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The Impact of Uncertainty on Firm Financial Fragility:

How Has It Evolved Over Time?

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Abstract

This study examines the impact of uncertainty on firm financial fragility, with a particular focus on the temporal dynamics of this relationship. Utilizing the World Uncertainty Index (WUI) to measure uncertainty and the Altman Z-score to assess financial fragility, this study employs panel data methodologies. The analysis incorporates firm-level financial data and macroeconomic indicators from 41 countries over the period 1990–2022. The findings reveal that uncertainty significantly increases firm fragility. Notably, this negative effect varies by national income level, with high-income and upper-middle-income countries experiencing more pronounced impacts. To explore these temporal dynamics, we employ a rolling window approach. This reveals a nuanced pattern: the negative impact of uncertainty diminished until approximately 2010 but has intensified in subsequent years. This trend underscores the growing importance of integrating uncertainty into corporate risk management strategies.

Keywords: Firm Financial Fragility, Altman Z-Score, Uncertainty, Panel Data

JEL Classifications: G33 D22 C51

1. Introduction

Uncertainty has become a defining feature of the global economy, shaping both macroeconomic stability and firm-level financial fragility. Nobel laureate economist Prof. Dr. Daron Acemoğlu aptly captures this reality: "The word that will best summarize the upcoming years in the world is uncertainty" (Acemoğlu and Wolitzky, 2024). This observation underscores the critical role of uncertainty for all economic agents, particularly for firms. Firms are inherently exposed to various internal (firm-specific) and external (macroeconomic and market) risks, including uncertainty, which can significantly undermine their financial stability. In response, they continuously monitor these risks and develop strategies to anticipate and mitigate their effects. Concurrently, researchers are increasingly seeking to identify and measure the factors that influence financial fragility to inform policy, improve risk management, and support corporate decision-making.

Reflecting the growing importance of uncertainty, an expanding body of research has focused on its measurement and its impact on firms' financial outcomes. Numerous studies, for instance, examine the relationship between corporate default and macroeconomic variables (Acosta-González et al., 2019; Sarikov & Kuprianov, 2020). Others focus specifically on how uncertainty affects corporate financial performance, such as stock prices and firm value (Gopalakrishnan & Mohapatra, 2020; Stolbov & Shchepeleva, 2020). However, despite these contributions, a limited number of studies analyze the direct link between uncertainty and firm-level financial fragility. This study aims to fill this research gap. We adopt an approach that integrates a large cross-country dataset of firm-level and macroeconomic data to assess how uncertainty shapes financial fragility over time and across countries.

We employ the World Uncertainty Index (WUI) (Ahir et al., 2022) to measure uncertainty and the Altman Z-score (Altman, 1968) as an indicator of firm fragility. Using firm-level balance sheet data from the Eikon database and macroeconomic indicators from the World Bank, we construct a panel dataset spanning 41 countries from 1990 to 2022. Following the methodology of Gopalakrishnan and Mohapatra (2020) and Alfaro et al. (2019), we employ a fixed effects panel model. In this model, the Altman Z-score is the dependent variable, and the explanatory variables include uncertainty, firm-specific characteristics, and macroeconomic controls (exchange rate, economic growth, and inflation). Our findings show that uncertainty significantly undermines firms' financial health. This negative effect is particularly pronounced in higher-income countries that are more integrated into global markets. We also find that this impact has intensified over time, highlighting the critical role of uncertainty in corporate financial resilience.

Research on firm failure, often resulting from financial fragility and inadequate risk management, has gained momentum since the 1950s (Ravi Kumar and Ravi, 2007). Early studies primarily relied on accounting data to predict firm failure (Beaver, 1966; Altman, 1968). As financial markets evolved, firms gained easier access to external funding and increasingly shifted from equity-based to debt-based financing. While this expansion allowed firms to scale up production and capacity, it also led to higher liabilities. A failure to fulfill these obligations translates into heightened bankruptcy risk and financial fragility. These fragilities are further

exacerbated by external factors such as managerial shortcomings, political instability, and macroeconomic volatility, which often interact with heightened uncertainty.

Over time, these challenges have become more pronounced. The Asian financial crisis, for example, demonstrated the severe consequences of high corporate indebtedness amid adverse macroeconomic shocks (Aizenman and Pinto, 2005). In such contexts, a combination of falling asset prices, currency depreciation, and elevated uncertainty can dramatically weaken a firm's ability to repay its obligations. This trend continued post-2008; since the global financial crisis, non-financial corporate debt has risen significantly, particularly in emerging economies (Avdjiev et al., 2014). More recently, unprecedented events such as the COVID-19 pandemic have further amplified uncertainty, underscoring the urgency of understanding its effect on firm resilience and fragility.

Understanding the determinants of financial fragility remains crucial, not only for the sectors in which firms operate but also for the broader financial system and the economy as a whole. Financially fragile firms unable to meet their obligations may experience negative equity, operational paralysis, and ultimately bankruptcy. Depending on their size and interconnectedness, such failures can propagate systemic risks, adversely affecting lenders, investors, and economic growth. Accordingly, assessing the impact of uncertainty on financial fragility constitutes the primary aim of this study. Against this backdrop, our paper makes three key contributions. First, we estimate the impact of uncertainty on firms across 41 countries using a fixed effects panel estimation approach. Our model incorporates both firm-specific and macroeconomic control variables associated with fragility risk. Second, we apply the estimation separately for countries classified into three income groups, allowing us to compare how uncertainty affects firms operating under different economic conditions. Lastly, we employ a rolling windows method to examine the temporal dynamics of this impact from 1990 to 2022.

The rest of the paper is structured as follows. Section 2 reviews the literature on financial fragility and related empirical studies. Section 3 describes our dataset and econometric methods. Section 4 presents the results and examines the impact of uncertainty across different income groups. Section 5 explores how uncertainty influences firm fragility over time using a rolling windows approach. Section 6 concludes the paper.

