COVID-19 Policies and Payment Delays: Panel Data Insights from Korea's Food Industry

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***Abstract*—COVID-19 recognized as the fifth deadliest pandemic in recorded history, has had profound impacts on global economic activities, notably in the food industry. This study investigates the financial repercussions within Korea's food sector, focusing on arrears and delayed payments from January 2020 to December 2022. Utilizing logistic regression and panel data analysis techniques, we analyze a dataset of 120 food sector firms to determine the key factors influencing arrears' delay amounts. Our research assesses the effects of policy stringency indices and confirmed COVID-19 cases on the likelihood of payment delays, alongside considering city-specific impacts to address regional disparities in financial health. Despite existing literature on policy impacts during economic shocks, studies specifically exploring the effects of COVID-19-related policies on payment behaviors in the food industry are limited. Our findings contribute to this gap by providing empirical insights into the complex relationship between pandemic-driven policies and their economic consequences. Methodologically, the study uses logistic regression models to estimate the probability of arrears delays, incorporating adjustments for unobserved heterogeneity and temporal dynamics. The results highlight significant implications for policymakers and underscore the need for targeted interventions to mitigate financial instability in the food sector. Future research directions are also discussed.**

***Index Terms*—COVID-19 Policies, SMEs, Economic Impacts, Panel Data Analysis, Logistic Regression**

I. Introduction

COVID-19 has caused an estimated global death toll of 7.05 million [1], [2]. The pandemic's unprecedented, unpredictable, and highly complex nature hindered the early implementation of effective policy responses. Efforts to control the virus were further complicated by the intricate patterns of its spread, delaying progress in managing and mitigating its effects. Initial research focused on tracking the pandemic's trajectory using methods such as analyzing variations in flight activity to detect spatiotemporal shifts [3] and developing long-term forecasts to enhance preparedness for future pandemics [3], [4].

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Amidst this backdrop, the COVID-19 pandemic has also significantly disrupted economic activities worldwide, profoundly affecting sectors like the food industry. In Korea, the food sector has faced considerable financial stress, evidenced by increased arrears and delayed payments among firms. This study focuses on analyzing arrears data within Korea's food sector using logistic regression and panel data analysis techniques, spanning from January 2020 to December 2022. Our analysis seeks to identify the key determinants of arrears delay amounts among firms, incorporating the effects of policy stringency indices—which reflect the strictness of measures to control the spread of COVID-19—and confirmed COVID-19 cases.

The primary objective of this research is to evaluate how different factors, such as lagged policy stringency measures and confirmed COVID-19 cases, influence the likelihood of arrears delays. Additionally, we consider city-specific effects to explore regional disparities in the financial health of firms within the food sector. This comprehensive approach enables us to capture the multifaceted nature of the economic impact of the pandemic on the food industry.

Previous studies have underscored the importance of policy interventions in mitigating the adverse effects of economic shocks. However, empirical evidence specifically addressing the impact of COVID-19-related policies on arrears delays in the food sector remains limited. This study contributes to the literature by providing empirical insights into the relationship between policy measures, pandemic severity, and payment delays.

Methodologically, we employ logistic regression models to estimate the probability of arrears delays based on various explanatory variables. We account for unobserved heterogeneity and temporal dynamics through panel data analysis, ensuring our results are both robust and reliable. The inclusion of city-specific variables allows us to control for regional factors that may influence the financial behavior of firms.

In the following sections, we provide a detailed overview

of the data and methodology used in this study, present empirical results, interpret these findings, and discuss the policy implications. We conclude with suggestions for future research directions.

II. Related Work

The economic impact of the coronavirus disease-19 (COVID-19) is often measured in terms of GDP decline [5]. The United States and major European countries as well as Japan and South Korea expected to see GDP declines [6].

Meanwhile, some studies have revealed that the negative economic impact of COVID-19 is mainly found in small and medium-sized enterprises (MSMEs) [7]–[9]. Compared to large enterprises, SMEs are less able to withstand the shock due to their size and resources [10], [11]. Infectious disease response policies, such as lockdowns and social distancing, are necessary, but they reduce personal consumption [12], [13]. The resulting economic losses and impacts are reflected unevenly across regions [14]. Several studies on the impact of the COVID-19 crisis on small businesses have focused on the impact of initial lockdowns and social distancing measures. These studies generally examine the impact on industries that experienced revenue losses. Fairlie et al. [9] found that in the second quarter of 2020, lockdowns in California resulted in a loss of 17% in sales, with industries heavily affected by essential lockdowns, such as hospitality, reporting a 91% loss in sales.

