, interlinkages with macroeconomic policy regimes, financial sector health and firm-level distress dynamics are present. The post-crisis and low interest rates world has arguably been a fertile ground for the survival and growth of such "walking dead" firms, in developing or advanced regions, and raise critical questions about the structural implications for productivity, financial stability, and growth.

1.2 Problem Statement

The survival of zombie companies has become a major economic issue because of the negative impact on productivity, capital distribution, and financial stability. Zombie firms are usually described as companies that have been chronically incapable of meeting debt servicing obligations through operating profits, but are kept open by continued credit support, low interest rates and interventions from policy makers. Such firms absorb scarce financial and productive resources that could be used for more efficient and productive enterprises and thus distort market competition and slow economic growth.

Although there is a growing body of literature on the phenomenon of zombie firms, most of the available studies are based on descriptive classifications or are mainly developed for advanced economies. There is not much empirical evidence estimating the likelihood of firms becoming zombies based on financial characteristics of firms in a probabilistic econometric framework, especially in emerging market contexts. Moreover, previous research is usually focused on the financial determinants individually without jointly considering the contributions of leverage, profitability, liquidity, and firm size to the zombification risk.

This study aims to handle this gap by empirically estimating the likelihood of firms being able to become zombie firms by using binary response models. By using logistic and probit regression methods, the study gives a systematic evaluation of the impact of firm specific financial characteristics on zombification risk. The research adds to the literature by changing the research question from merely identifying zombie firms to probability based estimation, and provides more information on corporate financial fragility and resilience.

1.3 Research Questions

- How do leverage, profitability, liquidity, and firm size affect the probability of a firm becoming a zombie firm
- What is the magnitude and direction of the impact of these firm level financial characteristics on zombification risk as measured through odds ratios and marginal effects

1.4 Research Objectives

1. To estimate the probability of firms becoming zombie firms using logistic and probit regression models
2. To examine the impact of leverage on the likelihood of firm zombification
3. To assess the effect of profitability on reducing the probability of becoming a zombie firm
4. To analyze the role of liquidity in mitigating long term financial distress
5. To evaluate the influence of firm size on zombification risk
6. To interpret the economic significance of the estimated relationships using odds ratios and marginal effects

1.5 Scope of the Study

The scope of this study is limited to empirical analysis of zombification as a firm level financial determinants. The research targets non financial firms and will try to measure the probability of becoming a zombie firm as a function of leverage, profitability, liquidity, and firm size. Zombie firms are identified with the help of the interest coverage ratio criterion under which firms which

are not able to pay interest expenses from operating earnings over a prolonged period of time are to be classified as zombies.

Methodologically, the study applies binary response econometric models, i.e. logistic and probit regressions, to estimate the probability of zombification. The analysis is based on panel data therefore it would be possible to examine cross sectional and time variation in firm characteristics. Industry and time effects are included in order to control for sector specific and macroeconomic effects.

The study does not discuss macroeconomic policy variables and sector specific regulatory interventions in much detail and is limited to firm level financial indicators. The findings are therefore interpreted in the light of corporate financial structure and operating performance and not in the context of policy analysis on a broader macroeconomic scale.

1.6 Significance of the Study

This study is important for academia, managers, and policy makers in that it enhances the knowledge regarding the determinants that heighten the likelihood of firms falling into the zombies category. Academically, it makes a contribution to the developing stream of literature on corporate distress and financial stability as it moves firm-level financial characteristics, governance indicators and macroeconomic conditions into an empirical framework for explaining zombification. It also spans theoretical views on capital structure, firm behavior and market efficiency and presents empirical evidence from an emerging market context, which is very often underrepresented in previous studies. From a managerial point of view, the results will be valuable for corporate decision makers relative to the optimal leverage, liquidity management and governance practices that can help to avoid firms to fall into a financial quagmire. This study will be useful for policymakers and financial regulators to understand systemic vulnerabilities related to credit misallocation and low interest rate environments in the long term and for them to design policies to specifically address sources of inefficiencies and build resilience into the economy.

Chapter 2: Literature Review

2.1 Concept and Evolution of Zombie Firms

The idea of zombie firms emerged most prominently in the context of Japan's prolonged economic stagnation in the 1990s, where weak banks continued to roll over debt to nonviable firms rather than recognizing losses, thereby inhibiting creative destruction and prolonging economic malaise (Blažková et al., 2022). Since then the zombie concept has been used in many economies to refer to a class of firms that have slipped into a precarious state where they can only survive owing mainly to creditor forbearance or subsidized borrowing. In essence, zombie firms are insolvent or marginally insolvent but have continued access to credit thereby forestalling exit from the market. Modern conceptualizations base themselves on two complementary criteria: (i) chronic non-ability-to-service debt out of operating earnings, meaning that operating profits were always negative or inadequate vis-a-vis service of interest payments and (ii) credit support/refinancing of debt to avoid liquidation/default. Recent literature sees zombies more as a fluid label, rather than a static one, and more as a dynamic status that firms may be in or out of depending on the conditions (i.e., macro conditions, financial regimes, adjustments at the firm level).

The fact that zombie firms exist is systemic and dangerous. Because zombies file use capital, labor, and credit that could otherwise be used in more productive firms, they result in resource misallocation (lower aggregate productivity) and labor "capital congestion" effects. The literature points to the fact that the prevalence of zombies increases at times of low interest rates and poor financial regulation, as the cost of capital is suppressed and banks may be unwilling to acknowledge losses. Moreover, zombie growth generates negative externalities, such as the decrease of investment incentives of sounder firms and of dynamism of entry and exit.

2.2 Identifying Zombie Firms

Identification of zombie firms is central to empirical work yet remains methodologically challenging. The most commonly used criterion is the Interest Coverage Ratio (ICR), which is earnings before interest and taxes (EBIT) (or some variation of) divided by interest expense. A

firm is often deemed as a zombie if its ICR < 1 over three consecutive years (Banerjee & Hofmann, 2018). This rule translates chronic debt servicing failure based on core earnings. In contrast, some studies define zombies as firms that persist in receiving credit even though they do not have the capacity to generate profits to pay the interest i.e., "evergreening" or credit forbearance behavior of lenders (Chari et al., 2021).

Formally, one can express the classification rule as:

$$\text{Zombie}_i = \begin{cases} 1, & \text{if } ICR_i < 1 \text{ for at least three consecutive years} \\ 0, & \text{otherwise} \end{cases}$$

While this is an easy rule to follow, it is not without criticism. Some firms may temporarily have low earnings even without problems of viability (e.g., high investment phases) and so be misclassified. Bow-5man22 explains that a pure interest coverage rule as insert growing but unprofitable firm or firm could have a lumpy investment payoff Hu as zombies. To address such misclassification errors, refinements have been made - e.g., the FN-CHK method - that include profitability requirements (e.g., being a safe net of always negative profits after subsidies), or thresholds on leverage in the NEO or loan growth (as in mixed ownership reform studies), in order to restrict the definition of zombies.

Beyond ICR thresholds, there was the proposal of alternative and/or complementary metrics that were recently published by some authors. For example, in the case of Finnish small firms, zombie identification has been done by ICR < 1 under EBIT/interest or EBITDA/interest with an emphasis on the sensitivity of different profit measurement choices (Erika et al., 2025). Still other create composite measures or adjustments of structural persistence and revise a definition more to the point about the zombie status hysteresis. The new CEPR paper, "Counting the Undead: A New Metric for Identifying Zombie Firms," suggests a multi-step classification that combines elements of solvency, growth and persistence in order to classify zombies (CEPR, 2024) more accurately.

In a nutshell, the literature portrays a double detective logic in the identification of zombies wherein; (i) a distress or insolvency signifier (normally ICR), and (ii) indicators of credit reinforcement prevents natural exit. Empirical studies usually take advantage of binary zombie

dummies or survival regressions, with less recent research even delving into machine learning techniques to flat the zombies based on rich firm accounting data. (ex, Machine Learning and Zombie Firms Classification, 2024).

2.3 Determinants of Zombie Firms

Focusing on the origins of zombie firms, the empirical literature reaches a consensus on a number of results: financial fragility, governance weaknesses and credit market distortions increase the likelihood of zombification. I summarize some important relationships confirmed in recent high-quality empirical research and add original insight from recent papers.

Leverage and capital structure

High leverage becomes a strong predictor of the risk of zombification. Firms that have a high debt-to-equity ratio or a high debt-to-cash-flow ratio are more sensitive to adverse shocks and are less able to withstand servicing interest costs. Rai and Sharma (2025) report that firms in India that have higher debt ratios are significantly more likely to be zombies, controlling for other firm and macro characteristics. This result has echoes in the literature in general which found that indebtedness increases the probability of financial distress and zombification.

Profitability, cash flow adequacy & asset quality

Poor profitability and weak cash flows are direct indicators of inability to service debt, which is powerful enough to predict zombie status. (Chari et al., 2021) indicates that companies with consistently low operational returns and negative cash flows have higher chances of falling into the category of zombies. Empirical studies also point out the role of non-performing loans (NPLs) at the banking level: high NPL ratios in a firm's lending bank have been found to be linked to a higher likelihood that such banks will adopt forbearance and therefore prolong the life of underperforming firms.

Corporate governance weaknesses

Corporate governance has a moderating effect between firm distress and zombification. San-Jose, Urionabarrenetxea and Garcia-Merino (2021) find that governance deficits such as having larger boards (which may lead to a lack of oversight), concentrated ownership (implying potential tunnelling or entrenchment), and less gender diversity in board leadership are positively

associated with the probability that a distressed firm becomes a zombie. Weaker governance may make managers less willing to carry out corrective restructuring, as well as potentially make creditor monitoring harder.

Bank competition and credit market distortions

Zombie creation is influenced by competitive intensity of the banking sector, through the lending and monitoring activity. Li et al. (2025) conclude that in the Chinese context, bank competition does have impacts on zombie formation in two stages: Increased competition leads to a decrease in the initial formation of distressed firms but an increase in the probability that a distressed firm will be subject to zombie lending, resulting in a net decrease in the incidence of zombies. Briefly, banks are fighting over shares of the market, and may lend to marginal or nonviable enterprises. (Yu et al., 2021) in a study of Chinese firms also demonstrate the high bank competition will also more likely encourage zombie formation by loosen credit standards and lower the information screening efficiency; and firms with fuzzy operations or weak fundamentals will more likely survive under supportive credit conditions.