2. Literature Review

The financial health and fragility of firms have been significant research topics in business and corporate finance since the 1950s. Financial health refers to a firm's ability to meet its financial obligations and maintain operations, while financial fragility describes the risk of a firm defaulting on its debts, experiencing liquidity problems, and ultimately facing bankruptcy (Beaver, 1966; Altman, 1968). The importance of these concepts stems from the potential for financial fragility to impose serious consequences, not only on the firms themselves but also on creditors, investors, employees, and the broader economic system (Opler and Titman, 1994)

As noted by Ravi Kumar and Ravi (2007), research on financial fragility and firm failure began in the 1950s with fundamental studies using accounting data and has since evolved into more

complex models. Beaver's (1966) univariate analysis and Altman's (1968) multivariate Z-score model are pioneering studies in this area. In subsequent years, alternative approaches emerged, such as the logistic regression models developed by Ohlson (1980) and Merton's (1974) structural credit risk model. Today, machine learning and artificial intelligence techniques are increasingly being applied to financial fragility prediction (Barboza et al., 2017).

Factors affecting a firm's financial health can be broadly categorized as internal (within the firm's control) and external (beyond its control). Among the most important internal factors is leverage, or a firm's debt level. Numerous studies show that high leverage ratios increase financial fragility (Andrade and Kaplan, 1998; Kalash, 2023). For instance, Andrade and Kaplan (1998) found that highly leveraged firms are more likely to experience financial distress, which negatively impacts their performance. This finding suggests that excessive debt increases bankruptcy risk and reduces performance. Alongside leverage, liquidity is another critical internal factor. Aslamiah et al. (2023) found that the current ratio positively impacts firm performance and reduces financial fragility, as high current ratio enhances financial resilience by enabling firms to meet unexpected cash needs more easily.

The effect of firm size on financial fragility appears bidirectional. Mselmi et al. (2017) showed that while SMEs may be more flexible and innovative, larger firms often benefit from better access to resources. Conversely, Dirman (2020) noted that larger firms may face disadvantages such as bureaucracy and management challenges. Beyond size, profitability and investment are also crucial. For instance, Saputri and Asrori (2019) found that an increase in return on equity (ROE) enhances financial strength, while Vosoughi et al. (2016) showed that increased capital investment reduces firm fragility. Finally, corporate governance structure and management quality are recognized as important internal factors. Salloum and Azoury (2012) found that strong corporate governance mechanisms are effective in reducing financial distress.

External factors, which are beyond a firm's control, also have a significant impact on financial health. Among the macroeconomic factors, variables such as economic growth, inflation, interest rates, and exchange rates are prominent. Campbell et al. (2008) showed that these variables affect firm fragility through channels like product demand, wages, and borrowing costs. Similarly, Acosta-González et al. (2019) demonstrated that GDP growth and exchange rates are associated with financial stability, while Sarikov and Kuprianov (2020) found that monetary policy tightening increases the risk of firm failure. Global financial conditions also play a key role, particularly in developing countries; Asis et al. (2021) have shown that US interest rates, global market liquidity, and risk aversion affect the financial fragility of firms in these economies.

In addition to macroeconomic conditions, other exogenous factors such as industry dynamics, competitive pressures, and financial market conditions are critical. Opler and Titman (1994), for instance, noted that financial distress can lead to a loss of market share in competitive markets. Relatedly, López-Gutiérrez et al. (2015) observed that distressed firms have limited access to external financing. Regulatory frameworks and policy changes also influence financial health; Ugur et al. (2022) showed that such policies affect firms' capital structure decisions and overall financial fragility risk.

In recent years, economic and political uncertainty has emerged as a significant exogenous

factor affecting firms' financial health. For instance, Stolbov and Shchepeleva (2020) and Iqbal et al. (2020) highlight the relationship between firm bankruptcy risk and economic policy uncertainty. Similarly, Sikhwal (2024) and Ahmed (2024) show that uncertainty strongly influences financial conditions. Significant interactions also exist between the internal and external factors affecting firm financial health. For example, Prasad et al. (2018) find that financially distressed firms are more sensitive to exchange rate fluctuations. These interactions demonstrate that financial health is a multidimensional concept, requiring internal and external factors to be considered in tandem.

Uncertainty, defined as the difficulty of predicting future economic events, complicates economic decisions (Lawson, 1985). Schinckus (2009) further emphasized that economic uncertainty is a natural consequence of complex economic systems and must be considered in economic models. In this context various indices have been developed to measure uncertainty. A prominent example is the Economic Policy Uncertainty (EPU) index (Baker et al., 2016), which measures uncertainty by analyzing the frequency of related terms in newspaper reports. Another key measure, and the one used in this study, The World Uncertainty Index (WUI) (Ahir et al., 2022), which is the measure used in this study, estimates global and country-level uncertainty by analyzing the frequency of such terms in Economist Intelligence Unit country reports. These indices are widely used in academic research and policy analysis, facilitating comparisons of uncertainty levels across countries and time periods.

Uncertainty significantly affects various firm behaviors. A foundational study by Bernanke (1983) showed that uncertainty leads firms to postpone investment decisions, which in turn contributes to economic fluctuations. Subsequent research, such as Kang et al. (2014), confirmed that economic policy uncertainty reduces firm-level investment, an effect that is more pronounced for small firms. Uncertainty also impacts liquidity management. Demir and Ersan (2017), for example, find that firms in BRIC countries hold more cash as uncertainty increases, suggesting they adopt precautionary savings motives to preserve liquidity. Uncertainty also suppresses firms' risk-taking behavior. Tran (2019) showed that firms take less risk as economic policy uncertainty increases, and Vural-Yavas (2020) found a similar negative effect on the risk-taking of firms in developed countries. Furthermore, innovation and R&D activities are dampened by uncertainty. Tajaddini and Gholipour (2020) found that firms reduce R&D spending as uncertainty increases. Taken together, these findings suggest that uncertainty has a wide range of effects on firm behavior, generally leading firms to act more cautiously.

A growing body of research examines the direct relationship between uncertainty and financial fragility. Sun et al. (2021), for instance, investigated whether economic policy uncertainty increases corporate financial risk, finding that it negatively affects financial performance. Similarly, Ali et al. (2023) examined the impact of EPU on financial stability, showing that uncertainty negatively affects stability in both developed and developing economies. Ahmed (2024) also investigated the relationship between various uncertainty indices and Russia's financial risks, finding that uncertainty strongly affects its financial position.

The impact of uncertainty also appears to vary by country income level. Carrière-Swallow and Céspedes (2013), for example, examined uncertainty shocks in developing economies and showed that they respond more strongly and for longer periods than developed economies. Sikhwal (2024) also analyzed the impact of U.S. uncertainty on emerging markets, finding that

the effects differed based on the level of development. Separately, other studies examine how these effects evolve over time. Altig et al. (2020) showed that the COVID-19 pandemic increased uncertainty to unprecedented levels, significantly affecting firm behavior. Li and Zhong (2020) also found that the impact of uncertainty shocks on China's financial conditions varied over time. Furthermore, Liu and Zhang (2015) linked economic policy uncertainty to increased stock market volatility, which in turn affects financial fragility by increasing the cost of capital.

