IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661, p-ISSN: 2278-8727, Volume 26, Issue 6, Ser. 2 (Nov. – Dec. 2024), PP 09-17
www.iosrjournals.org

Regional Characteristics And Anomaly Detection Of KODIT Default Rates Using Prophet

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Abstract:
Background*: Small and medium-sized enterprises (SMEs) are the backbone of the national economy, necessitating a stable financial environment. This study focuses on analyzing default rates from Korea Credit Guarantee Fund (KODIT) data across 18 regions in South Korea and detecting anomalies using the Prophet model. Prophet is recognized as a powerful tool for time series analysis, capable of effectively separating trends, seasonality, and external factors while identifying anomalies.*
Materials and Methods*: This study utilized KODIT default rate data spanning from 2012 to 2023. The data were preprocessed to fit the Prophet model's requirements, and information on national holidays and weekends was incorporated to enhance anomaly detection performance. The preprocessing ensured the model accurately captured temporal patterns and external influences within the data.*
Results*: The analysis revealed a common pattern of increasing default rates across most regions after 2022, likely reflecting the impact of external factors such as the COVID-19 pandemic. Notably, Sejong and Jeju exhibited higher frequencies and intensities of anomalies compared to other regions, highlighting the need for further exploration of the relationship between regional economic characteristics and external factors. Furthermore, the Prophet model demonstrated high predictive accuracy in economically stable regions like Seoul and Gyeonggi, but its anomaly detection performance was relatively limited in regions like Gyeongnam and Ulsan, dominated by manufacturing, and Jeonbuk and Jeonnam, centered around agriculture.*
Conclusion: *This study demonstrates that the Prophet model is a valuable tool for detecting anomalies and devising credit risk management strategies. While it underscores the importance of exploring quantitative correlations between anomalies and external factors, it also suggests that Prophet-based analyses can extend beyond credit risk management to broader economic decision-making processes.*
Key Word*: Prophet model; Credit risk management; Anomaly detection; Time series analysis.*

Date of Submission: 03-12-2024 Date of Acceptance: 13-12-2024

I. Introduction

Small and medium-sized enterprises (SMEs) are the backbone of economic growth and job creation, particularly in countries like South Korea, where SMEs constitute a significant portion of the national economy [1]. However, SMEs often face financial challenges due to limited access to capital and insufficient collateral, which hinder their ability to sustain operations and expand. To alleviate these difficulties, the Korea Credit Guarantee Fund (KODIT) was established to provide credit guarantees, thereby enhancing SMEs' access to loans from financial institutions and supporting their growth.

Despite KODIT's critical role, the importance of managing risks associated with guaranteed loans has been consistently emphasized. An increase in SMEs' default rates not only threatens the stability of the financial system but also has broader negative implications for the national economy. Sudden fluctuations in default rates are often driven by economic events or regional characteristics, making the timely detection and response to such changes essential for maintaining the resilience and sustainability of the financial system [2-4]. Understanding the characteristics of SME default rate data and analyzing its variability are crucial steps in this process. These data often exhibit temporal trends and seasonality, along with distinct patterns that may be disrupted by external factors or economic shocks, leading to **anomalies** [5]. For instance, during periods of heightened economic uncertainty or policy changes, default rates may increase more sharply than anticipated. Such anomalies can serve as key indicators for financial risk management, and their early detection and interpretation provide valuable insights for policy design and risk mitigation strategies [6,7]. In this context, a systematic approach to analyzing default rate data and detecting anomalies is essential.

This study applies the Prophet model to analyze KODIT's regional and monthly default rate data. Prophet is a robust tool for time series analysis, capable of integrating trends, seasonality, and anomalies, making it particularly well-suited for detecting irregular fluctuations. By employing the Prophet model, this research aims to identify anomalies, interpret the causes of significant variations, and provide policy-relevant insights. Furthermore, it seeks to enhance KODIT's risk management strategies by comprehensively analyzing the seasonality and regional characteristics of default rate data.

II. Literature Survey

Taylor and Letham [8] proposed a method for analyzing time series data in retail, logistics, and finance using the Prophet model. This approach effectively separates trends, seasonality, and external factors to identify anomalies. Prophet was praised for its simplicity and ease of use, allowing even users with limited data science expertise to apply it effectively. However, it was noted that the model does not handle multivariate interactions and may struggle to capture abrupt anomalies. Their study demonstrated Prophet's robust performance in detecting anomalies in data with seasonal and trend components, but also highlighted limitations when dealing with highly nonlinear or complex interactions.