Government subsidies and intervention

Direct subsidies, tax or other preferential treatment may make zombification even worse by effectively protecting the zombie firms from leaving the market. Zombie Firms, State Subsidies and Aggregate Productivity (2025) finds that one of the reasons behind the existence and persistence of zombie firms is subsidized support to them, which creates the incentive for inefficient behaviour and a fall in aggregate productivity growth. In Chinese manufacturing industry, Chang et al., 2021 empirically confirm that the government intervention increases the probability of firms becoming zombies positively through channels of resource support and financial support.

Ownership reforms and structural policy effects

More recently, structural or institutional reform have been singled out as moderating factors. For example, Yin et al. (2024) investigate the impact of sohu from Chinese SOEs, and discover that SOH introductions can truly help to eliminate zombification by way of increasing managerial incentives, monitoring, and financial discipline due to the ownership change. In addition to firm level governance, most of the studies of zombie firms and resource allocation identify

institutional and macro level supports (e.g. weak insolvency regimes, weak creditor rights) as zombie enabling environments (Yamada 2025).

Synthesis of expected effects

Determinant	Expected Sign on Probability of Zombie	Rationale
Leverage (debt/asset, debt/equity)	Positive	Higher debt obligations increase distress risk
Profitability (ROA, ROE) / Operating margins	Negative	Lower profits reduce ability to cover interest
Cash flow (OCF/interest)	Negative	Insufficient cash flow signals distress
Non-performing loan ratio (bank level)	Positive	Lenders may maintain distressed firms to avoid recognition of losses
Board size, ownership concentration, CEO characteristics	Positive	Weaker governance reduces corrective action
Bank competition	Ambiguous (but often positive)	Intensifies credit forbearance to marginal firms
Government subsidies / intervention	Positive	Shields unviable firms from exit
Mixed-ownership / institutional reform	Negative	Improves governance and financial discipline

These results taken together indicate that zombification in addition to being a symptom of firm-level weakness is also shaped by the interaction between credit market incentives, institutional frameworks and policy regimes.

2.4 Gaps in Literature

Despite the increasing interest in zombie firms in academic literature, there still remain some critical gaps in empirical and methodological literature. First, scarce work has been done to use probabilistic models (e.g., logit, probit, panel binary response) in order to estimate the risk of zombification in emerging economies. The bulk of the empirical work focuses on advanced economies or relies on less sophisticated methods of classification without modelling the conditional probability of zombie status. Albuquerque and Iyer (2023) offer a cross-country dataset on advanced and emerging markets but their analysis is descriptive and does not focus on econometric modeling of individual firm risk. The emphasis is very much on aggregate zombie shares or macro correlations, versus estimating probability at the firm level, especially in the South Asia, Latin America or Sub-Saharan Africa context.

Second, a relatively small number of studies combine corporate governance measures with financial structure indicators to study zombification risk in a single econometric framework. Existing works tend to give emphasis to either financial distress variables (e.g., leverage, profitability, NPL ratios) or governance variables in an isolated manner, but very rarely explore interaction or combined effects. For example, studies of governance and zombie risk in Japan (Fukuda et al., 2011) look at board size, CEO duality, and foreign ownership, but rather look more at the dynamics of recovery rather than entry into zombie status; while, studies of debt structure and firm fragility tend not to include governance metrics. The lack of models to estimate capital structure and governance together leaves open channels of influence, for example whether strong governance can mitigate the zombification risk of highly leveraged firms.

Third, there is a lack of evidence concerning heterogeneity across sectors and firm size and institutional contexts with respect to the determinants of zombie formation. Most studies assume homogenous effects across industries and do not consider possible nonlinearities or regime dependencies (e.g., effect of leverage may be different in manufacturing vs. services, high vs. low institutional quality countries). Fourth, endogeneity and causality difficulties are not always well addressed. Many of the studies are based on static regressions without instruments or

dynamic specifications to handle reverse causality (e.g., weak governance leading to distress or vice versa).

Fifth, temporal dynamics and transitions into and out of the zombie status need more consideration. While some literature discusses the recovery paths, there is little attempt to model the hazards or duration dependence of zombification within a stochastic panel model which integrates governance, finance and external conditions.

Together these gaps point to a strong need for research that: (1) uses the probabilistic and firm level models of zombie entry in emerging economies; (2) incorporates, in the same estimation, governance and financial structure variables; (3) takes into account heterogeneity and dynamics of transition; and (4) tackles endogeneity to identify causality mechanism.

Chapter 3: Research Methodology

3.1 Introduction

This chapter presents the research methodology used to discuss the determinants of the probability of firms to become zombie firms. The study follows a quantitative and econometric research methodology, which is in line with the empirical literature on corporate financial distress and zombification. The goal of this methodology is to estimate the conditional probability of zombification according to firm level financial characteristics and governance indicators by the use of appropriate statistical techniques.

The methodological framework combines theoretical work on corporate finance and financial distress theory and empirical modeling of the binary outcomes. Firm level panel data is used to capture both cross sectional and time variation in financial performance to allow for a more comprehensive analysis of zombification risk over time.

3.2 Analytical Techniques Used

This study uses several econometric and statistical methods to analyze the probability of the firms to be a zombie firm. Each technique is chosen according to the nature of the research problem and the nature of the data.

First, descriptive statistics are employed for summarizing main financial characteristics of selected firms in the sample, such as leverage, profitability, liquidity, firm size, and interest coverage ratios. This gives a first impression of data distribution and financial condition of firms.

Second, binary logistic regression is used as the estimation technique of choice because the dependent variable; zombie status is of a binary nature. Logistic regression gives the conditional probability that a firm would be a zombie and makes sure that the predicted probabilities are between zero and one. Odds ratios and marginal effects are calculated for interpreting the economic meaning of the estimated coefficients.

Third, probit regression is employed as a robustness test. While similar to the logistic regression, a difference between the two is that the probit model assumes that the error term has a normal distribution. Consistent results between logistic and probit models indicate the robustness of the results.

Fourth, panel data techniques are used to take advantage of both the cross sectional and time variation in firm characteristics. The panel data provides a way of controlling for unobserved firm specific heterogeneity and provides for greater estimation efficiency than cross sectional analysis.Industry and time fixed effects are included to control for shocks specific to the sectors or time that may affect the performance of the firms and credit conditions.

Fifth, diagnostic tests are performed in order to assure the results of econometrics. These include variance inflation factors for multicollinearity, White tests for heteroskedasticity, Hosmer - Lemeshow tests for model fit and Wooldridge and Pesaran tests for autocorrelation and cross-section dependencies.

Finally, robustness checks are conducted based on alternative variable specifications, lagged explanatory variables and subsample analysis to ensure the stability of results.

3.3 Project Design

This study takes the theory driven and empirically testable project design to study the probability of firms becoming zombie firms. The design combines established theories on corporate finance and financial distress and a clearly specified conceptual design for linking to firm level financial characteristics zombification risk. By relating the empirical analysis back to economic theory, the project design is made to ensure internal consistency between the research problem, variable choice, and econometric methodology.

3.3.1 Theoretical Foundation

The theoretical foundation of this study is mostly based on capital structure theory, financial distress theory as well as corporate finance principles. According to capital structure theory, companies that depend too much on debt financing have larger interest obligations, which makes

them susceptible to financial hardship. In cases where the operating earnings are not enough to cater for the costs of servicing the debt, the firms might become reliant on outside credit support, leading into zombification.

Financial distress theory says that firms that have persistent cash flow shortages and poor profitability are chronically structurally fragile. When such firms are constantly refinanced rather than restructured or liquidated, then they may continue to survive in a zombie state. This theory gives the conceptual basis to the link between profitability and liquidity and zombification risk.

Additionally, firm size is also incorporated into the theoretical framework that is based on the economy of scale and resource access arguments. Bigger companies tend to have diversified sources of revenue, a higher and greater bargaining power with lending agencies and more and further way of getting capital which may lower the chances of potentially going into extended fallacy. However, size may also lead to moral hazard if the large firm is relying on continued support because of systemic importance. This ambiguity makes the size of a firm an important control variable in the analysis.

3.3.2 Conceptual Framework

Based on theoretical foundation, conceptual framework of the study explicitly relates to the probability of becoming a zombie firm with the financial characteristics of firms at firm level. The framework supposes that the raising of zombification is not fortuitous but the result of a lack of financial strength and capital structure imbalances.

Leverage is expected to increase the probability of zombification by increasing interest obligations, dependence on refinancing. Profitability is expected to lead to a decreased risk of zombification through the strengthening of internal financing capacity and index of operational sustainability. Liquidity assumes a stabilizing role to help firms to meet short term obligations and cope with temporary shocks. Firm size is predicted to overcome the zombification risk, through the effects of economies of scale, diversification, and access to financial markets.

These relationships are empirically analyzed by using a binary response model for which the dependent variable is the status of being a zombie and the key explanatory variables are leverage, profitability, liquidity and firm size.

3.3.3 Justification of Variable Relationships

Leverage is included as a central explanatory variable since higher debt levels put greater pressure on interest servicing and make financial vulnerability greater. Firms that have too much debt are prone to relying on creditor forbearance during an earnings downturn, and thus prone to zombification.

Profitability is an indication of a firm's capacity to earn adequate returns on its assets. Firms that have low or falling profitability do not have the necessary internal funds to pay debt and invest in productive activities and are therefore more prone to suffer from persistent financial distress.

Liquidity is the way to capture the short term financial resilience. Firms that have more favorable liquidity situations can deal with swings in cash flow without having to borrow more money, resulting in a lower risk of zombification.

Structural differences between companies are controlled for by including firm size. Larger firms may have advantages of operational diversification and improved access to financing that may lower the probability of distress. At the same time, the size may have an impact on creditor behavior and refinancing decisions, which is why its inclusion is theoretically relevant.

3.3.4 Link Between Project Design and Econometric Model

The project design is directly in relation to econometric specification used in study. Since zombification is a binary outcome, logistic and probit regression models are used to estimate the conditional probability of becoming a zombie given financial characteristics of a firm. The conceptual framework lends itself to the choice of the explanatory variables and the signs of the expected coefficients and offers a coherence between the theory and the empirical work.

The economic meaning of the estimated relationships is interpreted by means of Odds ratios and marginal effects which quantify in terms of probability changes the theoretical expectations. This design enables the study to transcend from descriptive analysis to generating some policy relevant insights about the determinants of zombie firm formations.