While the existing literature confirms the impact of uncertainty on financial fragility, most studies focus on specific country groups or short time periods. Although studies like Sun et al. (2021) and Ali et al. (2023) provide important findings, comprehensive analyses examining how this impact evolves over time and how it differs systematically across income levels are limited. Similarly, while Carrière-Swallow and Céspedes (2013) and Sikhwal (2024) explored these effects in developing countries, comparative analyses using large, long-term panel datasets are lacking. This study aims to fill these gaps. By using a large panel dataset covering 41 countries (classified by income level) over a long and recent time horizon, this study provides a comprehensive overview of the impact of uncertainty on firm financial fragility, both across countries and over time.

3. Data and Empirical Model

This study utilizes a comprehensive panel dataset covering publicly listed firms from 41 countries at various stages of economic development from 1990 to 2022. The firm-level financial data, including leverage ratios, profitability measures, liquidity ratios, and firm size, were obtained from the Thomson Reuters Eikon database. These variables form the foundation of our analysis. We supplement this firm-level data with macroeconomic variables, including inflation, GDP growth, exchange rate, trade openness, and the World Uncertainty Index (WUI) sourced from the World Bank's World Development Indicators.

To address the influence of extreme values, we apply winsorization, truncating observations below the 1st and above the 99th percentiles to their respective threshold values. This procedure minimizes potential distortions from outliers while preserving the full sample size. The final panel dataset comprises 36,716 firms across 41 countries, yielding a total of 375,538 firm-year observations for the 1990–2022 period. To provide an overview of the data, summary statistics are reported in the next section.

3.1 Summary Statistics

Table 1 presents the descriptive statistics for the variables used in our analysis. These variables include our primary measure of firm financial fragility (Altman Z-score), the measure of uncertainty (WUI), a vector of other firm-level characteristics (e.g., Leverage, Current Ratio, ROE), and key macroeconomic variables (e.g., Inflation, Growth). The average Altman Z-score for the full sample is 4.23 with a standard deviation of 6.22, indicating considerable variation in firm financial fragility. As detailed in Appendix Table A4, this mean value corresponds to a "B" rating, placing the average firm in the 'grey zone' and close to the 'distress zone'.

Furthermore, the mean Altman Z-score values differ notably across country income groups.

Table 1. Summary Statistics

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
Firm financial fragility measure					
AltmanZS	437,056	4.23	6.22	-12.73	56.77
Uncertainty measure					
WUI	1,387	0.17	0.14	0	1.34
Measurement of firm-specific variables					
Leverage	625,477	1.36	2.23	-8.49	20.08
CapitalExp	563,669	8.29	2.62	0.91	14.39
Size	626,632	11.83	2.13	5.51	17.32
CurrentRatio	591,302	2.62	3.67	0.08	42.56
ROE	556,990	0.55	36.64	-298.76	119.29
Measurement of macroeconomic variables					
Inflation	1,348	10.54	135.28	-4.01	7481.66
Growth	1,402	3.57	3.64	-29.1	18.29
Openness	1,397	67.18	67.98	13.75	442.62
Exchange Rate	1,158	680.98	3138.05	0.00003	23271.21

Source: Calculated by the author using data from Thomson Reuters Eikon and World Bank datasets.

Table 2 reports the correlation matrix for the variables. As expected, a strong correlation is observed between CapitalExp and Size, as both are derived from logarithmic transformations related to firm assets. A relatively high positive correlation also exists between the AltmanZS and the Current Ratio. In contrast, the correlations among the remaining variables are generally low, suggesting that multicollinearity is not a significant concern for our model.

Table 2. Correlation Matrix

	AltmanZS	WUI	CapitalExp	CurrentRatio	Size	Leverage	Exchange Rate	Inflation	Growth	Openness
AltmanZS	1									
WUI	-0.02	1								
CapitalExp	-0.03	0.01	1							
CurrentRatio	0.46	-0.01	-0.17	1						
Size	-0.07	0.05	0.83	-0.13	1					
Leverage	-0.2	0.01	0.07	-0.22	0.12	1				
Exchange Rate	-0.02	-0.07	-0.15	-0.02	-0.17	0.007	1			
Inflation	-0.01	0.01	0.01	-0.09	0.0004	-0.002	0.01	1		
Growth	0.08	-0.25	0.002	-0.02	-0.04	-0.03	0.09	0.03	1	
Openness	-0.03	-0.09	-0.13	0.05	-0.08	-0.06	0.09	-0.01	-0.001	1

3.2 Empirical Model

To investigate the impact of uncertainty on firm financial fragility, we employ a fixed effects panel model and estimate the following equation:

$$AltmanZS_{it_{,}} = a_0 + b_1 WUI_{ct_{,}} + b_2 X_{it} + b_3 Z_{ct} + \gamma_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where the subscripts *i, t*, and *c* denote firm, time, and country, respectively. The dependent variable, $AltmanZS_{it}$, is the measure of firm financial fragility. Our primary explanatory variable of interest is WUI_{ct}, the World Uncertainty Index. X_{it} represents a vector of firm-level controls (capital expenditure, current ratio, size, leverage, and return on assets) , and Z_{ct} is a vector of country-level macroeconomic controls (inflation, GDP growth, openness, and real exchange rate). Finally, γ_i denotes firm fixed effects, δ_t represents year fixed effects, and ε_{it} is the error term. This specification allows us to assess the uncertainty-fragility relationship while controlling for potential omitted variable bias through the inclusion of time-invariant firm heterogeneity and common time shocks.

4. Estimation Results

We conduct the regression analysis in a stepwise manner. Our analysis begins with a baseline fixed-effects panel model (using variables in levels) that includes only firm-specific variables. We then extend this specification to incorporate our primary variable of interest, the World Uncertainty Index (WUI), along with macroeconomic controls. To address potential endogeneity concerns, we subsequently re-estimate the model using lagged explanatory variables. Finally, we estimate the model separately for country groups classified by income level to explore heterogeneous effects.