Sang *et al.* [9] applied the Prophet model to industrial datasets to evaluate its performance in anomaly detection and forecasting. Their findings emphasized Prophet's superior anomaly detection accuracy compared to traditional models like ARIMA, particularly due to its ability to automatically incorporate seasonality and external factors. They also highlighted the model's intuitive setup and reliable outcomes, which make it valuable for both researchers and practitioners. However, in long-term forecasting, Prophet's accuracy was found to be comparable to or lower than ARIMA, underscoring the importance of choosing a model suited to the specific dataset and research objectives.

Ren *et al.* [10] proposed a hybrid model combining Prophet and LSTM to address Prophet's limitations. While Prophet excels in isolating trends and seasonality, LSTM effectively captures nonlinear characteristics and complex data patterns. The hybrid model demonstrated over a 20% improvement in anomaly detection accuracy compared to Prophet alone. However, the integration of these two models resulted in slower training times and reduced interpretability, posing challenges for practical applications.

Kumar *et al.* [11] explored the application of Prophet in real-time anomaly detection for IoT sensor data. Their study demonstrated Prophet's ability to promptly detect anomalies in real-time data, making it highly applicable to environments requiring continuous monitoring, such as IoT systems. The model's automated configuration and intuitive interface simplified real-time prediction and anomaly detection tasks. However, challenges were noted in handling noisy or irregular data, necessitating further enhancements to improve its predictive accuracy.

These studies collectively highlight the efficacy of Prophet in time series analysis, particularly for anomaly detection and forecasting. The model's strengths lie in its ability to separate trends and seasonality, making anomalies more apparent, while its straightforward setup and interpretability enhance its usability in both research and practical contexts. However, the limitations of handling nonlinear data structures or multivariate interactions underscore the need for alternative or hybrid approaches depending on the data characteristics and research objectives. Prophet has been proven effective in integrating external factors such as holidays and weekends to precisely detect anomaly occurrences. It has shown high performance across diverse applications, including IoT, industrial, and financial data. While these studies emphasize Prophet's role as a robust tool for anomaly detection and forecasting, they also call for further analysis of its limitations in specific datasets or under the influence of external factors.

Building upon these findings, this study applies the Prophet model to analyze the default rate data of Korea Credit Guarantee Fund (KODIT) across different regions in South Korea. By incorporating regional economic characteristics and external factors, the study aims to explore the causes of anomalies and provide actionable insights for developing credit risk management strategies.

III. Material And Methods

1. Data description

The dataset utilized in this study was sourced from the **Korea Credit Guarantee Fund (KODIT)** and comprises regional monthly default rate records spanning from January 2012 to December 2023 (DATA.GO.KR). It includes default rate information from 18 major regions in South Korea (e.g., Seoul, Gyeonggi, Sejong, Gyeongnam, and Jeonnam), reflecting the economic conditions and industrial structures unique to each region. Consequently, the dataset exhibits distinct default rate patterns across different regions. The data spans a total of 144 months, recorded monthly from January 31, 2012, to December 31, 2023, with default rates expressed as percentages (%). The default rate for a given month represents the proportion of total loans that transitioned into non-repayment status by the end of that month, relative to the total loan amount in each region. This dataset provides critical insights for evaluating regional credit risks and analyzing factors influencing default rate fluctuations. The data exhibits temporal continuity, characteristic of time series data. This enables the identification of seasonal patterns and long-term trends that reflect the economic and industrial attributes of each

region. Moreover, the dataset captures irregular variations induced by external factors, such as economic shocks, further underscoring its value for understanding and managing regional credit risks.
Table 1 presents the key statistical characteristics of the default rate data. The average default rate is approximately 3.49%, indicating a generally stable level. However, certain periods or regions exhibit sharp increases, with a maximum default rate reaching 8.48%. The minimum default rate is recorded at 1.77%, and the standard deviation is approximately 0.91%, suggesting that the variability in the data is relatively low. This statistical summary provides a foundational understanding of the overall distribution of the data and is crucial for identifying anomalies that occur in specific periods or regions. For instance, values significantly higher than the average default rate may be classified as anomalies. Such insights will be instrumental in the subsequent anomaly detection process using the Prophet model.

Table 1: Statistical Summary of the Default Rate Data.