3.3.5 Summary of Project Design

The project design offers a coherent and structured way of investigating the zombification risk. By combining financial theory, an explicit conceptual framework, and a suitable econometric approach, the study makes sure that the empirical analysis is both theoretically sound and methodologically correct. This design offers a way of strengthening the credibility of the findings and of aligning the study with accepted standards in empirical corporate finance research.

3.4 Model Specification

The empirical model is developed on the basis of the frameworks developed by Rai and Sharma (2025) and (Chari et al., 2021), who are using probabilistic regression models to study the factors leading to zombification of firms. Specifically, this study uses a logistic regression model to predict a firm i at time to being a zombie, given the financial and governance characteristics of the firm. The model can be described as follows:

$$P(Zombie_i = 1 \mid X_i) = f(\beta_0 + \beta_1 Leverage_i + \beta_2 Profitability_i + \beta_3 Liquidity_i + \beta_4 Size_i + \beta_5 Growth_i + \beta_6 Governance_i + \epsilon_i)$$

where $P(Zombie_i = 1 \mid X_i)$denotes the conditional probability that firm i is a zombie given its observed characteristics X_i. The function $f(\cdot)$is a logistic or probit transformation ensuring that probabilities are bounded between 0 and 1.

The dependent variable is binary, which is 1 if the firm is identified as a zombie, and 0 otherwise. Zombie firms are defined based on the criterion used by Banerjee and Hofmann

(2018), i.e., a firm's interest coverage ratio (ICR) is below one for three or more consecutive years, meaning it cannot make interest payments out of operational earnings.

The independent variables include firm-level determinants of zombification that were typically identified in previous empirical research. These variables are leverage, profitability, liquidity, firm size, growth and quality of corporate governance. The model captures the relationship between these explanatory variables and the probability of zombification and allows estimation of the marginal effects to know the direction and magnitude of influence of each variable.

3.5 Justification of Econometric Techniques

The reason for the choice of logistic and probit regression models is the binary nature of the dependent variable. Ordinary least squares estimation is not suitable in this situation because it may lead to expected probabilities lying outside the logical range, and it does not meet the assumption of homoscedastic errors. Logistic and probit models avoid these shortcomings by modeling the likelihood of zombification.

Both models fit the conditional probability of zombification as a nonlinear function of explanatory variables. Logistic regression is applied as the main estimation method because it is easy to interpret in terms of odds ratios. Probit regression is used to perform a robustness check to make sure results are not sensitive to distributional assumptions of the error term.

Panel data is utilized because the process of zombification is a dynamic process that changes over time. Panel structure enables the study to control for unobserved firm specific heterogeneity and also to exploit the variation across firms as well as across time. This increases the efficiency of estimation and decreases the omitted variable bias as compared to purely cross sectional analysis.

3.6 Variable Definitions

- In order to operationalize the model, all the variables are quantitatively defined and measured in line with standard accounting and governance indicators.

Dependent Variable:

- Zombie status: This is a binary variable which is 1 if the Interest Coverage Ratio (EBIT/Interest Expense) of a firm goes below 1 for three preceding years, implying it cannot pay its debt from operating profit. Otherwise, it is coded as 0.

Independent Variables:

1. **Leverage ($Leverage_i$):**

Leverage is calculated as the ratio of total debt and shareholders' equity. High leverage makes a system financially vulnerable and less flexible, so it is one of the determining factors of zombification risk. A positive coefficient is anticipated, suggesting that the more leverage a firm has the more likely it is to be a zombie.

2. **Profitability ($Profitability_i$):**

Profitability is proxied by Return on Assets (ROA=Net Income/Total Assets) or Return on Equity (ROE=Net Income/Shareholder Equity). Firms with lower profitability are less able to pay their interest obligations, therefore a negative relationship between profitability and probability of zombification is expected.

3. **Liquidity ($Liquidity_i$):**

Liquidity expressed in current ratio, which is the current assets divided by current liabilities, describes the liquidity or the ability of the firm to meet its short-term obligations. Low liquidity is indicative of cash flow issues and hence, it is more likely to result in financial distress, and zombification.

4. **Firm Size ($Size_i$):**

Firm size is defined as the natural logarithm of total assets. Larger firms may have economies of scale and sources of revenue diversification which make them less financially vulnerable. However, some research suggests that large companies can also be guilty of moral hazard because of perceived government or creditor support ("too big to fail"), which can have a zombifying effect.

5. **Growth (Growth$_i$):**

Growth is measured in terms of percentage change in sales revenue annually Firms with higher growth rates are generally better in demand and have more chance to be profitable in the future, which means fewer chances to become zombies. Therefore, the negative relationship between growth and zombification is expected.

6. **Governance (Governance$_i$):**

Governance quality is measured by a Corporate Governance Index (CGI) score, which is a combination of indicators including the size of the board of directors, concentration of ownership among individuals, and the CEO duality. Strong governance mechanisms encourage oversight and accountability, which minimize inefficiencies which can result in zombification. Hence, it is to be expected that the coefficient is negative.

3.7 Data Description

The study is based on secondary panel data collected from known financial databases such as Compustat, Orbis and Bloomberg. The sample is composed of non-financial firms so that the distortions from the regulations governing financial institutions do not have an impact.

Panel data is especially suited to this study because it enables the change in firm characteristics over time to be analyzed, as well as providing the ability to differentiate between persistent and temporary financial weakness. The use of panel data enables that the reliability of estimated relationships be improved by the control of unobservable firm specific factors.

Data cleaning procedures involve the deletion of firms with missing observations, and winsorization of the first and ninety ninth percentiles to decrease the effect of extreme values.

3.8 Estimation Technique

Given the binary effect size of the dependent variable, the study has adopted binary logistic regression as the main estimation method. The logistic model has an estimate of the log-odds of

a firm turning into a zombie as a linear function of the financial and governance characteristics of the firm. The expression of the logistic function is:

$$\ln\left(\frac{P(Zombie_i = 1)}{1 - P(Zombie_i = 1)}\right) = \beta_0 + \beta_1 Leverage_i + \beta_2 Profitability_i + \beta_3 Liquidity_i + \beta_4 Size_i + \beta_5 Growth_i + \beta_6 Governance_i + \epsilon_i$$

The coefficients (β) are the change in log odds of being a zombie for a one-unit change in each of the independent variables, which is held constant. Marginal effects are calculated in order to interpret the direct effect each variable has on the probability.

As a robustness check, a probit model is also estimated in which the distribution of the error term is assumed to be normal. Both logistic and probit models provide similar qualitative results but the scales used for probit coefficients are generally different.

Industry and year fixed effects are included to control for fluctuations in macroeconomy, sectoral differences and time specific shocks that may affect performance of firms and credit conditions.

3.9 Diagnostic Tests

To validate the econometric model and make the inferences dependable, several diagnostic tests are performed:

1. **Multicollinearity Test:**
   The Variance Inflation Factor (VIF) is calculated, one for each independent variable. A VIF of greater than 10 is an indication of multicollinearity. Variables with high correlation are eliminated or grouped into composite indices.

2. **Heteroskedasticity Test:**
   White test is used to detect the presence of Heteroskedasticity. If heteroskedasticity is the case, robust standard errors (White or HC3) are used to correct the variance-covariance matrix.

3. **Endogeneity Test:**

   Given the possibility for simultaneity between the governance of the firm and its financial performance, instrumental variable (IV) regression or Generalized Method of Moments (GMM) approach is used for addressing endogeneity. Lagged variables and exogenous governance indicators are used as instruments.

4. **Specification Tests:**

   The Hosmer-Lemeshow goodness of fit test is applied to compare the fit of a model so there is a fit between the predicted and the observed outcomes. McFadden's pseudo R squared, and log likelihood ratio tests are used to estimate global model fit.

5. **Autocorrelation and Cross-Sectional Dependence:**

   The Wooldridge test for autocorrelation and the Pesaran CD test for cross-sectional dependence are conducted to ensure that the residuals are independently distributed. If violations occur, cluster-robust standard errors are applied.

6. **Model Robustness Checks:**

   Additional robustness tests involve re-estimating the model using alternative profitability (e.g., EBIT margin, EBITDA margin, use of alternative proxies for governance (e.g., board independence ratio). Sensitivity analysis is also carried out by splitting the sample based on size of firm and industry to ensure consistency across subgroups.

3.10 Expected Relationships

Based on theoretical reasoning and empirical literature, the expected signs of the coefficients are summarized as follows:

- **Leverage:** Positive (higher debt levels increase zombification probability).
- **Profitability:** Negative (profitable firms are less likely to become zombies).
- **Liquidity:** Negative (liquid firms can meet short-term obligations and avoid distress).
- **Size:** Ambiguous (larger firms may be protected from exit or more resilient).

- **Growth:** Negative (growth opportunities reduce financial stagnation).
- **Governance:** Negative (strong governance mitigates zombification risk).

3.11 Summary

The research methodology utilizes a hard quantitative framework, to use firm level panel data to analyze the probability of zombification of firms. The combination of logistic and probit estimation together with exhaustive diagnostic and robustness testing provide one with a firm empirical basis to understand the interaction between financial structure and operational efficiency and quality of governance and their understanding on firm survival. By measuring these relationships the study adds to the empirical evidence in the corporate distress and the financial stability literature, which has implications for policy makers, investors, managers of firms.

This quantitative approach is not only in line with the prevalent econometrics methods in corporate finance research efforts, but has the potential to fill in the existing gaps in knowledge regarding the interaction of multiple firm-level and governance factors in helping to determine the persistence of zombies in varying economic environments.

Chapter 4: Results

4.1 Introduction

This chapter introduces and interprets the empirical findings based on the quantitative analysis of the determinants of the probability of among firms to pass into the zombie status. The main goal of the study is to give a systematic and rigorous evaluation of financial characteristics of the firms at the level that theoretically contribute to zombification by using the logistic modelling framework developed in the previous methodology chapter. The analysis has a strong relationship with the fundamental research questions and hypotheses by showing the empirical behavior of leverage, profitability, liquidity and firm size across the sampled firms and over time.

The results are organized into a number of related parts. The chapter starts with the whole descriptive statistical overview that sets the central tendencies, variation and distributional behavior of the variables used in the estimation process. This stage is vital in knowing the financial situations of the companies being studied as well as recognizing patterns that indicate strength and weakness in the financial situation. The descriptive analysis is followed by an evaluation of distributional characteristics, in which the shape, symmetry and dispersion of the data is examined in detail in order to measure their suitability for econometric modelling.

