General Audience Project Summary

Financial crises can have devastating consequences, not just for individual companies, but for entire cities. When a city depends heavily on a specific industry, economic downturns in that sector can lead to widespread financial distress and, in extreme cases, municipal bankruptcy. This project seeks to develop a statistical model using Extreme Value Theory (EVT) to better predict when a city's financial health might be at risk due to struggles within key industries. Extreme Value Theory is an area within statistics designed to analyze rare but significant events, such as economic crashes. Traditional financial models often assume that market fluctuations follow a normal pattern, which underestimates the likelihood of extreme downturns. EVT, on the other hand, focuses specifically on extreme events, making it a more effective tool for assessing financial risk. This research will begin by applying EVT to financial data from Detroit, a city that declared bankruptcy in 2013 after years of economic decline, substantially correlated with the automotive industry. By analyzing financial trends from Detroit's major auto companies alongside municipal economic indicators, I aim to identify patterns that signal financial distress that the city level. Building on this case study, I will then develop a more general EVT-based model, or highly complex formula in more simple terms, that can be applied to other cities with similar economic structures. The ultimate goal of this project is to provide a framework for predicting municipal financial instability based on corporate sector trends, and with even more in-depth research beyond the undergraduate level, potentially help policymakers and economists better anticipate and mitigate economic downturns before they reach a crisis point.

Proposed Title and Project Abstract

Constructing an Extreme Value Model to Predict Municipal Financial Risk Based on Corporate Bankruptcy

Extreme Value Theory (EVT) provides a rigorous statistical framework for modeling rare and extreme events, such as financial crises leading to bankruptcy. Traditional financial models, even those accounting for extreme events, often assume Gaussian distributions and rely on historical data for predictions. While effective in many cases, these models primarily apply to individual corporations rather than entire municipalities. Detroit, the largest U.S. city to declare bankruptcy, presents a compelling case study due to its strong economic ties to the automotive industry. This thesis aims to apply EVT to analyze the financial time series of Detroit's three major automotive companies using the Block Maxima Method and the Generalized Extreme Value distribution. The same methods will be used to model key economic indicators from Detroit's historical financial data. By performing cross-correlation analysis and conducting Granger causality tests, this study will assess whether extreme corporate financial events, as identified through EVT, serve as significant predictors of municipal financial distress. The findings will provide a mathematical basis for understanding the relationship between corporate instability and large-scale economic downturns, reinforcing the auto industry's role in Detroit's financial collapse. This foundation will hopefully lead to an EVT-centered statistical model applicable to other U.S. cities with significant economic dependence on a single industry, such as steel in Pittsburgh or technology in Silicon Valley, to assist in foreseeing large-scale, city-wide, monetary downturns.

Project Description

Specific Aims: (1) Develop an EVT-based model tailored to Detroit, analyzing the financial decline of key automotive companies and its impact on municipal bankruptcy risk. (2) Generalize the model to assess municipal financial risk in various cities based on corporate bankruptcy patterns, providing a broader predictive framework.

Hypothesis: A municipality with substantial ties to a specific industry, particularly major companies within that industry, fiscal success depends heavily on the success of that industry, and this relationship can be modeled using Extreme Value Theory.

Background and Methods: Extreme Value Theory is often described as analyzing the random probability distribution of extreme value in an event or process (13). EVT has significant applications in assessing the probability of rare and impactful events, such as financial crashes, economic crises, and extreme losses. In the financial sector, EVT is widely applied to model risk and assess the probability of tail events in asset returns, market crashes, and bankruptcy risks (3). Traditional financial models often rely on Gaussian distributions and minute, differing statistical performance measures that lead to large differences in model predictions (3). Additionally, Value-at-Risk (VaR) is the most common risk measure used in the finance industry defined as:

$$VaR^{\Delta}{}_{\alpha} = \inf\{\mathrm{x} \in \mathbb{R}: \mathrm{P}(\mathrm{L} > \mathrm{x}) \leq 1\text{-}\alpha\} \ = \ \inf\{\mathrm{x} \in \mathbb{R}: \mathrm{F_L}(\mathrm{x}) \geq \alpha\}$$

Clearly, this equation is largely theoretical and not rigorous in statistical estimation. Another measure commonly used, known as the expected shortfall (ES), defined as

$$\mathrm{ES}^{\Delta}{}_{\alpha}(L) = \frac{1}{1\text{-}\alpha}\int_{\alpha}^{1} VaR^{\Delta}{}_{\alpha}(\mathrm{L})\mathrm{dx}$$

assuming the loss is continuous, also presents similar issues of rigor in estimation, with an increased risk of variability due to the tail. Because both equations are focused on the tail, EVT can make an estimate for both, and more accurately. Currently, an EVT-generated model is one of the few, highly accurate estimators for extreme events in finance (3).

EVT has also been employed in predicting corporate bankruptcies by analyzing extreme financial stress indicators such as high debt rations, liquidity shortages, and drastic declines in asset turnover for companies. By focusing on tail distributions rather than average financial performance, extreme value-based models consistently outperform benchmark methods of analyzing schemes of financial distress of businesses (9). Where the methodology has been particularly effective in identifying patterns that lead to bankruptcy in firms with historically volatile financial profiles.

Detroit's bankruptcy in 2013 remains the largest municipal bankruptcy in U.S. history, making it an ideal case for studying extreme financial tail events (6). Traditional financial models, which assume normal distributions, fail to capture the severity of such downturns, as discussed previously. Extreme Value Theory financial models also primarily focus on corporations, so this case study further presents a unique situation.