Statistic	Value
Total Data Points	144
Average Default Rate	3.49%
Minimum Default Rate	1.77%
Maximum Default Rate	8.48%
Standard Deviation	0.91%

2. Methodology

In this study, the Prophet model was utilized to analyze regional default rate data. Prophet is recognized as an effective tool for time series analysis, particularly for separating trends and seasonality and detecting anomalies. The analysis process to identify key patterns in default rates and detect anomalies was conducted through the following steps. First, the Prophet model was applied to the default rate data for each region to separate trend and seasonality components. Designed to effectively capture temporal continuity and seasonal patterns, Prophet is well-suited for analyzing the variability of regional default rates. Next, residual analysis was performed for anomaly detection. The difference between the model's predictions and the actual data was defined as the residual, which served as the basis for identifying anomalies. Anomalies were defined as values exceeding ±2 standard deviations, a commonly used criterion for anomaly detection. This threshold effectively identifies values that deviate significantly from the mean of the data distribution.

Finally, anomalies were visually represented and the key periods of variation were interpreted. The visualized results enabled clear identification of the timing of anomalies, which were analyzed in relation to economic events or external factors. For instance, the occurrence of specific anomalies was evaluated to determine whether they coincided with major events such as economic crises or policy changes, thereby deriving the causes and implications of the anomalies.

IV. Experimental Results

1. Analysis of default rate data

Figure 1 visualizes the overall trends in default rates over the past decade based on data from 18 major regions in South Korea. Data for Sejong was included starting from June 2015, as the city was newly established in 2012 as an administrative hub, with a gradual development of its economic infrastructure. Consequently, the averages prior to June 2015 were calculated based on the remaining 17 regions. The graph reveals a significant anomaly in early 2012, with default rates spiking to approximately 9%, followed by a gradual stabilization. From 2016 onwards, default rates remained relatively stable within a range of 3% to 5%. However, 2023 shows a renewed upward trend in default rates, which stands out as an anomaly likely influenced by changes in economic conditions and external factors in the post-pandemic era.

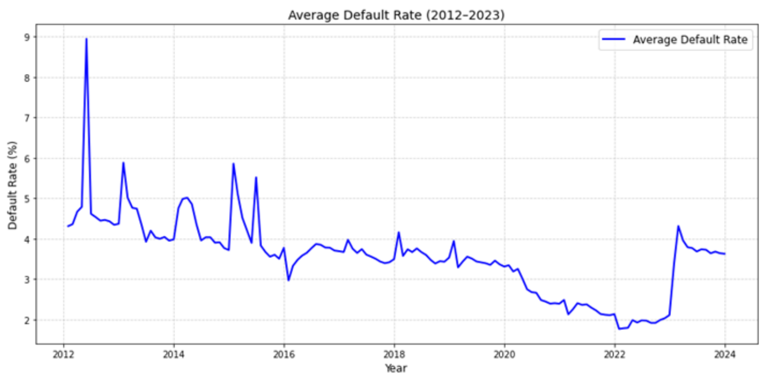

Figure 1. Monthly Average Default Rate Trends (2012–2023)

Default rates exhibit varying patterns of seasonality and anomalies across different regions. To further explore these differences, **Figure 2** and **Figure 3** present the trends in annual average default rates and monthly average default rates, respectively, for each region.

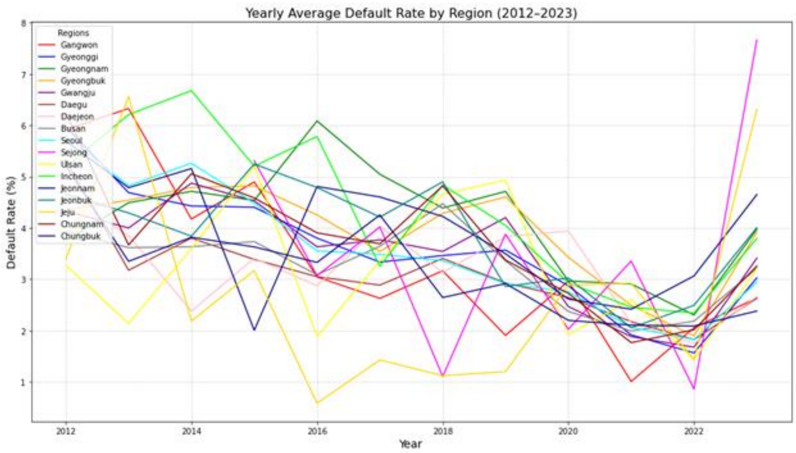

Figure 2. Yearly Average Default Rate by Region (2012–2023)