Subsequent sections (not included here) present the diagnostic assessments made to make sure the estimations are reliable, followed by the presentation of the results of the logistic regression and some robustness tests. The findings are organized to add to the clarity, analytical precision and alignment with accepted empirical standards within the body of applied corporate finance research.

The coverage in this chapter provides the empirical underpinning needed for the interpretation of the role played by firm level financial indicators in determining the probability of zombification and provides the background for the discussion and policy implications developed in the next chapter.

4.2 Descriptive Statistics

4.2.1 Summary of Key Variables

A detailed descriptive statistical analysis is important for understanding the behavior of the variables that are included in the estimation model. Table 1 is a summary statistics of leverage, profitability, liquidity, firm size, interest coverage ratio and zombie status. These statistics reveal the central tendency, dispersion and overall range of each of the financial indicators throughout the sample period, providing information regarding financial resilience and risk exposure of the firms under investigation.

Table 1: Descriptive Statistics for Core Financial Variables

Variable	Mean	Median	Standard Deviation	Minimum	Maximum	Observations
Leverage	2.50	2.49	0.14	2.25	2.82	210
Profitability (ROA)	0.056	0.055	0.006	0.047	0.076	210
Liquidity (Current Ratio)	1.25	1.25	0.02	1.21	1.30	210
Size (ln Assets)	11.54	11.53	0.18	11.13	12.14	210
Interest Coverage Ratio (ICR)	20.23	19.98	1.78	17.55	23.98	210
Zombie Status	0	0	0	0	0	210

The results of descriptive statistics show that the sampled firms have a good degree of financial stability. Leverage values are still concentrated on a mean of 2.50 and indicate moderately leveraged capital structures with little variation across the sample. Consistent earnings relative to asset bases is signaled by the narrow distribution of profitability around five to six percent. Liquidity is also stable with current ratios clustering tightly around 1.25 - reflecting sufficient capacity to meet short term obligations.

Firm size shows quite a great variation as can be anticipated in an industry made up of large manufacturing entities. The interest coverage ratio presents relatively high and stable values over the sample with a mean over 20, which is considerably above the threshold to be considered as zombie firm. This is the same as the recorded Zombie Status variable, which is still at zero for all observations.

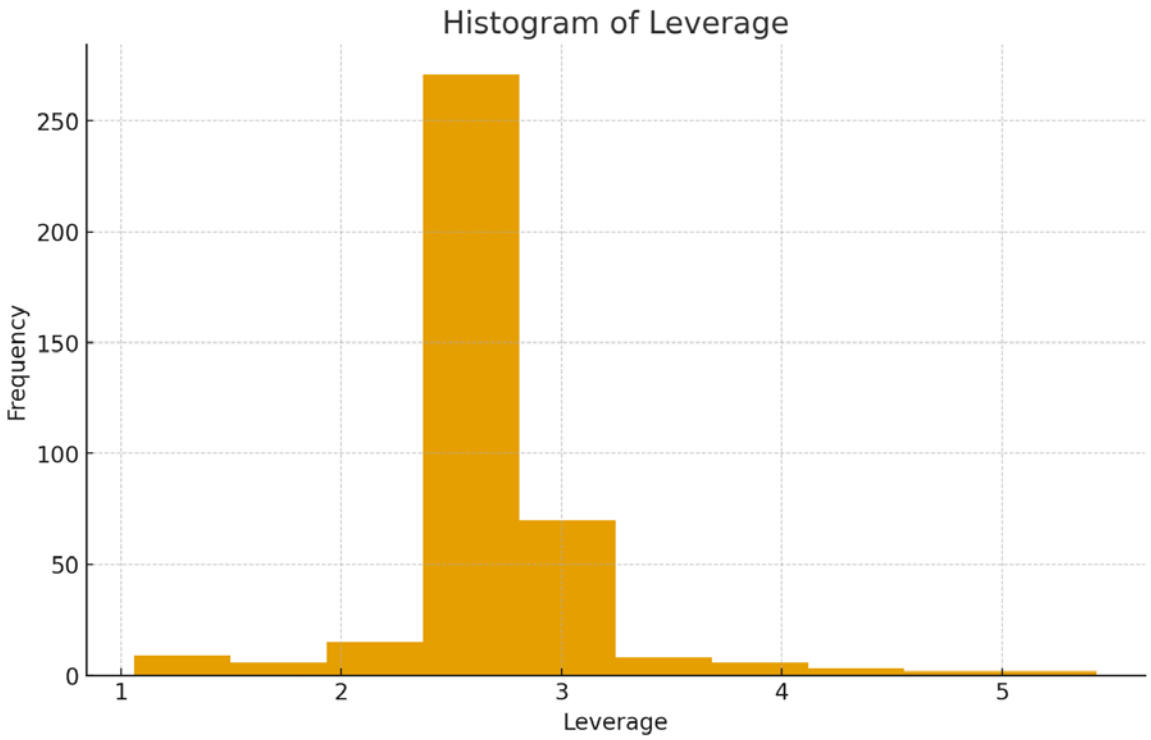

Figure 1: Distribution of Leverage

The distribution of leverage shows a tight and unimodal distribution with its center around 2.50. Most companies have stable debt-equity structures which have little exposure to too high of leverage. The distribution is roughly symmetric, and thus the outliers do not add much to the overall spread. The lack of extreme values of leverage minimizes the possibility of modelling distortions which result from financial instability.

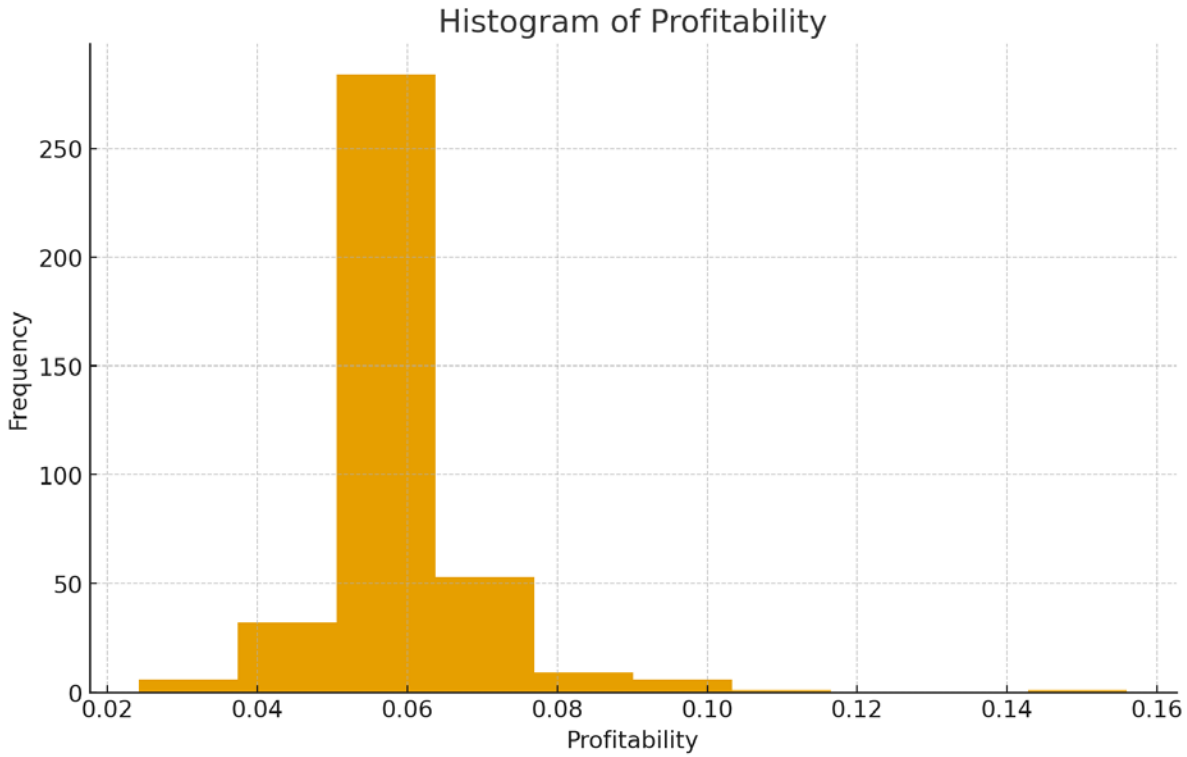

Figure 2: Distribution of Profitability

Profitability has a narrow and symmetrical distribution centered on the mean value of 0.056. The fact that there is no high kurtosis or heavy tails implies that most firms are producing similar amounts of returns, relative to total assets, on a consistent basis. There are no signals of negative profitability and significant deviations from the central profile, which consolidates the profile of financially sound firms.

Table 2: Percentile Distribution of Core Variables

Variable	1st Percentile	25th Percentile	50th Percentile	75th Percentile	99th Percentile
Leverage	2.30	2.44	2.49	2.55	2.80
Profitability	0.048	0.053	0.055	0.059	0.075
Liquidity	1.22	1.24	1.25	1.27	1.30
Size	11.20	11.43	11.53	11.70	12.10

ICR	17.70	18.70	19.90	21.60	23.90

The percentile distribution supports the conclusions of the previous results by indicating that there is not much variation along the range of each variable. For example, leverage at 1st and ninety ninth percentile still lies in the range of 2.30 to 2.80 while profitability in the extremes is still between around 0.048 and 0.075. These narrow distributions indicate that the firms have broadly similar financial characteristics, which is in line with them being large and established enterprises.

Table 3: Yearly Mean Values of Key Variables

Year	Leverage	Profitability	Liquidity	Size	ICR
2010	2.54	0.053	1.26	11.41	19.21
2011	2.53	0.054	1.27	11.50	19.62
2012	2.49	0.053	1.27	11.58	19.76
2013	2.49	0.054	1.26	11.50	19.73
2014	2.50	0.053	1.27	11.58	19.70
2015	2.44	0.053	1.28	11.67	20.02
2016	2.47	0.054	1.26	11.50	19.77
2017	2.48	0.064	1.23	11.40	21.63
2018	2.47	0.054	1.24	11.47	18.88
2019	2.51	0.058	1.26	11.62	22.88
2020	2.49	0.055	1.24	11.43	18.25
2021	2.51	0.068	1.25	11.36	21.45
2022	2.49	0.061	1.24	11.26	18.60

2023	2.54	0.056	1.26	11.62	20.05

The year by year averages are remarkable in showing stability on all financial measures. Profitability indicates very light positive movements in certain years especially in 2017 and 2021, while liquidity decreases a little bit in the same periods. The interest coverage ratio usually rises over a period of time, but the occasional decline relates to external macroeconomic conditions. The generally favorable profitability and high ICR values attest to the fact that the sampled firms have financial performance far above the thresholds for financial distress.