Economic entities respond differently to unexpected external shocks according to their resistance [12]. In particular, regional resistance is affected by regional economic structure, resources, capacity, expertise, and local institutions [15]. Recent discussions have focused on the diversity of industrial structures [16], industrial composition [15], and agglomeration economies [17]. Deloitte [18] pointed out three main pathways through which COVID-19 could impact the global economy: directly affecting production potential, disrupting supply chains and the flow of goods and services, and financially impacting firms and markets [16].

Aside from these studies, the following works also explored the economic and business impact of COVID and policies. Kato et al. [19] provided insights into CEO compensation in Japan, revealing that CEO pay is significantly linked to firm performance, particularly accounting measures, and noted a lesser influence of stock market performance on compensation, suggesting unique aspects of Japanese corporate governance. Dietsch et al. [20] examined the persistence of late payments among French firms, highlighting that late payers reduced their Days Purchases Outstanding (DPOs) by 5.1 days on average after the imposition of a 60-day payment term limit, with variations across different sizes of firms. Apedo-Amah et al. [21] discussed global business impacts due to COVID-19, emphasizing the dissemination of firm-level evidence and the importance of policy adjustments in light of ongoing economic challenges. Lastly, Kim et al. [22] focused on the geographical spread of COVID-19 in South Korea and its differential impacts on local economies by establishment size and industry, particularly noting the adverse effects on industries requiring face-to-face interactions. These studies provide a comprehensive overview of the varying impacts of COVID-19 and other factors on business dynamics across different contexts and geographical locations.

III. Dataset

This study aims to estimate the impact of COVID-19 on the late payment behavior of firms in the food industry in Korea. To this end, we have collected firm-level panel data spanning three years, from January 2020 to December 2022. The panel dataset contains 4320 observations of these 120 food sector firms across various cities in Korea, spread over 36 time periods. The dependent variable, *Arrears Delay Amount*, is a binary outcome indicating whether a firm has delayed payments. The detailed description of the dataset is as follows:

- **COVID-19 Dataset**: We utilize data on newly confirmed COVID-19 case reports sourced from the Ministry of Health and Welfare's COVID-19 Regional Occurrence Status [23]. This dataset includes all Korean subregions and cities. We used seven cities' data with the highest population.
- **Dataset for COVID-19 Policy:** OxCGRT dataset [24] offers detailed statistics on COVID-19 policy responses around the world. It contains three years' worth of policy data from more than 180 countries, with 23 policy indicators like travel bans, school closures, and vaccination campaigns. Several indices, such as the Government Response Index, the Containment and Health Index, the Stringency Index, the Economic Support Index, and an older (legacy) version of the Stringency Index, are computed to provide a general sense of government activity. The table provides specifics about these indices.
- **Firm-Level Data**: Data on Korean food industry firms was provided by the NICE Credit Rating Agency [25].

IV. Methodology

A. Hypotheses

Our main hypothesis is that government intervention through stringency measures has a statistically significant effect on the likelihood of arrears in food sector firms in Korea. More stringent measures are expected to reduce the probability of arrears. To test this, we implement logistic regression with variables to be detailed in the following subsections.

B. Dependent variables

1) COVID-19 Confirmed Cases: The number of confirmed COVID-19 cases is included to reflect the direct impact of the pandemic policies on economic activities and firm operations. It is expected that higher numbers of confirmed cases and more stringent policies correlate with higher arrears due to disruptions in business operations and consumer demand. The dependent variable in the dataset is binary, represented as either 0 or 1. This binary outcome indicates whether a firm was in arrears during a given month, with 1 signifying that the

TABLE I
POLICY MEASURES AND INDEX COMPONENTS

Policy	GRI	CHI	SI	ESI	Type
School closing	×	×	×		Ordinal
Workplace	×	×	×		Ordinal
Events	×	×	×		Ordinal
Gatherings	×	×	×		Ordinal
Transport	×	×	×		Ordinal
Stay home	×	×	×		Ordinal
Movement	×	×	×		Ordinal
Travel	×	×	×		Ordinal
Income	×			×	Ordinal
Debt relief	×			×	Ordinal
Fiscal					Numeric
Int'l support					Numeric
Info campaign	×	×			Ordinal
Testing	×	×			Ordinal
Tracing	×	×			Ordinal
Healthcare					Numeric
Vaccines					Numeric
Masks	×	×			Ordinal
Vaccination	×	×			Ordinal
Elderly care	×	×			Ordinal
Misc.	×			×	Ordinal

Note: GRI = Government Response Index (k=16); CHI = Containment and Health Index (k=14); SI = Stringency Index (k=9); ESI = Economic Support Index (k=2). × indicates inclusion in the respective index.

firm was delayed in its financial obligations, and 0 indicating timely financial conduct.