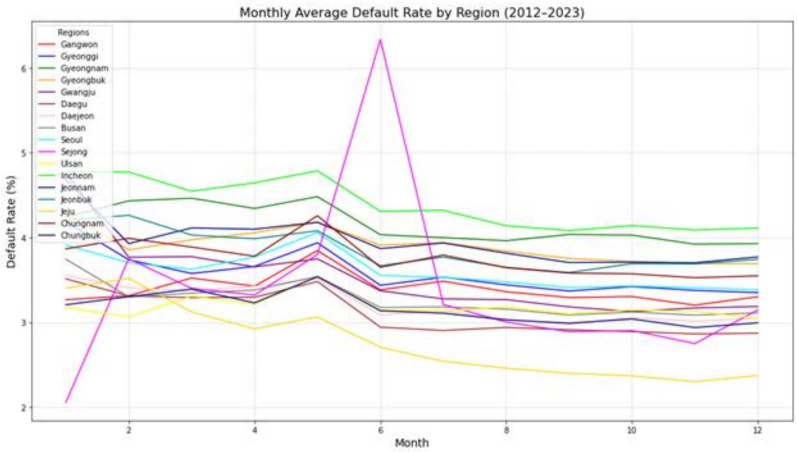

Figure 3. Monthly Average Default Rate by Region (2012–2023)

Figure 2 illustrates the annual average default rate trends for 18 major regions in South Korea, providing valuable insights into long-term variations and anomalies in regional default rates. Most regions exhibit a declining trend in default rates after 2012, followed by an upward trajectory starting in 2022. This shift likely reflects the economic changes and external shocks in the post-pandemic era. Sejong and Jeju demonstrate unique patterns compared to other regions. In Sejong, default rates remained at the lowest levels in 2018 and 2022, indicating relative stability. However, a sharp increase in default rates occurred after 2022, suggesting that Sejong's status as an administrative city with a relatively young economic structure may have made it more sensitive to specific external factors. In Jeju, a significant decline in default rates was observed in 2016, but this trend reversed with a sharp increase in subsequent years, likely influenced by its dependence on specific industries such as tourism.

In contrast, Gangwon, Incheon, and Gyeongnam exhibited relatively high default rates in the early years of analysis but showed consistent declines over time. This pattern suggests that economic stabilization efforts and credit guarantee policies in these regions may have positively impacted their credit risk profiles. Since 2022, a common trend of rising default rates has been observed across all regions, with Sejong and Jeju exhibiting the steepest increases. These anomalies appear to be closely linked to each region's economic characteristics, industrial structures, and external factors, such as the speed of economic recovery following the pandemic.

Figure 3 highlights the monthly average default rate trends, offering critical insights into how default rates vary across months. A prominent feature is a sharp increase in default rates in June for Sejong. This anomaly may be related to Sejong's status as a newly established administrative city in 2012, with data availability beginning in June 2015. The initial economic development efforts in the city, involving large-scale financial support, might have contributed to this anomaly. Other regions do not exhibit distinct anomalies, and most show relatively stable monthly default rate trends with minimal seasonal effects. However, Incheon and Gyeongnam report higher default rates than other regions on average, potentially reflecting the influence of their industrial structures and economic conditions. Conversely, Jeju records the lowest default rates, with a pronounced decrease in default rates in the latter half of the analysis period. This trend likely reflects the unique characteristics of Jeju as an island region and its economic reliance on tourism and leisure industries.

To further quantify the stability and variability of default rates across regions, **Figure 4** presents an analysis of the range of default rate fluctuations (maximum - minimum) from 2012 to 2023. This provides a basis for assessing the magnitude of changes in default rates across regions and for comparing the characteristics of regions with high variability against those with more stable default rate patterns. Through this analysis, the sensitivity of each region's default rates to external factors and economic characteristics can be understood in greater detail.