Table 3 reports our main regression results. Consistent with prior studies (e.g., Vosoughi et al., 2016; Lhutfi et al., 2020), capital expenditures show a positive and statistically significant coefficient across all specifications, suggesting that higher capital investment reduces firm fragility. This finding is logical, as capital expenditures often involve expanding production capacity, adopting technological innovations, and improving productivity, all of which enhance a firm's financial resilience (Vithessonthi, 2016). Similarly, the current ratio is positive and significant in all models, a finding that aligns with Aslamiah et al. (2023). As the current ratio reflects a firm’s ability to meet short-term obligations, a higher ratio indicates greater liquidity and financial soundness. This enhanced liquidity allows firms to manage unexpected cash needs more effectively, thus reducing fragility and increasing the Altman Z-score.

Firm size, in contrast, enters negatively and significantly, consistent with Mselmi et al. (2017) and Dirman (2020). This result suggests that larger firms may be more fragile, potentially due to bureaucracy, coordination problems, and management difficulties. Conversely, smaller and medium-sized firms might possess greater flexibility and dynamism, making them more resilient. Leverage is another factor that exhibits a strong negative relationship with the Z-score, indicating it significantly increases financial fragility. This aligns with the findings of Andrade

and Kaplan (1998) and Kalash (2023), as higher debt ratios increase financial risk, raise financing costs, and elevate bankruptcy risk. We note, however, that some studies report mixed or neutral effects of leverage (Dalci, 2018). Finally, among the firm-specific variables, return on equity (ROE) is positive and significant, echoing Saputri and Asrori (2019) and Chandio and Anwar (2020). A higher ROE indicates effective management and efficient resource use, which boosts shareholder returns and firm value, thereby strengthening financial health.

Turning to the macroeconomic controls, only GDP growth exerts a statistically significant positive effect on the AltmanZS. This aligns with the expectation that a strong macroeconomic environment strengthens firms by increasing demand and sales. This result is also consistent with prior evidence suggesting that the overall impact of the macroeconomic environment can be mixed or uncertain (Fernandez Tinoco et al., 2018; Ceylan, 2021). The coefficients for other macroeconomic factors, such as trade openness and exchange rate movements, are not statistically significant in our models.

Having established the effects of the control variables, we now turn to our central variable of interest: uncertainty. As shown in columns (II) and (IV) of Table 3, the World Uncertainty Index (WUI) has a negative and highly statistically significant effect on the Altman Z-score. This finding implies that higher uncertainty significantly increases firm financial fragility, a result consistent with the work of Sun et al. (2021) and Ali et al. (2023). The mechanism for this relationship is multifaceted. In periods of heightened uncertainty, firms face greater risks regarding future demand, costs, and investments, leading them to adopt more cautious strategies (Merschmann and Thonemann, 2011; Feng et al., 2023). This cautiousness can reduce investment and innovation, thereby increasing fragility (Iqbal et al., 2020). Moreover, lenders may impose higher risk premiums under uncertainty, raising financing costs and further limiting profitability (Drobetz et al., 2018). While some firms might exploit uncertainty through flexibility, the dominant trend indicates that uncertainty suppresses firm performance and amplifies financial fragility. Overall, the strong negative effect of WUI underscores the importance of reducing economic and political uncertainty to enhance firm resilience.

Table 3. Baseline Regressions

	I	II	III	IV
WUI		-0.624***		-0.546***
		(0.071)		(0.072)
CapitalExp	0.200***	0.199***	0.195***	0.194***
	(0.011)	(0.011)	(0.012)	(0.012)
CurrentRatio	0.897***	0.896***	0.897***	0.896***
	(0.014)	(0.014)	(0.014)	(0.014)
Size	-0.678***	-0.674***	-0.652***	-0.650***
	(0.027)	(0.027)	(0.028)	(0.028)
Leverage	-0.209***	-0.208***	-0.210***	-0.209***
	(0.007)	(0.007)	(0.007)	(0.007)
ROE	0.026***	0.026***	0.025***	0.025***
	(0.001)	(0.001)	(0.001)	(0.001)

Inflation			0.0001 (0.0001)	0.0001 (0.0001)
Growth			0.056*** (0.004)	0.053*** (0.004)
Openness			-0.001 (0.001)	-0.001 (0.001)
ExcRate			-0.00002 (0.00003)	-0.00004 (0.00003)
Constant	8.481*** (0.285)	8.507*** (0.285)	8.073*** (0.298)	8.119*** (0.298)
Firm Fixed Effects	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes
Number of Obs.	382008	382008	375538	375538
Overall R^2	0.305	0.306	0.312	0.312

Robust standard errors are in parentheses.
$p < 0.1^{*}, p < 0.05^{**}, p < 0.01^{***}$

4.1 Addressing Endogeneity

A significant econometric challenge in this analysis is the potential for endogeneity, which may arise from reverse causality or omitted variable bias between the dependent variable (AltmanZS) and firm-specific characteristics. To ensure the robustness of our results and bolster causal inference, we implement two complementary strategies.

First, we re-estimate the model by including lagged values (L.) of the firm-level explanatory variables (Table 4). This specification aims to reduce potential simultaneity under the assumption that past firm characteristics influence current financial fragility but are not contemporaneously affected by it.

As shown in Table 4, the results remain remarkably stable compared with the baseline estimates. The firm-level variables maintain their expected theoretical signs and statistical significance: higher capital expenditure, liquidity (current ratio), and profitability (ROE) strengthen firm resilience, whereas higher leverage and larger firm size intensify financial fragility. Crucially, the World Uncertainty Index (WUI) continues to exhibit a negative and highly significant effect on the Altman Z-Score, with coefficients ranging between –0.749 and –0.817. This indicates that, holding other factors constant, a one-unit increase in global uncertainty lowers a firm's Z-Score by approximately 0.8 points, signaling higher financial vulnerability. The persistence and magnitude of this coefficient suggest that uncertainty exerts a robust adverse effect on corporate stability even after accounting for potential short-term endogeneity.