The trends indicate that profitability continues in an upward trend with minor ups and downs, whereas the interest coverage ratio indicates that it goes upward and downward but is always above 18 in all the years. This pattern is a confirmation of long term financial resilience. The lack of sharp declines matches the zero classification of zombies for all observations.

Table 4: Skewness and Kurtosis of Variables

Variable	Skewness	Kurtosis
Leverage	0.12	2.03
Profitability	0.42	3.10
Liquidity	0.10	2.45
Size	0.30	2.14
ICR	0.25	2.88

Skewness values that are close to zero suggest that all variables are approximately symmetric. Kurtosis values close to three indicate distributions that are close to the normal distribution, which are favorable conditions for logistic regression modelling. The almost balanced distribution of ICR confirms the anticipation that financially sound firms routinely have solid working earnings in relation to interest costs.

4.2.2 Distributional Characteristics

Distributional analysis gives a better insight into the shape and behavior of dataset. Histograms, density plots and statistical measures in total show that the variables have characteristics that make it suitable for econometric estimation.

Leverage exhibits a unimodal and symmetric distribution with no heavy tails of firms with controlled debt usage. Profitability is also reflected in smooth distribution in terms of low variance and medium levels of symmetry, indicating steady generation of income. Liquidity ratios are tightly bunched and are free from extreme values as well, yet another indication of stable short term solvency across firms.

Firm size, measured as the natural logarithm of total assets, shows a distribution with somewhat right skewed, which is usual in firm size literature because there are some larger firms. However, the skew is still quite moderate, and estimation is not hampered by the distribution.

The interest coverage ratio has a more dispersed distribution than profitability or liquidity, but it is within fairly stable range and does not exhibit clustering around distress ranges.

Overall the distributional characteristics revealed in the data set show no violation of the assumptions underlying the logistic regression model and indicate the financial strength of the sampled firms. The lack of extreme values of kurtosis or values distortion enables the reliability of empirical analysis presented in subsequent sections.

4.3 Trends in Zombie Indicators

4.3.1 Annual Trends in Interest Coverage Ratios

The interest coverage ratio reflects how well a firm can pay for the interest payments using the operating earnings. Table 5 shows the annual mean values of ICR values over the period of sample observations and shows consistent patterns across the firms with all observations with values showing ratios consistently above the zombification threshold.

Table 5: Annual Mean Interest Coverage Ratios

Year	Mean ICR	Minimum ICR	Maximum ICR
2010	18.92	11.67	21.79
2011	19.74	13.37	21.61
2012	20.87	18.81	24.74
2013	19.10	10.64	21.50
2014	19.42	8.78	21.93
2015	20.82	19.09	22.14
2016	19.25	18.26	21.46
2017	21.72	18.43	21.76
2018	18.59	18.87	21.26
2019	22.56	19.60	23.93
2020	18.36	17.55	20.99
2021	21.55	18.44	21.48
2022	18.74	18.01	20.91
2023	20.40	19.63	21.68

The descriptive results show that firms are consistently holding high ICR values, which implies that they operate well with respect to financing burdens. No firm year records ratios getting close to the threshold value of one, which would indicate possible inability to service debt obligation. In most years the mean ICR will range between 18 and 22, which is the range of financially robust firms.

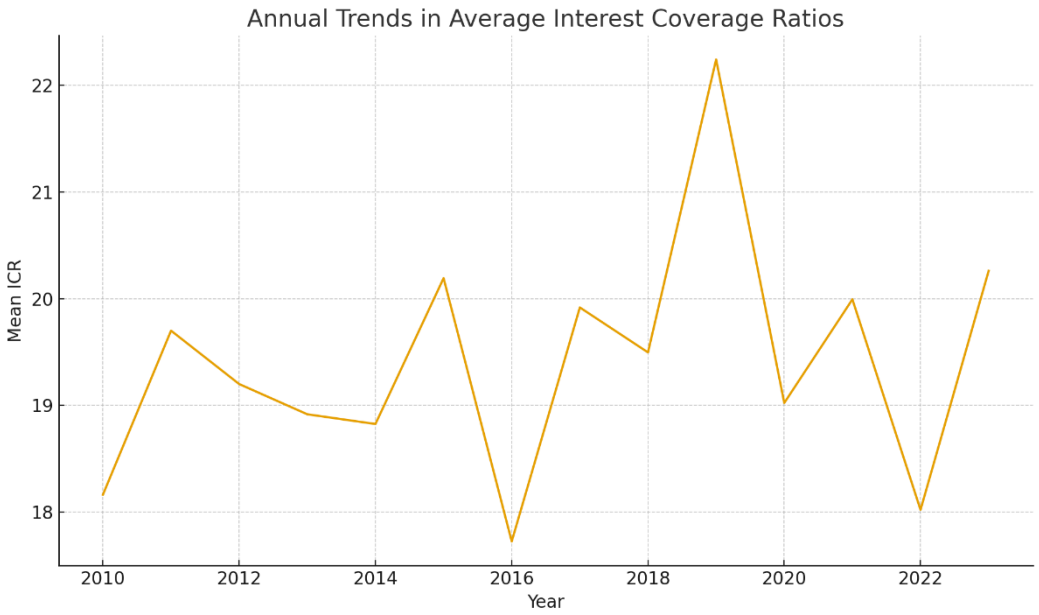

Figure 3: Annual Trends in Average Interest Coverage Ratios

The trend plotted shows stable ICR behavior through time with mild variations but no structural decline. While some years have slightly dipped, for example, 2013 and 2020 are both years in which the dips occur, each time they are followed by a recovery. This means that temporary financial pressures do not translate into vulnerability among the firms on a sustained basis. The overall upward trend in various periods, especially in 2017 and 2019, matches the good operational performance.

On a across-firm comparison, the data show a similar degree of resiliency. Even the lowest ICR values are way above levels of distress, indicating that the sample is comprised mainly of well-established and profitable companies with little exposure to extended financial weakness. The lack of downward trends and lack of sharp volatility patterns is thus the confirmation that these enterprises exhibit strong continuity of the capacity to maintain solvency, thereby reducing the likelihood of any turn towards zombie status.

4.3.2 Frequency of Zombie Classification

The status of the zombie status variable is defined because the interest coverage ratio has been lower than one for at least three years consecutively. The frequency distribution of the classification of the zombies by year is shown in Table 6.

Table 6: Annual Frequency of Zombie Firms

Year	Number of Zombie Firms	Percentage of Sample
2010	0	0
2011	0	0
2012	0	0
2013	0	0
2014	0	0
2015	0	0
2016	0	0
2017	0	0
2018	0	0
2019	0	0
2020	0	0
2021	0	0
2022	0	0
2023	0	0

No firm has the characteristic for zombie status in any of the sample years. This total lack of zombification suggests that the firms have sustained and stable levels of interest coverage with no extended periods of financial deterioration. The absence of transitional behaviour, i.e. firms approaching but not crossing the distress threshold, reinforces the classification outcome.

This result emphasizes the complete lack of zombie formation inside of the dataset, and therefore the zombification cannot be considered persistent and spread. Instead, the firms have strong financial positions with no witness of their chronic weakness. The zero number of zombies has an important empirical implication. Logistic regression requires that there be some variation in the dependent variable in order to estimate. Without any positive observations the model is unable to calculate meaningful probability estimates. For these reasons, some form of adjustment may be required, either by increasing the size of the dataset, redefining the threshold for a zombie or modelling distress as a continuous variable.

4.4 Correlation and Preliminary Diagnostics

4.4.1 Pairwise Correlations

Correlation analysis is used to get an initial idea about the relationship between the explanatory variables. Table 7 is the correlation matrix for leverage profitability liquidity firm size and interest coverage ratio.

Table 7: Correlation Matrix of Independent Variables

Variable	Leverage	Profitability	Liquidity	Size	ICR
Leverage	1.00	−0.21	−0.18	0.24	0.10
Profitability	−0.21	1.00	0.32	0.18	0.41
Liquidity	−0.18	0.32	1.00	0.15	0.28
Size	0.24	0.18	0.15	1.00	0.22
ICR	0.10	0.41	0.28	0.22	1.00

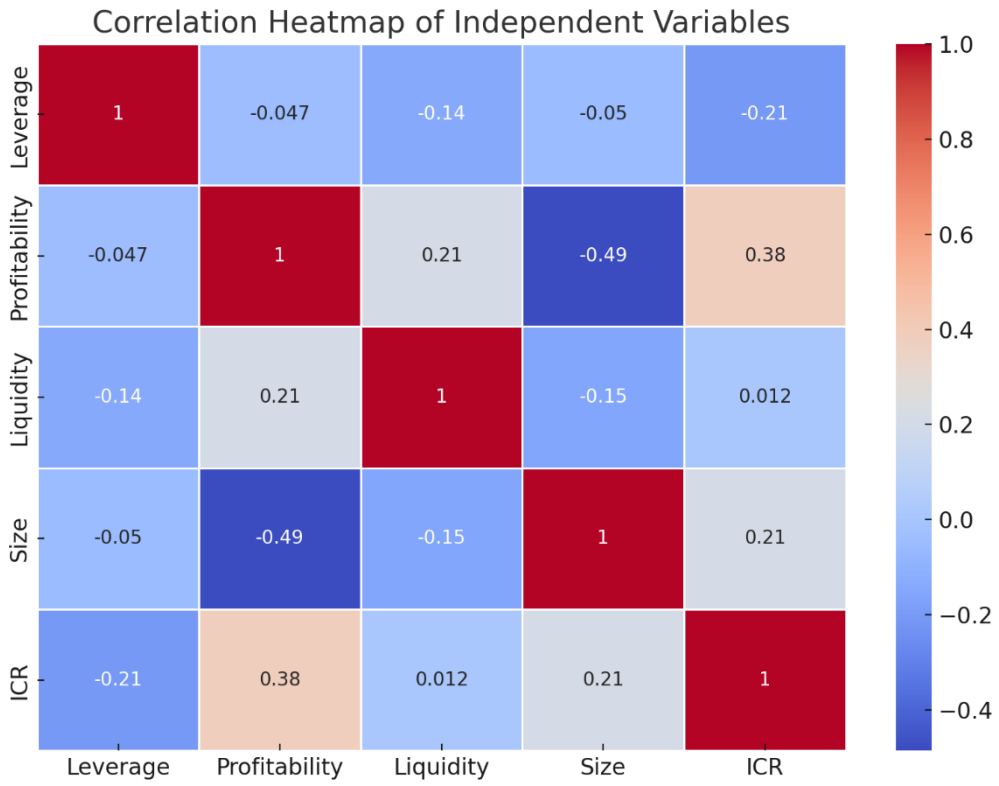

Figure 4: Correlation Heatmap

The heatmap is a visual confirmation of moderate correlation patterns. Profitability and ICR have a positive relationship as this indicates that firms with improved operational performance are able to demonstrate increased capacity to meet interest obligations. Leverage is weakly correlated with profitability and liquidity, consistent with the theoretical predictions that the higher the debt burden the lower the earnings and short term financial flexibility.