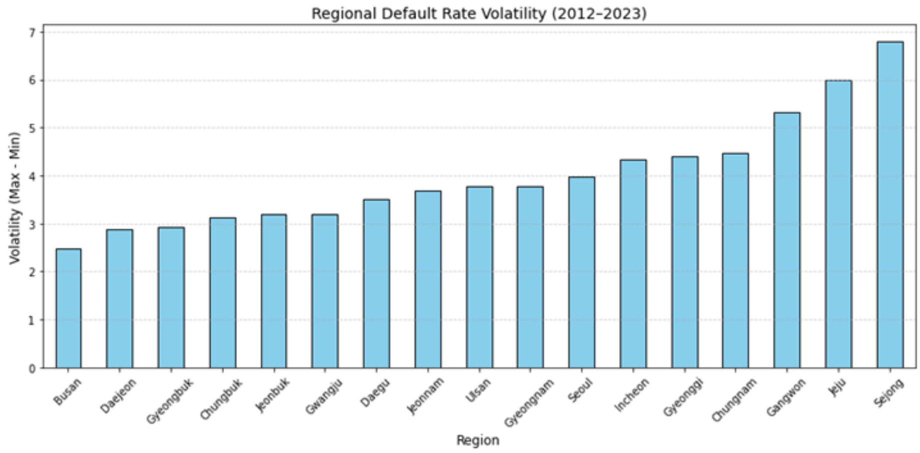

Figure 4. Regional Default Rate Volatility (2012–2023)

The region with the highest fluctuation range in default rates is Sejong, with a fluctuation of approximately 7%, showing significantly greater variability compared to other regions. This variability is likely attributable to Sejong's status as a newly established city, with data collection beginning only in 2015. The city's economic structure remained unstable during the initial stages, and specific anomalies at certain time points could have contributed significantly to this observed variability. Similarly, Jeju recorded a fluctuation range of approximately 6%, ranking second after Sejong. Jeju's reliance on specific industries such as tourism suggests that it was particularly sensitive to external factors such as the pandemic and international travel restrictions, which could have amplified its economic vulnerability.

In contrast, regions such as Busan, Daejeon, Gyeongbuk, and Chungbuk exhibited fluctuation ranges below 3%, indicating relatively stable patterns in default rates. This stability suggests that these regions possess more mature economic structures and balanced industrial bases. Notably, Busan demonstrated the lowest fluctuation range, maintaining stability despite its exposure to globally sensitive industries such as shipping and trade. The fluctuation ranges for Seoul and Gyeonggi were moderate, reflecting their large-scale and diversified economic structures. This diversification likely provides these regions with a higher degree of resilience against external shocks compared to other regions.

The analysis from **Figure 1** to **Figure 4** provided a comprehensive visual comparison of default rate patterns and anomalies across regions. Particularly, the anomalies in Sejong and Jeju highlighted the instability and abrupt variability in default rates at specific time points. These anomalies could be attributed to policy changes, external economic shocks, or structural characteristics unique to each regional economy. In contrast, regions with smaller fluctuation ranges, such as Busan and Daejeon, demonstrated more stable default rate patterns, suggesting greater resilience to economic shocks and a more balanced industrial base.

However, visual analysis alone is insufficient to quantitatively identify the specific timing and impact of anomalies. To determine the precise causes of anomalies and their relative importance within the overall dataset, more advanced time series analysis techniques are required. Consequently, the next phase of this study employs the Prophet model to detect anomalies and quantitatively evaluate how specific anomalies relate to overall trends and seasonality in the data. As a robust tool for time series analysis, the Prophet model enables the separation of trends and seasonality while effectively detecting anomalies. This will allow for an in-depth examination of the timing and characteristics of anomalies in each region.

2. Anomaly detection using the Prophet model

The Prophet model, developed by Meta (formerly Facebook), is recognized as a robust tool for time series analysis, capable of effectively decomposing data into trend, seasonality, and external events. Particularly, it excels in detecting anomalies, offering intuitive and interpretable results while handling irregularities in data with efficiency. In this study, the Prophet model was utilized to analyze regional default rate data and identify anomalies. Unlike traditional time series models that focus solely on forecasting, the Prophet model enhances analysis by pinpointing the timing and characteristics of anomalies. By separating trends and seasonality from the data, the model provides a clear framework to evaluate the extent to which anomalies deviate from the natural progression of the dataset.

The model proves to be especially suitable for examining anomalies in regions such as Sejong and Jeju. For instance, Sejong's significant surge in default rates can be attributed to its status as a newly established city, where economic structures are less stable. The Prophet model enables the precise separation of such anomalies from broader trends and seasonal patterns, facilitating a more nuanced analysis. Similarly, Jeju's dependency on tourism-related industries likely renders it more sensitive to external factors, such as economic shocks and policy changes. The Prophet model effectively captures such external disruptions, allowing for detailed anomaly detection. Therefore, the Prophet model serves as a critical tool for identifying the timing and characteristics of anomalies. By evaluating the significance of each anomaly in the context of the dataset's overall flow, the model contributes valuable insights to the regional analysis of default rates. This study demonstrates the model's utility in advancing anomaly detection and its potential to play a pivotal role in developing risk management strategies based on regional default rate data.