Table 4. Estimation Results with Lagged Values

Variable	I	II	III	IV
WUI		-0.817*** (0.076)		-0.749*** (0.077)
L.CapitalExp	0.053*** (0.012)	0.051*** (0.012)	0.048*** (0.012)	0.047*** (0.012)

L.CurrentRatio	0.367*** (0.011)	0.367*** (0.011)	0.368*** (0.011)	0.368*** (0.011)
L.Size	-1.060*** (0.030)	-1.053*** (0.030)	-1.029*** (0.030)	-1.024*** (0.030)
L.Leverage	-0.100*** (0.007)	-0.099*** (0.007)	-0.100*** (0.007)	-0.099*** (0.007)
L.ROE	0.021*** (0.001)	0.021*** (0.001)	0.021*** (0.001)	0.021*** (0.001)
Inflation			0.001*** (0.0001)	0.001*** (0.0001)
Growth			0.050*** (0.005)	0.046*** (0.005)
Openness			-0.001 (0.001)	0.0003 (0.001)
ExcRate			0.00002 (0.00003)	-0.00001 (0.00003)
Constant	14.81*** (0.310)	14.79*** (0.309)	14.43*** (0.322)	14.43*** (0.321)
Firm FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Obs.	364178	364178	357805	357805
R^2 (Overall)	0.132	0.132	0.137	0.137

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Second, to further verify robustness and address endogeneity more formally, **we implement** a two-stage least squares (2SLS) estimation with firm and year fixed effects. In this specification, lagged values of the firm-level variables—L.Leverage, L.CapitalExp, L.CurrentRatio, L.Size, and L.ROE—serve as instruments for their potentially endogenous contemporaneous counterparts. This instrumenting strategy exploits the exogenous variation from predetermined firm attributes that are unlikely to respond to current shocks in financial fragility.

The instrument relevance condition is strongly satisfied, as demonstrated by first-stage F-statistics ranging from 145 to over 8,000 (well above the conventional benchmark value of 10). The second-stage results (Table 5) confirm the robustness of our main conclusions. The WUI coefficient remains negative (–0.403 to –0.443) and statistically significant at the 1% level, reaffirming that higher global uncertainty consistently deteriorates firm financial stability even after controlling for potential reverse causality. Quantitatively, the 2SLS estimates imply that a one-unit increase in WUI reduces the Altman Z-Score by approximately 0.4 points, underscoring the economically meaningful role of uncertainty. Moreover, the signs and magnitudes of the firm-specific variables are broadly consistent with expectations: leverage and firm size continue to exert significant negative effects on financial health, while capital expenditures, liquidity, and profitability remain positive and significant. Among macroeconomic variables, GDP growth retains a stable positive effect, whereas inflation, openness, and exchange rate fluctuations are generally insignificant.

Table 5. Two-Stage Least Squares (2SLS) Estimation Results

	I	II	III	IV
WUI		-0.443*** (0.072)		-0.403*** (0.073)
CapitalExp	0.274*** (0.034)	0.272*** (0.034)	0.269*** (0.035)	0.266*** (0.035)
CurrentRatio	0.989*** (0.032)	0.988*** (0.032)	0.995*** (0.033)	0.995*** (0.033)
Size	-0.963*** (0.047)	-0.957*** (0.047)	-0.940*** (0.048)	-0.936*** (0.048)
Leverage	-0.310*** (0.017)	-0.308*** (0.017)	-0.311*** (0.018)	-0.309*** (0.018)
ROE	0.059*** (0.002)	0.059*** (0.002)	0.059*** (0.002)	0.059*** (0.002)
Inflation			0.00020 (0.00019)	0.00020 (0.00019)
Growth			0.0227*** (0.0045)	0.0206*** (0.0045)
Openness			-0.0010 (0.0008)	-0.0009 (0.0008)
ExcRate			0.00002 (0.00003)	0.00001 (0.00003)
Constant	10.968*** (0.447)	11.034*** (0.448)	10.752*** (0.470)	10.833*** (0.471)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p < 0.01, ** p < 0.05, * p < 0.10

Taken together, the lagged-variable estimation and the 2SLS approach jointly demonstrate that the inverse relationship between uncertainty and firm resilience is not an artifact of endogeneity or measurement bias. The consistent, substantively large, and negative WUI coefficients across all models offer compelling evidence that rising uncertainty systematically erodes firm financial stability, amplifying financial fragility across countries and over time.

4.2 Estimation Results by Income Level of Countries

While financial fragility is a challenge all firms face, its impact can vary significantly based on the surrounding economic environment, particularly between developed and emerging economies. To explore this heterogeneity, this section examines the estimation results disaggregated by country income level. The findings, presented in Table 6, reveal significant variations in the effects of uncertainty and other control variables, which is crucial for understanding the complex dynamics affecting firm fragility.

As shown in Table 6, the overall impact of uncertainty (WUI) on firm fragility for the full

sample ('World') is negative and significant (coefficient of -0.749). However, this aggregate effect masks significant heterogeneity across income groups. The negative impact is most pronounced in upper-middle-income countries (coefficient of -0.897), and it remains strong and significant in high-income countries (-0.577). In contrast, for lower-middle-income countries, the coefficient (0.119) is positive but not statistically significant. These findings suggest that the adverse effects of uncertainty are concentrated primarily in middle- and high-income economies.

The firm-specific variables also exhibit heterogeneous effects. Capital expenditure, for example, is positive and significant in high-income countries but negative in upper-middle-income countries, perhaps suggesting different utilization effectiveness. The resilience-enhancing effects of the current ratio (liquidity) and ROE (profitability) are positive and significant across all income groups, as expected. Conversely, firm size has a significant negative effect in all groups, with the strongest impact in upper-middle-income countries. Similarly, the negative effect of the leverage ratio is consistent across all groups, confirming that high indebtedness persistently increases firm fragility.

Regarding macroeconomic variables, economic growth generally has a positive and significant effect, which is particularly strong in upper-middle-income countries. The impact of other macro controls varies. For instance, inflation is negative in lower-middle-income countries but positive in high-income countries. Trade openness shows a positive and significant effect in both upper-middle and high-income countries, supporting the positive implications of international trade integration. The exchange rate effect is negative and significant only in high-income countries.

These findings have important implications, suggesting that risk management strategies must be adapted to a country's specific income level. Firms in upper-middle and high-income countries appear particularly vulnerable and may need more comprehensive measures to mitigate uncertainty risk. The stronger impact of uncertainty in these countries is likely attributable to their higher integration with global financial markets and greater exposure to international economic fluctuations. Conversely, the statistically insignificant effect in lower-middle-income countries suggests that firms in these economies may be more insulated from global uncertainty shocks, perhaps being more affected by local institutional or structural factors (Carrière-Swallow and Céspedes, 2013).