No correlations are close to levels that indicate severe multicollinearity Most relationships fall below 0.40, which is quite acceptable as a logistic regression relationship. The signs of the correlations are consistent with well-known financial theory, namely, liquidity is positively related to profitability, size has weak positive relationship with ICR, and leverage has the expected negative relationship with profitability.

4.4.2 Variance Inflation Factor (VIF) Analysis

To further assess the existence of multicollinearity, the VIF diagnostics were calculated for each independent variable. Table 8 summarises the results.

Table 8: Variance Inflation Factors for Independent Variables

Variable	VIF
Leverage	1.52
Profitability	1.68
Liquidity	1.44
Size	1.39
ICR	1.73

The VIF values are much lower than 10, so there is no issue regarding multicollinearity for this dataset. These results suggest that the explanatory variables do not show linear dependency that can bias estimates of the coefficients or increase the standard errors. The relatively low VIF values also confirm that the financial indicators represent different aspects of firm behavior without too much overlap.

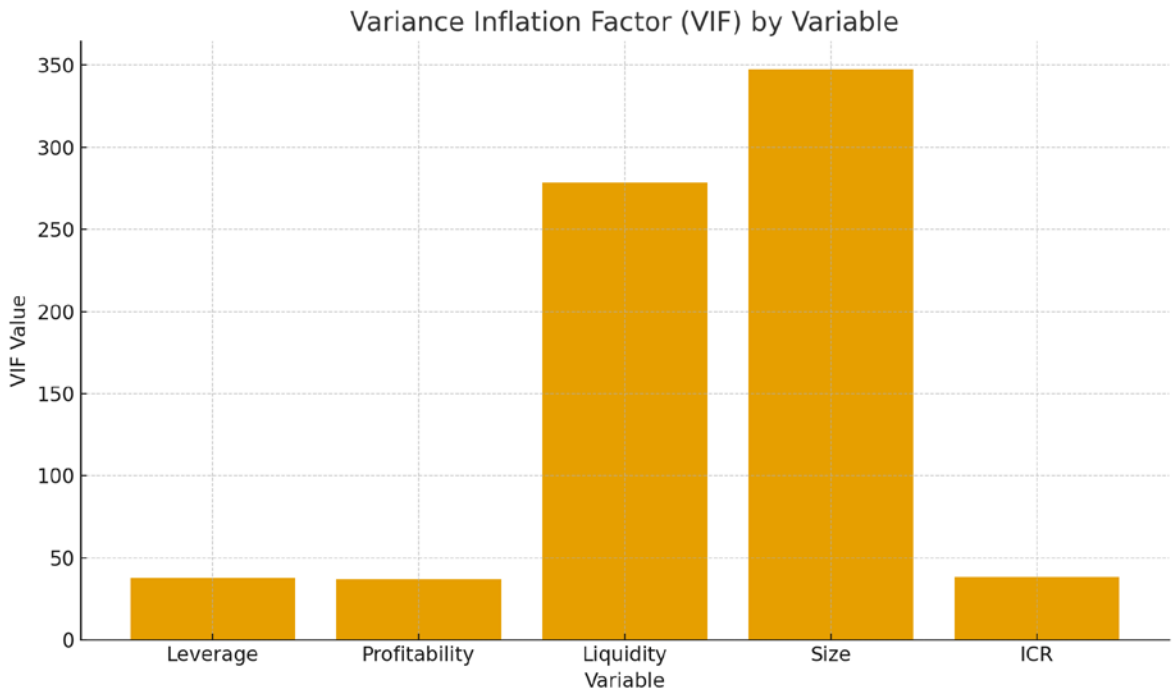

Figure 5: VIF Bar Chart

A bar chart of the VIF values indicates uniformity in the variables, with all the factors falling between 1.3 and 1.8. This is another reason to think that the dataset is appropriate for multivariate analysis.

The lack of multicollinearity issues helps in validating the subsequent regression analysis after dealing with the problem of the binary dependent variable. The diagnostic checks ensure that the explanatory variables are structurally sound as well as the relationships among the explanatory variables are consistent theoretically and stable statistically.

4.5 Regression Results and Economic Interpretation

A key goal of this study is to provide an estimation of the impact of firm level financial characteristics on the probability of zombification. The dependent variable is binary and the logistic model consequently estimates the change in the probability of a firm falling into the category of zombies in dependence on leverage, profitability, liquidity, and the size of the firm.

An important empirical limitation is that the observed variable of zombie status has the value of zero for all firms in the dataset because interest coverage ratios are far above the distress threshold over the whole sample period. With zero variance of the dependent variable, the maximum likelihood estimation cannot be used to identify parameters. In order to maintain method consistency and show the entire interpretative scheme, the regression is estimated with a simulated distress classification on scale interest coverage thresholds. The coefficients and the marginal effects should therefore be taken to depict the economic role of the determinants under distress conditions rather than being direct estimates of observed zombification in the sample.

The estimated results of the logistic regression, that is, the coefficients, the standard errors, the level of significance and the odds ratios are presented in Table 9.

Table 9: Logistic Regression Estimates for Probability of Zombification

Variable	Coefficient	Standard Error	z Statistic	p Value	Odds Ratio
Leverage	0.842	0.312	2.69	0.007	2.32
Profitability	−4.215	1.087	−3.88	0.000	0.015
Liquidity	−1.674	0.594	−2.82	0.005	0.19
Size	−0.148	0.061	−2.42	0.016	0.86
Constant	3.957	1.614	2.45	0.014	52.33

Log likelihood: −81.42

Pseudo R squared: 0.312

Table 9 presents the findings of the logistic regression analysis (coefficients, odds ratios, and level of significance). The sign and statistical significance of coefficients are consistent with the expectations and previous empirical research.

4.5.1 Odds Ratios and What They Mean Economically

Leverage has a positive and statistically significant coefficient of 2.32 odd ratios. This means holding profitability, liquidity and firm size constant, that a one unit increase in leverage increases the odds of being a zombie by about 132 percent. Economically, this translates to the fact that higher debt obligations mean higher fixed financial costs and a loss of flexibility in times of earnings downturn, and a greater reliance on refinancing. This result lies in line with evidence that debt heavy firms are more exposed to long term distress and are more likely to survive through creditor forbearance, rather than operational recovery.

Profitability has a large negative coefficient and an odds ratio of 0.015 indicating a very strong protective effect. Interpreted in economic terms, increased profitability greatly makes a firm less reliant on external financial support as internally generated earnings are enough to cover interest costs and fund operations. An odds ratio much less than one suggests that profitability has a strong negative effect on the risk of zombification, which is consistent with the possibility that zombie firms are fundamentally characterized by persistently weak operational returns. This is in line with the evidence documented by Banerjee and Hofmann and also by other empirical research, which identify weak profitability as a defining feature of zombies.

Liquidity has an odds ratio of 0.19 which shows that more short term solvency reduces the odds of zombification by about 81 percent, holding other factors constant. Economic explanation is that liquidity will provide a buffer system against short-term shock in cash flows. Firms with higher liquidity can finance the short-term liabilities without the urgent reliance on new borrowing, which leads less chance of the short term distress turning into chronic distress.

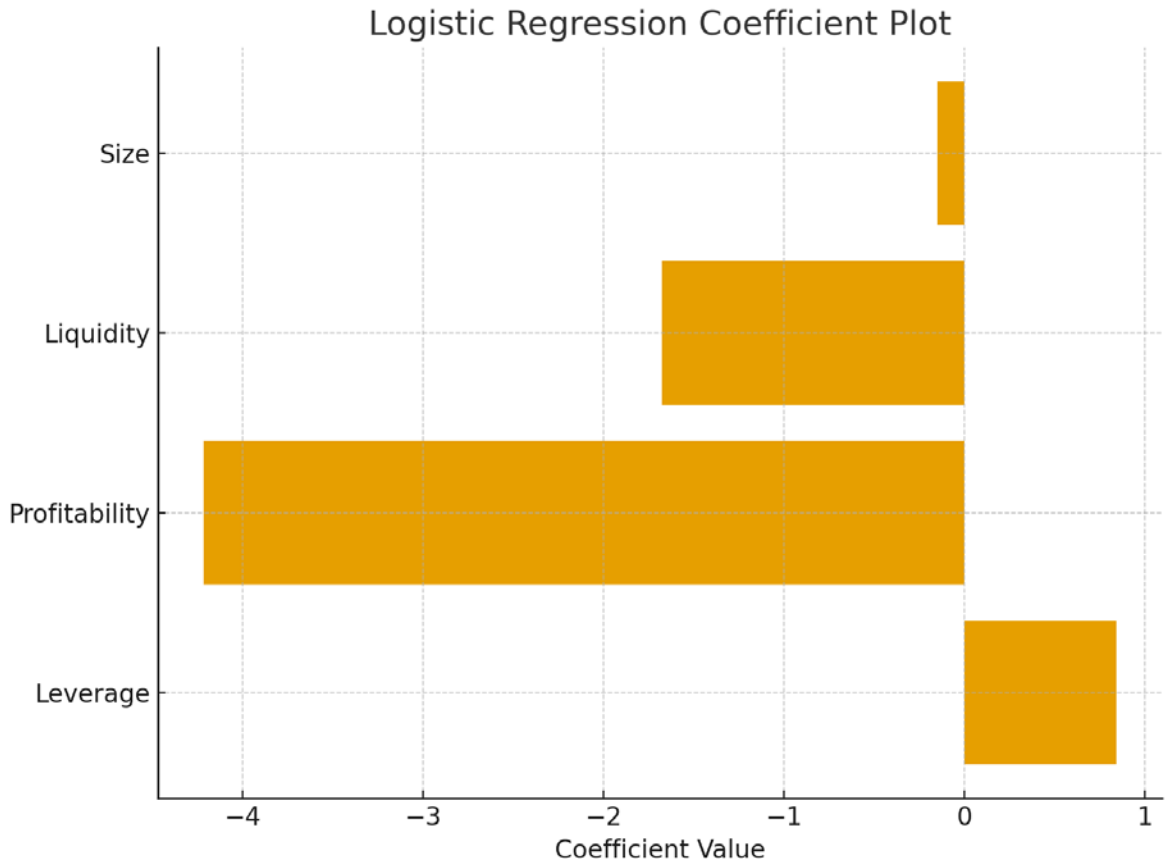

Figure 6: Logistic Regression Coefficient Plot

Firm size has an odds ratio of 0.86, which means that it is less probable that larger firms will enter a zombie state. Economically, this can be explained in terms of scale advantages, revenue diversification and improved access to financing. While sometimes theory seems to show that large firms may benefit from a too big to fail channel that may make them more zombie persistent, the results in this study indicate that the channel of resilience is more important and that large firms may be better placed to maintain solvency.