Data preprocessing

The Prophet model requires input data in a specific format for effective time series analysis. The default rate data used in this study originally consisted of a multidimensional structure where each region was represented as a column. However, the Prophet model requires a univariate structure with two specific columns: *ds* (date) and *y* (value). To meet this requirement, the date information from the original dataset was mapped to the *ds* column, and the default rate values for each region were assigned to the *y* column as the target variable for prediction. To enhance the accuracy of anomaly detection and forecasting, external factors were incorporated into the analysis. Public holiday data from 2012 to 2023 was collected using the holidays library and integrated into the Prophet model. Additionally, a variable called Holiday_or_Weekend, which combines public holiday and weekend indicators, was created to enable a more precise analysis of whether specific anomalies were influenced by external factors. By incorporating these external influences, the Prophet model improves anomaly detection accuracy and evaluates the significance of anomalies relative to the dataset's natural flow.

As Sejong is a newly established city that came into existence in 2012, its data collection began in June 2015. To address this, data for Sejong prior to June 2015 was excluded from the Prophet model analysis. This decision ensures consistency by eliminating incomplete or incomparable data from the early stages of the city's development. Moreover, to mitigate potential analysis errors caused by missing values, an interpolation technique was applied, ensuring the consistency and completeness of the training data for the Prophet model.

The final dataset prepared for the Prophet model consists of the following columns: *ds* (date), *y* (default rate), Holiday (public holidays), Weekend (weekend indicator), and Holiday_or_Weekend (combined holiday and weekend indicator). This preprocessing enables the effective separation of trends and seasonality from the default rate data, facilitating improved anomaly detection and prediction. The structure of the dataset after preprocessing is as follows:

Table 2: Final Dataset Structure for Prophet Model Analysis.

ds	y	Holiday	Weekend	Holiday_or_Weekend
				144
				3.49%
				1.77%
				8.48%
				0.91%

Model training and anomaly detection

In this study, the Prophet model's holidays parameter was utilized to incorporate a total of 208 public holiday dates in South Korea, along with additional weekend data to evaluate anomaly occurrence with greater precision. The trained Prophet model generates predictions based on historical data, and anomalies are defined as points where the residuals—the difference between the predicted values (*yhat*) and the actual values (*y*)—exceed a set threshold (e.g., ±2 standard deviations). This anomaly definition enables the Prophet model to distinguish between normal data flows and irregular variations effectively. **Figure 5** visualizes the anomaly detection results for the default rate data across 18 major regions using the Prophet model. The blue line represents the actual default rate data, the orange line shows the predictions made by the Prophet model, and the red dots indicate the points identified as anomalies. Anomalies are visualized alongside public holiday and weekend data, facilitating the assessment of their correlation with external factors.

Seoul and Gyeonggi displayed the smallest discrepancies between the Prophet model's predictions and the actual data, demonstrating relatively stable default rate patterns. This stability suggests that these regions, with their large economic scale and diversified industrial structures, are less affected by external factors, allowing the Prophet model to accurately reflect trends and seasonality. In contrast, regions such as Gyeongnam, Ulsan, Jeonnam, and Jeonbuk showed larger differences between the actual data and the predictions, indicating a higher sensitivity to specific industrial structures or external factors.

Gyeongnam and Ulsan, characterized by manufacturing-centric economic structures, are likely to experience sharp fluctuations in default rates due to global economic changes or seasonal demand variations in specific industries. Such volatility is reflected as anomalies that are challenging for the Prophet model to predict, increasing the discrepancy between the actual and predicted values. Similarly, Jeonnam and Jeonbuk, with agriculture-based economic structures, may experience significant impacts from seasonal factors, leading to deviations between the Prophet model's predictions and the actual values. A quantitative evaluation of anomaly intensity could further clarify the characteristics of these regions.

Sejong exhibited the most pronounced anomalies among the regions, particularly during 2022 and 2023, when default rates spiked dramatically. This pattern is likely linked to Sejong's status as a newly established administrative city, with an economic base that is not yet fully stabilized. The anomalies in Sejong appear to be highly responsive to external factors such as public holidays and weekends. Notably, the economic impact of the COVID-19 pandemic likely exacerbated these anomalies, as economic activities contracted more significantly in regions like Sejong with weaker economic foundations. The post-pandemic economic uncertainty and decreased industrial activity are presumed to be key contributors to the intensity of anomalies observed in these regions.