Table 6. Subsample Analysis

	World	Lower	Upper	High
WUI	-0.749***	0.119	-0.897***	-0.577***
	(0.076)	(0.323)	(0.124)	(0.11)
L.CapitalExp	0.0466***	0.014	-0.039*	0.109***
	(0.012)	(0.021)	(0.022)	(0.017)
L.CurrentRatio	0.368***	0.235***	0.504***	0.335***
	(0.011)	(0.031)	(0.023)	(0.013)
L.Size	-1.024***	-0.570***	-1.579***	-0.947***
	(0.030)	(0.125)	(0.056)	(0.037)

L.Leverage	-0.099***	-0.117***	-0.079***	-0.097***
	(0.007)	(0.016)	(0.016)	(0.009)
L.ROE	0.021***	0.024***	0.032***	0.019***
	(0.001)	(0.002)	(0.001)	(0.001)
Inflation	0.001***	-0.058***	0.0004**	0.023**
	(0.0001)	(0.007)	(0.0002)	(0.009)
Growth	0.046***	0.015	0.051***	0.0303***
	(0.005)	(0.01)	(0.008)	(0.007)
Openness	-0.0004	0.009***	0.022***	0.005***
	(0.001)	(0.003)	(0.002)	(0.001)
ExcRate	-0.00001	-0.0001***	-0.0001	-0.002***
	(0.00003)	(0.00004)	(0.0003)	(0.0003)
Constant	14.43***	10.52***	20.82***	12.86***
	(0.321)	(1.22)	(0.645)	(0.384)
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Number of Obs.	357805	30736	88171	238898
Overall R^2	0.137	0.148	0.125	0.129

Robust standard errors are in parentheses.
$p < 0.1^{*}, p < 0.05^{**}, p < 0.01^{***}$

5. The Impact of Uncertainty on Firm Financial Fragility over Time

We extend the analysis to examine the temporal dynamics of the WUI's impact on firm fragility. To do this, we conduct fixed-effect estimations using 10-year rolling windows over the 1990–2022 period. The first estimation window covers 1990–1999, and the final window covers 2013–2022[1]. We run this analysis for both the full sample and disaggregated by income group. The resulting WUI coefficients are plotted over time in Graphs 1 through 4, illustrating the evolution of this relationship.

Graph 1 shows that the WUI coefficient for the full sample is time-varying and not stable. The negative impact of uncertainty on firm fragility was substantial in the 1990–1999 period (coefficient of -1.477) but became statistically insignificant during the early 2000s. However, the negative effect began to re-emerge and intensify around the 2005–2014 window, reaching its peak magnitude (-1.419) in the 2012–2021 period. This trend suggests that the adverse impact of uncertainty on firm performance has worsened in recent years, a finding consistent with Kang et al. (2014).

Disaggregating the results reveals divergent trends across income groups. For lower-middle-income countries (Graph 2), the impact of uncertainty on firm fragility is generally statistically insignificant. This might suggest that firm fragility in these economies is driven more by domestic structural factors, such as institutional inefficiencies or underdeveloped financial markets, rather than the global uncertainty captured by the WUI (Ahir et al., 2022).

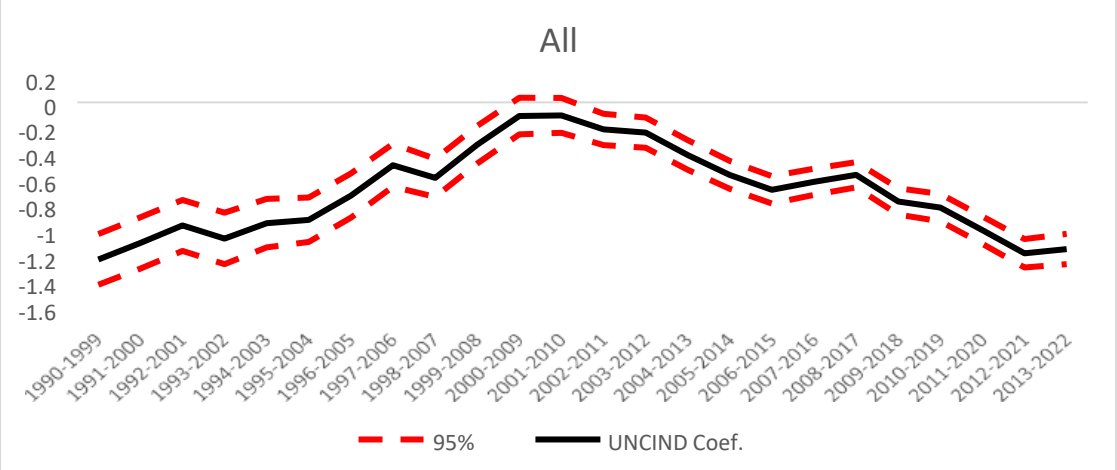
In contrast, both upper-middle-income (Graph 3) and high-income (Graph 4) countries show a clear U-shaped pattern over time. For both groups, the negative impact of uncertainty was high

[1] Detailed estimation results can be shared upon request.

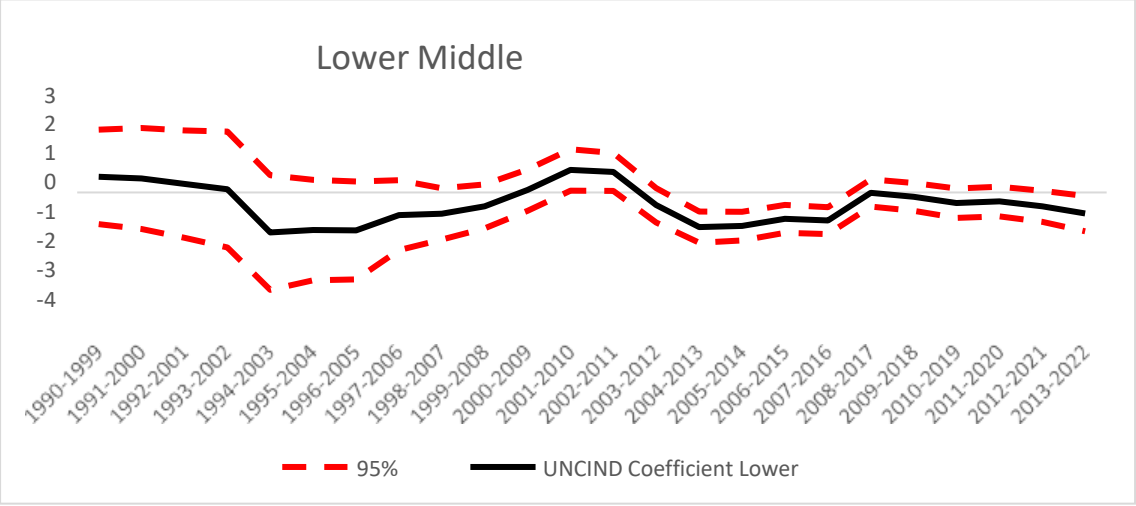
in the 1990s, declined and often became insignificant during the 2000s, but has intensified again since approximately 2010. This recent increase in sensitivity can be attributed to the deepening of global economic integration (Carrière-Swallow and Céspedes, 2013) and recent major shocks such as the COVID-19 pandemic and rising geopolitical risks (Altig et al., 2020).