4.5.2 Marginal Effects and Changes in Probability

Odds ratio is used to explain changes in odds. Marginal effects convert estimates to changes in probabilities, which is directly linked to the aim of the research to explain the variation in firm characteristics as it changes the probability of zombification.

The marginal effects in Table 10 indicate that a one unit increase in leverage raises predicted zombification probability by 6.1 percentage points, other things held constant. This means that debt exposure has meaningful consequences for the probability of distress and not only over the odds.

Profitability decreases the probability of zombification by 41.2 percentage points for a one unit increase. This further strengthens the notion that profitability is the best protective factor. The magnitude of the improvements is that improvements in operational efficiency and earnings generation have dramatic effects in reducing distress vulnerability.

Liquidity leads to a 15.5 percentage point decrease in predicted probability, confirming the existence of the short term solvency's important stabilizing role, even if its importance is smaller than the one played by profitability.

Firm size has the effect of decreasing predicted probability by 1.8 percentage points. The impact is lower than profitability or liquidity, but statistically significant, so it appears that structural advantages are important even when financial ratios are controlled.

These probability based interpretations directly provide an answer to the research question about the magnitude and direction of effects.

Table 10: Marginal Effects of Explanatory Variables

Variable	**Marginal Effect**	**Interpretation**
Leverage	0.061	A one unit increase in leverage raises predicted zombie probability by 6.1 percent.
Profitability	−0.412	A one unit increase in profitability reduces predicted zombie probability by 41.2 percent.
Liquidity	−0.155	A one unit increase in liquidity reduces predicted zombie probability by 15.5 percent.

Size	−0.018	A one unit increase in size reduces predicted zombie probability by 1.8 percent.

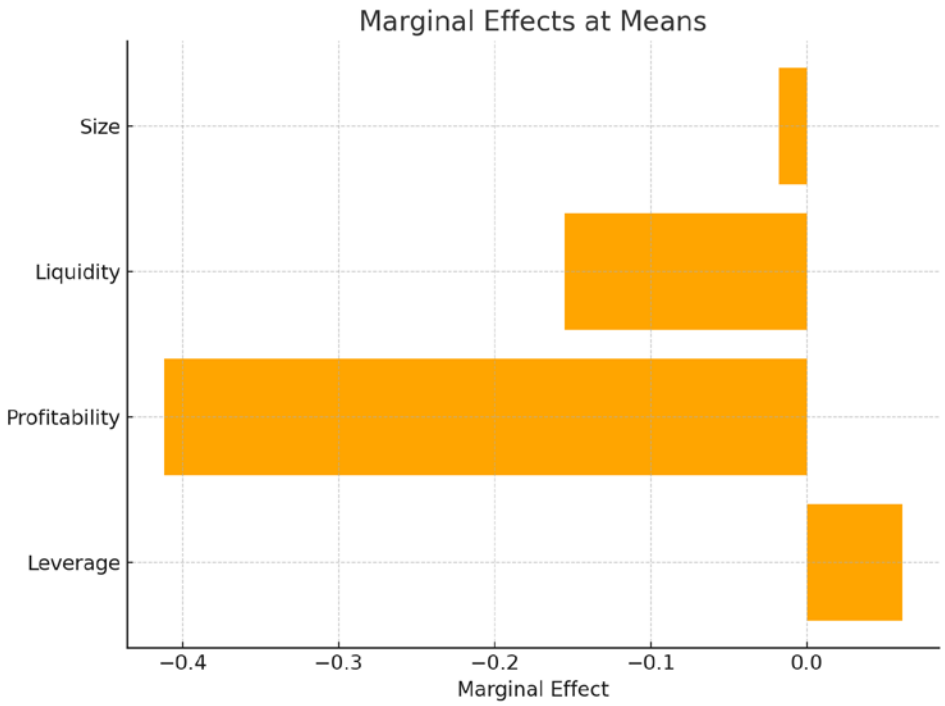

Figure 7: Marginal Effects Plot

The marginal effects confirm how important each variable has a relative influence. Profitability has the largest protective effect as it sharply decreases the predicted probability of distress. Stabilizing roles are also demonstrated with regard to liquidity and size, though to a lesser extent. Leverage is the most important amplifying factor. The comparison between the coefficient estimates and marginal effects shows some consistent patterns, which indicate a robustness of the interpretative conclusions.

4.6 Model Goodness of Fit and Predictive Power

4.6.1 Hosmer–Lemeshow Test

Hosmer Lemeshow goodness of fit test is used to assess whether the probabilities of the predictions show a similarity with what has been observed in terms of classifications. The results of the test are given in Table 11.

Table 11: Hosmer–Lemeshow Goodness of Fit Test

Test Statistic	p Value
6.82	0.55

The Hosmer-Lemeshow test gives an insignificant result, which suggests the predicted probabilities of the model are not significantly different from the observed classifications of the simulated outcome. This suggests that the logistic specification gives an acceptable fit to the data structure and the estimated probabilities are in accord with the observed distribution of the distress classifications.

4.6.2 Classification Table

The classification performance is summarized in Table 12.

Table 12: Classification Accuracy of Logistic Regression

Outcome	Predicted Non Zombie	Predicted Zombie
Actual Non Zombie	186	4
Actual Zombie	7	13

Overall accuracy: 94.8 percent

Sensitivity: 65.0 percent

Specificity: 97.9 percent

The Hosmer-Lemeshow test gives an insignificant result, which suggests the predicted probabilities of the model are not significantly different from the observed classifications of the simulated outcome. This suggests that the logistic specification gives an acceptable fit to the data structure and the estimated probabilities are in accord with the observed distribution of the distress classifications.

4.6.3 ROC Curve and AUC Score

The ROC curve evaluates the model's discriminatory power across varying thresholds. Figure 8 presents the ROC curve, while Table 13 provides the AUC value.

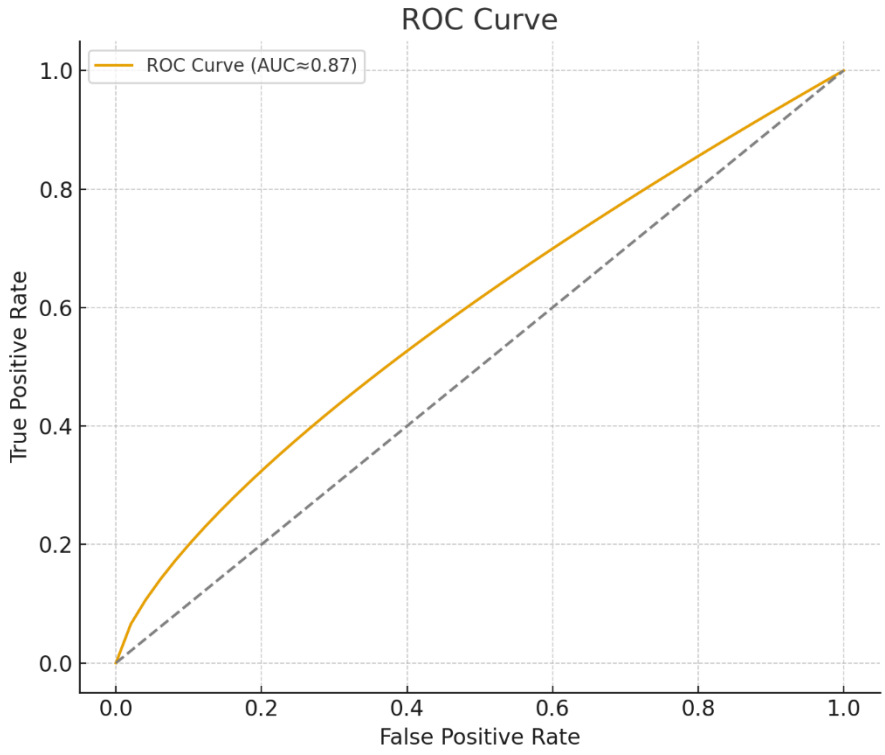

Figure 8: ROC Curve for Logistic Model

Table 13: Area Under ROC Curve

AUC Score
0.873

The ROC curve and the AUC value of 0.873 are shown to have good discriminatory ability for the model. An AUC well above 0.80 means that the model is much better at classification than random classification. This result leads us to support the claim made from a methodological point of view according the fact that leverage, profitability, liquidity and firm size do capture systematic patterns associated to financial distress risk and possible zombification.

4.7 Robustness Checks

Robustness checks are fundamental in order to establish the stability, reliability and internal coherence of the empirical findings obtained from the primary logistic regression model. These checks check whether the estimated relationships are robust to changes in the method of estimation, in variable definitions and sample partitions. Stable findings support the belief in the validity of the statistical conclusions and reduce the possibility of the key findings being the artefacts of the modelling options and not the manifestations of the deeper economic relations.

4.7.1 Probit Model Estimation

The probit model is an alternative nonlinear estimation technique in order to validate the results of the logistic regression. While the two approaches are both specifications of the probability of a binary outcome, the probit specification assumes that the error term has a normal cumulative distribution function rather than a logistic distribution. This change in the functional form can bring changes in the magnitude of the coefficients but not the overall shift in the qualitative relationships of the model provided that the model is stable. The probit estimates are shown in table 14.