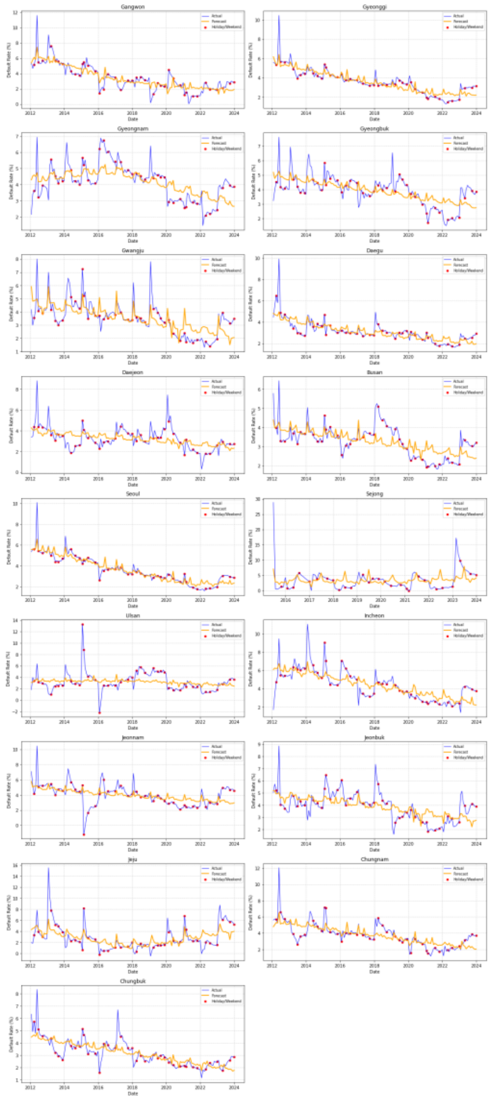

Figure 5. Anomaly Detection of Default Rates in 18 Regions Using the Prophet Model

Jeju stands out as a region with distinct anomaly occurrence points and high anomaly intensity. Its economy, heavily reliant on tourism, shows a strong correlation between anomalies and changes in economic activities during holidays and weekends. During the COVID-19 pandemic, travel restrictions and the decline in the tourism industry significantly impacted Jeju's regional economy, leading to a sharp increase in default rates that manifested as anomalies. The Prophet model effectively detected these anomaly points, offering opportunities to analyze the relationship between external factors and anomalies.

Incheon consistently recorded higher-than-average default rates and exhibited a relatively high frequency of anomalies. Notably, patterns of anomalies closely associated with holidays and weekends were observed, suggesting that the seasonal characteristics of logistics and industrial activities centered around airports and seaports might have influenced default rates. Gangwon, on the other hand, showed high default rates in the initial data but later exhibited a stable declining trend with a lower frequency of anomalies. This suggests that, as a less significant economic hub, Gangwon was less affected by external factors such as holidays and weekends.

Major cities such as Daejeon, Daegu, and Busan demonstrated low frequencies of anomalies and stable economic patterns with no clear association between anomalies and holidays or weekends. This indicates that these cities, with their diverse industrial bases, are less sensitive to external factors. Gwangju, as a metropolitan area, also exhibited a low frequency of anomalies but displayed significant anomalies at certain points, indicating localized impacts from specific industries or external factors. Jeonnam, similar to Chungbuk and Chungnam, showed a low frequency of anomalies and minimal influence of holidays or weekends on default rate fluctuations, reflecting its stable economic characteristics.

V. Conclusion

This study utilized the Prophet model to analyze the default rate data of Korea Credit Guarantee Fund (KODIT) for 18 major regions in South Korea from 2012 to 2023. Through the process of detecting anomalies, this research aimed to derive insights for regional credit risk management strategies. The anomaly detection results of the Prophet model revealed that economically stable and diversified regions, such as metropolitan areas like Seoul and Gyeonggi, exhibited minimal discrepancies between predicted and actual values, resulting in low anomaly occurrence rates and stable default rate patterns. In contrast, regions with nascent economic structures or those reliant on specific industries, such as Sejong and Jeju, experienced more frequent and intense anomalies. The frequent anomalies in Sejong can be attributed to its status as a newly developed administrative city, making it more susceptible to external shocks such as the COVID-19 pandemic. Similarly, Jeju's tourism-dependent economic structure likely played a significant role in the anomalies observed during the pandemic when travel restrictions and the decline in the tourism sector had a substantial impact on the region's economy.