These findings suggest that the sensitivity of firms' financial performance to economic uncertainty has increased over time, particularly in tandem with globalization and deeper economic integration. The effects of uncertainty have recently become particularly pronounced in upper-middle-income countries. Overall, our results confirm that the relationship between uncertainty and firm fragility is not static; it evolves over time and varies significantly across countries at different stages of development, highlighting the need for risk management strategies to adapt to these changing dynamics.

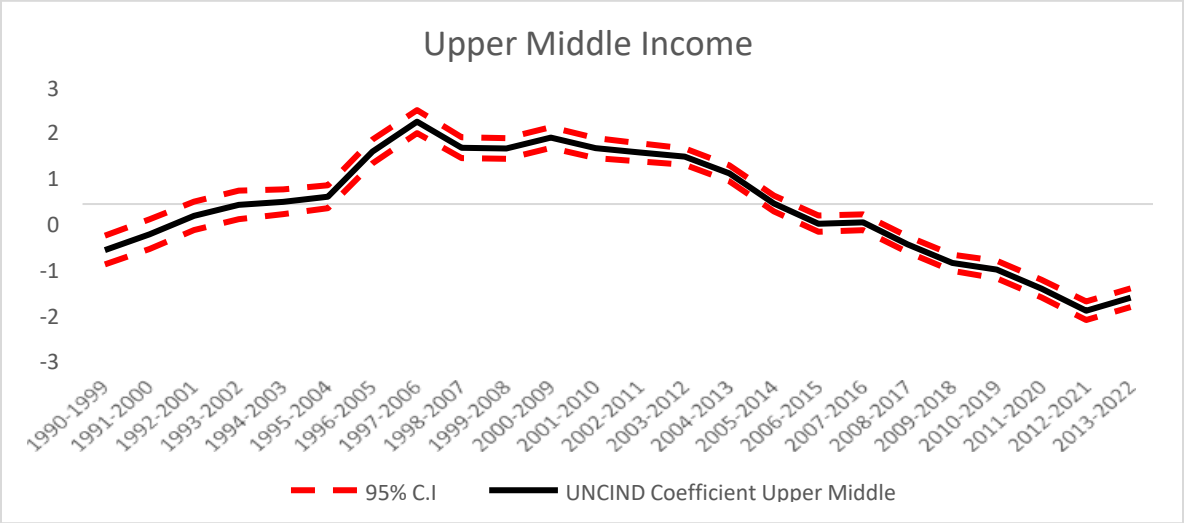
Graph 1. Change in WUI Coefficient over Time



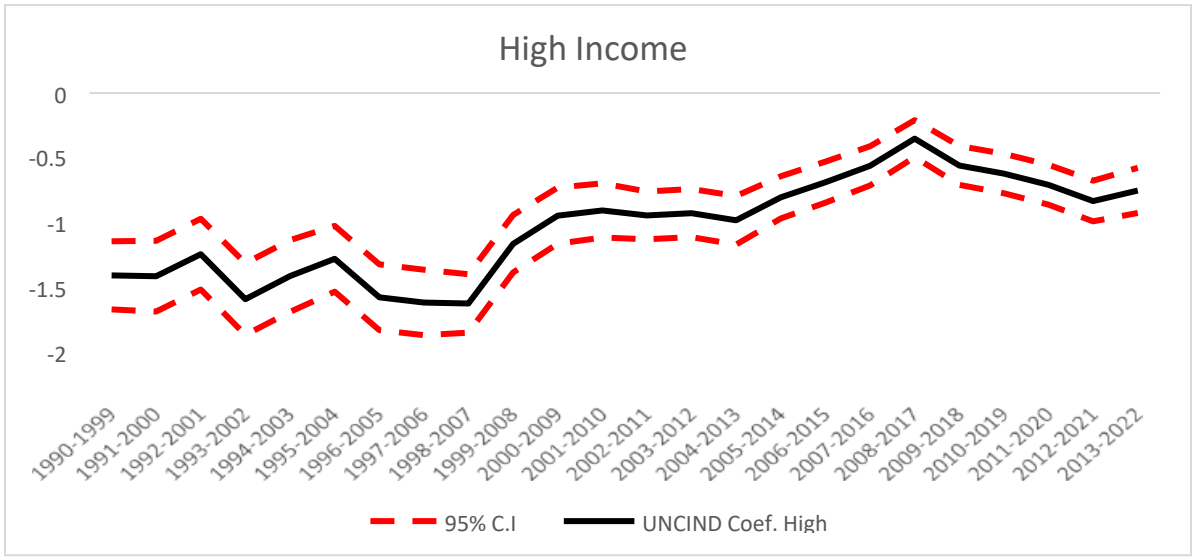
Graph 2. WUI Coefficient over Time in Lower Middle Income Countries



Graph 3. WUI Coefficient over time in Upper Middle Income Countries



Graph 4. WUI Coefficient over Time in High Income Countries



6. Conclusion

This study provides a comprehensive examination of the relationship between uncertainty and firm financial fragility across 41 countries spanning more than three decades. Our findings reveal that uncertainty, as measured by the World Uncertainty Index (WUI), has a significant negative impact on firm financial health, as measured by the Altman Z-score. This relationship, however, is not uniform across economic contexts or time periods.

The analysis demonstrates that the impact of uncertainty varies substantially across different income groups. Firms in high-income and upper-middle-income countries experience more pronounced negative effects from uncertainty, likely due to their deeper integration into global financial markets and complex economic systems. In contrast, firms in lower-middle-income countries appear relatively insulated from global uncertainty shocks, possibly due to different industry compositions, less global market exposure, or alternative financing structures.