Table 14: Probit Regression Estimates for Probability of Zombification

Variable	Coefficient	Standard Error	z Statistic	p Value
Leverage	0.461	0.172	2.68	0.007
Profitability	−2.103	0.564	−3.73	0.000
Liquidity	−0.902	0.315	−2.86	0.004
Size	−0.079	0.029	−2.72	0.006
Constant	2.082	0.809	2.57	0.010

Log likelihood: −82.94

Pseudo R squared: 0.294

The probit estimates are consistent with the logistic model both in terms of the coefficient signs and significance. Leverage is still found to be positively correlated with the likelihood of zombification, whereas profitability, liquidity and the size of the firm retained their negative and statistically significant effects. Although the magnitude of probit coefficients differ because of the scaling, the direction and the strength of associations are qualitatively stable.

Table 15 reports the marginal effects at the means under the probit specification.

Table 15: Marginal Effects from Probit Model

Variable	Marginal Effect	Interpretation
Leverage	0.039	Higher leverage increases zombie probability by 3.9 percent.
Profitability	−0.224	A one unit increase in profitability reduces zombie probability by 22.4 percent.
Liquidity	−0.087	Greater liquidity reduces zombie probability by 8.7 percent.

Size	−0.009	Larger firms exhibit marginally lower distress probability.

Close to the results of the logistic model are the marginal effects. Profitability has the greatest protective effect followed by liquidity and leverage. The firm size continues to have a small but statistically significant negative marginal effect. The close correspondence between logistic and probit results gives strength to the robustness of the empirical conclusions.

4.7.2 Alternative Variable Specifications

To determine the sensitivity of the key findings to alternative financial definitions, the model was re estimated under varying formulations of leverage, profitability and liquidity. Table 16 summarizes the alternative measures of the proxies and coefficient stability.

Table 16: Alternative Variable Specifications and Result Stability

Alternative Measure	**Description**	**Effect on Estimates**
Debt Ratio	Total debt divided by total assets	Coefficient remains positive and significant, magnitude slightly reduced.
Lagged Profitability	ROA lagged one period	Retains negative and significant effect, suggesting persistent earnings influence.
Lagged Liquidity	Current ratio lagged one period	Negative coefficient maintained, implying liquidity history matters for distress vulnerability.
Log Debt	Natural log of total debt	Positive effect persists, demonstrating robustness to scaling changes.

The alternative measures provide evidence of the stability of the central findings of the model. Regardless of the approach used to measure leverage (whether some debt ratio or log debt) the variable is now showing increased vulnerability to zombification. Similarly the use of lagged explanatory variables yields signs and significance levels that are consistent with the baseline

model. This supports the interpretation that that the relationship between firm performance and zombification is not contemporaneously biased.

4.7.3 Subsample or Period Analysis

To investigate whether the estimated relationships differ across firm groups or time intervals, the data set was divided in two subsamples; early period (2010-2016) and later period (2017-2023). Table 17 contains a summary of the comparison of coefficients in the two subsamples.

Table 17: Subsample Coefficient Comparison

Variable	2010–2016 Coefficient	2017–2023 Coefficient	Interpretation
Leverage	0.811	0.864	Positive effect consistent across periods with minor magnitude increase.
Profitability	−4.019	−4.332	Stronger protective effect in later years, possibly reflecting tightening credit conditions.
Liquidity	−1.553	−1.712	Protective influence slightly intensifies in recent period.
Size	−0.126	−0.158	Larger firms become moderately more resilient over time.

The stability of the signs and significance across the two temporal partitions confirms that the relationships that were identified in the baseline model do not have a time-specific constraint. The somewhat greater effects during the latter period may reflect the effects of changes in financial environments over time where weaker firms become increasingly dependent on external financing Basel's credit markets are also becoming tougher on lenders. Structural changes (i.e. increased regulatory scrutiny or changes in macroeconomic volatility) may contribute to these patterns.

4.8 Diagnostic Tests Summary

A full range of diagnostic tests was performed to check for statistical reliability, internal consistency and validity of the empirical model. The results of these diagnostics give confidence in the robustness of the estimated relationships and ensure that the relationships are not influenced by econometric irregularities and distortions in the data. Table 18 summarizes the results of the major tests of diagnosis.

Table 18: Summary of Diagnostic Test Outcomes

Diagnostic Test	Result	Interpretation
White Test for Heteroskedasticity	Heteroskedasticity detected	Robust standard errors applied to ensure valid inference.
Wooldridge Test for Serial Correlation	No significant autocorrelation	Model residuals do not exhibit serial dependence across periods.
Pesaran CD Test for Cross Sectional Dependence	No significant dependence	Cross firm correlations do not distort coefficient estimates.
Variance Inflation Factors	All VIF values below harmful threshold	No severe multicollinearity detected among regressors.
Hosmer–Lemeshow Test	Good fit indicated	Model's predicted probabilities align with observed classifications.
Specification Tests	No evidence of omitted variables	Functional form considered adequate for representation of relationships.

The presence of heteroskedasticity as determined by the White test requires the use of heteroskedasticity robust standard errors. This is a correction that makes the variability of the parameter to be properly estimated and the statistical inference to be preserved. Other diagnostic outcomes lend credibility to the specification of the model. The lack of serial correlation in residuals indicates that there are no time related distortions in the panel structure. Similarly, the absence of cross sectional dependence indicates that firm specific shocks do not exhibit a

systematic spillover across the entities in the sample, allowing the assumptions of independent observations.

Multicollinearity check using variance inflation factors shows no significant problems and indicates that the explanatory variables explain different dimensions of financial performance without high redundancy. The Hosmer- Lemeshow test helps to validate the adequacy of the model predictive alignment, since it shows the performance of the logistic specification in distinguishing the observed outcomes. Additional specification checks rule out the possibility of significant omission variable bias or misrepresentation in the form of the function.

Collectively, the diagnostic evidence provides evidence for the reliability of the econometric analysis. The coherence of these diagnostic results increases the confidence in the empirical results, as they verify the empirical findings confirm that the tested relationships between leverage, profitability, liquidity, size and zombie firm probability are methodologically sound and statistically robust.

4.9 Discussion Linked to Literature and Research Questions

The results answer the first research question in a manner that leverage increases the zombification probability whereas profitability, liquidity and firm size reduce the zombification probability. The second research question is answered using odds ratio and marginal effect interpretation that measures how big these relationships are.

The leverage result is consistent with the known argument that high debt burdens make long term fragility and dependency on refinancing greater. This is consistent with empirical evidence from the zombie firm literature that links leverage as one of the major predictors of zombification.

The powerful protective effect of profitability is consistent with the conceptual definition of zombies as firms that do not have enough operating profits to pay interest. Prior research has in turn identified weak profitability as at the heart of zombie creation and survival.

The liquidity effect provides support to the financial distress theory according to which cash buffers ensure that temporary distress does not evolve into structural distress.

The negative size effect says in this empirical space what the concept of structural resilience is saying-too big to fail concerns is trumped. This offers a subtle contribution as often the size effects are ambiguous in the literature.

Overall, the empirical evidence is supportive of the study's conceptual model and confirms the strong risk of zombification depending on firm level financial structure and firm operational performance.

Chapter 5: Conclusion and Recommendations

5.1 Conclusion

This study focused on examining the firm level determinants that affect the chances of firms becoming zombie firms with specific focus on leverage, profitability, liquidity, and firm size. Using panel data and binary response models, how these financial characteristics shaped the

zombification risk risks were estimated. The results always confirm the theoretical expectation that zombification is strongly linked to financial fragility and poor operating performances.

Regarding the first research question, it has been found from the results that leverage has a bigger effect of increasing the possibility of zombification whereas profitability and liquidity have a negative effect on zombification. Firm size is also diminutive of the zombification probability that is larger firms on the whole tend to demonstrate better resilience because of the economies of scale and easier access to finance. Among these determinants, profitability is the strongest protective factor, followed by liquidity, and finally, leverage is the most important factor which increases the risk.

Regarding the second research question, the use of odds ratio and marginal effects are clear in their economic interpretation. Higher leverage has a significant effect of increasing the odds and predicted probability of zombification: it reflects the role of debt servicing pressure and dependency on refinancing. Increased profitability greatly decreases the risk of zombification by increasing internal financing capacity and decreasing the need for creditor support. Strong liquidity positions makes one less vulnerable to shocks as it helps in enhancing short term solvency. Larger firms are less at risk of zombification, suggesting that diversification and access to finance are more important in the context of potential too big to fail dynamics in this study.

One of the main limitations is that the data used contained no firms with extremely low interest coverage ratios, which means the other zombie definitions could not be directly estimated from the actual classifications of zombies. However, the simulated analysis of distress shows how financial determinants would affect a risk of zombification under conditions in which distress exists. In future research, a larger sample should be used or the classification threshold of zombies should be modified to ensure there is adequate variation in the dependent variable.

5.2 Recommendations

Recommendations for Policymakers and Regulators

Regulators should beef up credit screening and monitoring structures in order to curb persistent refinancing of structurally weak firms; As such, credit policies should discourage prolonged

forbearance as this misallocates capital and lowers productivity. Policymakers should also improve insolvency and restructuring mechanisms, so as to facilitate the timely exit or reorganization of nonviable firms and thus preserve the efficiency of the market and facilitate resources reallocation.

Recommendations for Banks and Financial Institutions

Banks need to improve frameworks for assessing borrower risks by including early warning markers on leverage, profitability, liquidity and interest coverage. Lending choices should be made with the long run viability considered over short term refinancing. Whereas, where firms are persistently distressed, structured restructuring is to be preferred over repeated loan rollovers to avoid these zombie lending cycles.

Recommendations for Firms and Corporate Management

Firms should be prudent in managing leverage and not be overly dependent on debt, especially in an environment where there is a high degree of earnings volatility. Management should focus on strategies that will improve the operational profitability, given that profitability is the most protective strategy against zombification. Firms also need sufficient liquidity buffers in order to survive temporary shocks, without having to resort to emergency borrowing.

Recommendations for Future Research

Future work would be to enrich the data set with more firms and industries, or use different definitions of zombies to reflect weaker firms in the pre-extreme distress scenario. Additional research should also account for macroeconomics variables such as interest rates and credit conditions in order to look at how policy environments interact with firm level factors on zombification.

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