Since the EVT models discussed apply mainly to corporations, it would be valuable to consider some of the primary corporations that are headquartered in Detroit: Ford, General Motors, and Stellantis (previously known as Chrysler). The automotive industry has played a pivotal role in Detroit's financial success and downturns. The rise and decline of Detroit's financial health have closely mirrored the performance of its major automobile companies (1). In this research, I will analyze the correlation between Detroit's economic health and the financial performance of its automakers. Understanding this correlation is crucial in assessing the extent to which the automotive industry's financial instability may have contribute to Detroit's municipal bankruptcy. Throughout the research, this relationship will be broadened to more general variables in hopes of generating a more complete model based on EVT to predict such bankruptcy based on these instabilities.

To address the issue of correlation versus causation, I will investigate whether financial distress in the automotive industry preceded Detroit's broader financial collapse. This will involve examining financial indicators from automakers before the city experienced significant economic distress. By doing so, I aim to determine whether the financial instability of Detroit's automotive giants was a leading indicator of the city's broader fiscal downturn.

The research will employ time series data, denoted as X_t, which will include corporate debt ratios, asset turnover ratios, and stock price returns for Ford, GM, and Stellantis. A financial time series is a sequence of financial data points indexed in time order, commonly used in economic forecasting and risk analysis (11). The hope is that these variables will exhibit heavy-tailed distributions in the selected period, suggesting non-negligible probabilities of extreme downturns and eligible for EVT-based analysis.

I will employ the Generalized Extreme Value (GEV) distribution to model the smallest or largest values among a large set of independent, identically distributed financial indicators. Utilizing the cumulative distribution function of the GEV distribution given by (13):

$$F(x;\mu,\sigma,\xi) = \exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)^{-1/\xi}\right]\right\}$$

Additionally, employing concepts seen in a "GEV Application in Financial Risk Management" demonstration on wolfram, GEV distribution is particularly effective in modeling extreme financial risks by capturing the behavior of rare yet severe financial shocks (12).

After fixing the heavy-tailed distributions for Detroit's Three (automotive companies), an EVT analysis method for corporate financial risks (3) will be applied to estimate tail risks beyond a specific threshold, we'll call this threshold u. Using the Block Maxima method, I will determine the probability distribution of the largest values within segmented time blocks (5), which is essential for estimating the likelihood that the maximum observed financial stress remains within a given range. Since the data will have been fixed to the GEV distribution, the Block Maxima method will be applicable, and I will mainly utilize pyextremes.extremes.block_maxima.get_extremes_block_maxima (2) to find extremes of the data.

Then I will fit a separate EVT model to municipal financial indicators, including revenue declines, unemployment spikes, and surges in municipal debt. By extracting EVT parameters for municipal financial distress, I can assess the risks associated with extreme downturns in Detroit's performance. Similarly, I will analyze the municipal data using the GEV distribution and Block Maxima method.

A cross-correlation analysis will be conducted to determine whether extreme corporate debt surges in the automotive industry preceded Detroit's extreme municipal debt growth. I will analyze whether sharp stock price declines in automakers correlated with significant drops in city tax revenue and whether extreme reductions in corporate asset turnover aligned with periods of economic stagnation in Detroit.

To establish causality, I will implement a Granger causality test, a time-series econometric approach that determines whether extreme financial shocks in the auto industry statistically predict extreme downturns in Detroit's municipal finances. If EVT-extracted extreme events in the corporate sector significantly predict municipal financial distress, this would confirm the role of the auto industry in Detroit's economic decline.

The goal of this computation is to generate an EVT-based model that can take data from corporations that hold significant financial power in a city and use that to predict a city's economic situation. I will conclude the study with testing this theoretical model by applying it to another city with an industry heavily associated with its fiscal success.

In my research to date, I have extensively studied Extreme Value Theory as a whole, its methods and its applications within the financial industry. I have focused on understanding EVT's role in modeling financial extremes, particularly in corporate bankruptcy prediction. Additionally, I have explored how EVT is utilized in the financial industry to assess tail risk and financial crises. I have also gathered datasets relevant to municipal financial health and corporate distress, preparing the foundation for applying EVT methodologies to real-world economic patterns.

Working Bibliography

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Timeline

Spring 2025 (March – May):

- Conduct background research on EVT applications in municipal and corporate financial distress.
- Gather and preprocess relevant datasets for Detroit's financial history and key industry trends. Parse the data into a useable format for the modeling.
- Begin preliminary EVT modeling on corporate bankruptcy data.

Summer 2025 (June – August)

- Complete EVT model construction for corporate financial risk analysis.
- Apply EVT to Detroit's municipal financial data and assess correlations.
- Begin initial statistical tests to evaluate relationships between corporate distress and municipal financial downturns.
- Begin analyzing patterns to start developing the generalized model, focusing on the corporate inputs.

Fall 2025 (September – December):

- Extend EVT analysis to additional cities with dominant industries (e.g. Pittsburgh, Silicon Valley).
- Conduct comparative analysis across municipalities to generalize findings.
- Begin drafting methodology and early results section for research write-up.
- Continue developing the generalized model, focusing now on the municipal prediction.

Spring 2026 (January – February):

- Finalize EVT-based predictive model for municipal financial distress.
- Validate model accuracy though back testing on historical financial crises.

- Refine statistical conclusions and policy implications.

March – April 2026:

- Draft and revise thesis.
- Prepare final presentation.
- Finalize research paper for submission.
- Present oral presentation at the Honors Symposium.
- Present findings in the poster session at the Stander Symposium.

Budget

This project does not require a budget. The datasets needed for analysis are public available through online sources such as government financial records, Kaggle, and finbox. Additionally, all necessary textbooks can be accessed through the Libraries Catalog. Computing for this project will be performed on my personal laptop, which has the required capabilities for statistical analysis and modeling.