Our temporal analysis using rolling windows reveals important dynamics in the uncertainty-fragility relationship. We find a U-shaped pattern: the negative impact of uncertainty on firm fragility diminished until approximately 2010 but has intensified in subsequent years, particularly during periods of global disruption such as the COVID-19 pandemic. This trend underscores the growing importance of uncertainty as a critical factor in firm financial resilience in the contemporary global economy.

Firm-specific characteristics play a crucial role in determining financial fragility. Our findings confirm that higher capital expenditure, stronger current ratios, and improved return on equity enhance firm resilience, while increased leverage and larger firm size tend to exacerbate financial fragility. Among macroeconomic factors, GDP growth consistently demonstrates a positive effect on firm financial health across different specifications.

These findings have significant implications for corporate financial management, investment strategies, and risk assessment. For firms, particularly those in more developed and integrated economies, implementing robust risk management frameworks that specifically address uncertainty is no longer optional, but critical. Financial institutions may also need to refine their risk assessment models to better account for the varying and time-dependent impact of uncertainty across different economic contexts.

Future research could build upon these findings by exploring the specific mechanisms through which uncertainty affects firm financial decisions. Other avenues include examining sector-specific impacts, investigating the effectiveness of various risk mitigation strategies, or analyzing the interplay between uncertainty and institutional quality. Such analyses could provide valuable insights into how governance structures might buffer or amplify the effects of uncertainty on firm performance.

Policy Implications

Our findings offer several important policy implications for various stakeholders. Specifically

for policymakers, efforts to reduce economic policy uncertainty and enhance policy stability could yield substantial benefits for corporate financial stability and, by extension, broader economic resilience.

For monetary authorities, developing transparent and predictable policy frameworks is crucial for reducing economic uncertainty and enhancing firm resilience. Central banks should also consider the heterogeneous impacts of monetary policy changes, potentially implementing targeted measures to support vulnerable sectors during periods of heightened uncertainty.

Financial regulatory bodies, in turn, should develop early warning systems that incorporate uncertainty metrics into financial stability assessments. Such systems could help identify emerging risks before they materialize into widespread financial distress. Additionally, regulatory requirements for corporate risk disclosure could be enhanced to specifically address exposure to uncertainty factors, thereby improving market transparency.

For governments, particularly in upper-middle and high-income countries where uncertainty effects are more pronounced, policy stability and clear communication of economic policy intentions are crucial. Establishing independent fiscal institutions that provide objective economic forecasts could help reduce policy uncertainty. Governments should also consider implementing countercyclical support mechanisms that automatically activate during periods of heightened uncertainty to stabilize business conditions.

Firms themselves should adopt more sophisticated risk management strategies that explicitly account for uncertainty beyond traditional risk factors. This includes diversifying funding sources, maintaining adequate liquidity buffers, implementing flexible operational structures, and developing contingency plans specifically designed for high-uncertainty scenarios.

In an increasingly interconnected and volatile global economy, understanding the evolving relationship between uncertainty and firm financial fragility remains critical. By implementing targeted policies and robust corporate strategies that address the heterogeneous and time-varying impacts of uncertainty, stakeholders can work toward building a more resilient global financial system that supports firm stability and promotes sustainable growth.

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Appendix

Table A1. Number of Firm Year Observations and Average Value of AltmanZS in High Income Countries

Country Code	Firm Year Observation	AltmanZS Mean	AltmanZS St. D.
AUS	21,404	6.58	10.65
BEL	941	3.31	4.78
CAN	12,223	3.76	5.91
CHE	1,117	4.16	5.35
CHL	2,402	3.27	3.59
DEU	10,628	3.52	4.16
DNK	2,005	4.60	5.58
ESP	1,136	2.57	2.81
FIN	1,243	3.93	4.39
FRA	13,641	2.83	2.90
GBR	21,607	4.27	5.76
HKG	23,131	3.90	5.52
HUN	553	3.45	3.95
ISR	4,547	2.85	3.90
ITA	2,202	2.41	2.64
JPN	57,367	3.68	4.05
KOR	12,996	4.29	4.94
NLD	550	3.47	4.25
NOR	985	3.47	5.55
POL	5,522	3.98	5.02
PRT	689	1.59	1.77
SAU	1,680	5.92	6.84

SWE	3,719	5.56	8.31
USA	50,218	4.83	6.35
Total	252,506	3.84	4.96

Tablo A2 Number of Firm Year Observations and Average Value of AltmanZS in Upper Middle Income Countries

Country Code	Firm Year Observation	AltmanZS Mean	AltmanZS St. D.
BRA	3,883	2.49	3.06
CHN	48,036	6.33	7.86
COL	289	3.16	3.26
MEX	889	3.35	3.09
MYS	17,542	3.58	4.81
PER	1,552	3.06	4.04
RUS	2,881	3.82	4.09
THA	7,395	4.37	5.23
TUR	3,140	3.86	4.78
ZAF	5,460	3.91	3.29
Total	91,067	3.79	4.35

Table A3. Number of Firm Year Observations and Average Value of AltmanZS in Lower Middle Income Countries

Country Code	Firm Year Observation	AltmanZS Mean	AltmanZS St. D.
EGY	2,103	3.77	4.16
IDN	1,174	4.38	5.26
IND	19,362	4.32	5.07
PHL	3,122	3.47	4.98

TUN	519	3.56	3.66
UKR	420	2.60	2.77
VNM	5,265	3.75	4.08
Total	31,965	3.69	4.28

Table A4: Altman's Z-Score and Bond Rating

	Z' Score	Rating		Z' Score	Rating
Safe Zone	> 8.15	AAA	Grey Zone	5.65-5.85	BBB-
	7.60-8.15	AA+		5.25-5.65	BB+
	7.30-7.60	AA		4.95-5.25	BB
	7.00-7.30	AA_		4.75-4.95	BB-
	6.85-7.00	A+		4.50-4.75	B+
	6.65-6.85	A		4.15-4.50	B
	6.40-6.65	A-		3.75-4.15	B-
	6.25-6.40	BBB+	Distress Zone	3.20-3.75	CCC+
	5.85-6.25	BBB		2.50-3.20	CCC
				1.75-2.50	CCC-
				<1.75	D

Source: Altman (2005)