Furthermore, the Prophet model facilitated a visual analysis of the impact of external factors, such as public holidays and weekends, on the occurrence of anomalies. While some regions showed a concentration of anomalies during these periods, others exhibited no clear correlation. This finding underscores the varying influence of economic structures and industrial characteristics on the anomaly patterns across regions. For instance, regions like Gyeongnam and Ulsan, with their manufacturing-based economies, were highly sensitive to seasonal factors and global economic changes, whereas metropolitan cities such as Gwangju showed anomalies at specific points but generally exhibited stable economic activities.

In conclusion, this study demonstrated the effectiveness of the Prophet model in analyzing regional default rate data and detecting anomalies. However, it also highlighted several limitations and areas for future research. First, the analysis of anomaly causes relied primarily on visual and qualitative assessments. Future studies should focus on quantitatively evaluating the intensity and frequency of anomalies and systematically linking them to external factors, such as global economic changes, policy shifts, or natural disasters, to identify the underlying causes more precisely. Second, while this study provided some policy implications based on anomaly detection results, it did not propose detailed risk mitigation strategies for regions or periods with high anomaly frequencies. Future research should develop region-specific credit risk management strategies and actionable policy recommendations, validated through empirical analysis, to ensure practical economic contributions. Finally, although the study emphasized the performance of the Prophet model, it also observed certain limitations in explaining long-term trends and seasonality in default rate data. Future research should explore the integration of data-driven machine learning techniques or hybrid models incorporating external factors to enhance anomaly detection and prediction capabilities.

References

[1]. Status Of Korean Smes. Available Online: Https://Www.Mss.Go.Kr/Site/Eng/02/20202000000002019110610.Jsp (Accessed On 12 June 2024).

[2]. Lee, J.H., Ryu, J., Tsomocos, D.P. Measures Of Systemic Risk And Financial Fragility In Korea. Ann Finance 2013, 9, Pp. 757—786. Https://Doi.Org/10.1007/S10436-012-0218-X

[3]. Yun, J., Moon, H. Measuring Systemic Risk In The Korean Banking Sector Via Dynamic Conditional Correlation Models. Pac.-Basin Financ. J. 2014, 27, Pp. 94–114. Https://Doi.Org/10.1016/J.Pacfin.2014.02.005

[4]. Syrova, L., Špiˇcka, J. Exploring The Indirect Links Between Enterprise Risk Management And The Financial Performance Of Smes. Risk Manag 2023, 25, Article Number 1. Https://Doi.Org/10.1057/S41283-022-00107-9
[5]. Kim, H.J., Park, S.Y. The Relationship Between Business Cycles And SME Default Rates. Korean Economic Review 2015, 31, Pp. 45–67. Https://Doi.Org/10.1007/S10436-012-0218-X.
[6]. Kim, D., Kim, S., Lee, J.S. The Rise And Fall Of Industrial Clusters: Experience From The Resilient Transformation In South Korea. Ann Reg Sci 2023, 71, Pp. 391-–413. Https://Doi.Org/10.1007/S00168-022-01170-6
[7]. Lee, S., Ishiro, T. Regional Economic Analysis Of Major Areas In South Korea: Using 2005–2010–2015 Multi-Regional Input–Output Tables. Economic Structures 12, 2023, 12. Https://Doi.Org/10.1186/S40008-023-00304-Z
[8]. Taylor, S.J., Letham, B. Forecasting At Scale. American Statistician 2018, 72, Pp. 37–45. Https://Doi.Org/10.1080/00031305.2018.1510937
[9]. Sang, L., Zhou, H., Yang, K. Robust Forecasting With Facebook Prophet: Application In Anomaly Detection. International Journal Of Forecasting 2020, 36, Pp. 1181–1193. Https://Doi.Org/10.1016/J.Ijforecast.2019.09.012
[10]. Ren, H., Xu, B., Wang, Y., Zeng, H. Time Series Anomaly Detection: A Survey On The State-Of-The-Art. Data Science And Engineering 2019, 4, Pp. 76–93. Https://Doi.Org/10.1007/S41019-019-00118-9
[11]. Kumar, V., Singh, A., Rathore, A.K. Real-Time Anomaly Detection For Iot Data Using Facebook Prophet. Journal Of Internet Of Things 2021, 6, Pp. 220–233. Https://Doi.Org/10.1016/J.Iot.2021.101063