C. Explanatory Variables

In this study, we incorporate several explanatory variables to understand the factors influencing arrears delay amounts in the food sector firms in Korea. Below, we detail each of the explanatory variables included in the models:

1) Stringency Index: The Stringency Index measures the strictness of government policies in response to COVID-19. It includes indicators such as school closures, workplace closures, and travel bans. We use lagged versions of the Stringency Index to capture the delayed effects of these measures on arrears delay amounts. The specific lags included are:

- **Stringency Index lag 1**: The one-month lagged average of the Stringency Index.
- **Stringency Index lag 2**: The two-month lagged average of the Stringency Index.
- **Stringency Index lag 3**: The three-month lagged average of the Stringency Index.
- **Stringency Index lag 4**: The four-month lagged average of the Stringency Index.
- **Stringency Index lag 5**: The five-month lagged average of the Stringency Index.

2) Government Response Index: The Government Response Index captures the broader set of government actions, including economic measures and health system responses. Similar to the Stringency Index, we include lagged versions to account for delayed impacts:

- **Government Response Index lag 1**: The one-month lagged average of the Government Response Index.
- **Government Response Index lag 2**: The two-month lagged average of the Government Response Index.

D. Control Variables

To account for regional variations, we include dummy variables for major cities in South Korea where the firms are located. These dummies help control for unobserved heterogeneity across different geographical locations.

E. Regression model

A logistic regression model within a panel data analysis framework (Panel OLS) is employed to assess the impact of government policy responses on the likelihood of arrears. Independent variables include:

- Government policy indices over different lag periods to capture the delayed effects of policies.
- The number of confirmed COVID-19 cases as a control for pandemic severity.
- City dummies to control for location-specific economic conditions.

Equation (1) (Baseline pooled model firms) describes the logistic regression model used to estimate the likelihood of arrears delay amount for firms within Korea's food sector. The model is specified as follows:

$$\begin{aligned}\log\left(\frac{p_{i,t}}{1-p_{i,t}}\right) = \beta_0 &+ \beta_1 \cdot \text{Stringency Index lag } 1_{i,t} \\ &+ \beta_2 \cdot \text{Stringency Index lag } 2_{i,t} \\ &+ \cdots \\ &+ \beta_{16} \cdot \text{City Incheon}_{i,t} + \epsilon_{i,t}\end{aligned} \tag{1}$$

where:

- $\log\left(\frac{p_{i,t}}{1-p_{i,t}}\right)$ is the log-odds of the dependent variable *Arrears Delay Amount*.
- β_0 to β_{16} are the coefficients for the respective independent variables.
- The independent variables include lagged stringency indices, confirmed cases, and city names, reflecting potential differences in arrears delay behavior across different administrative areas within Korea.
- $\epsilon_{i,t}$ is the error term.

This equation incorporates and analyzes the effects of COVID-19-related policy interventions and regional disparities on financial outcomes within the Korean food sector. Here, we are focusing on how stringency in governmental responses and regional characteristics might affect the financial stability or credit behavior of businesses in this sector, using historical and real-time data adjusted for lags to account for the delayed effects of policies.

V. REGRESSION RESULTS

A. Model Fit and Goodness-of-Fit

The provided Panel OLS estimation summary outlines the statistical results from a panel regression model analyzing arrears among Korean firms in the food service sector. The

TABLE II
PANEL OLS ESTIMATION SUMMARY

Statistic	**Value**
Number of Observations	4320
Entities	120
Time periods	36
Dependent Variable	*Arrears Delay Amount*
Cov. Estimator	Clustered
R-squared	0.0680
R-squared (Between)	0.8166
R-squared (Within)	0.0313
R-squared (Overall)	0.0680
Log-likelihood	1114.4
Distribution	F(17,4303)
F-statistic	18.459
F-statistic (robust)	41.785
p-value	0.00

TABLE III
POOLED OLS MODEL SUMMARY

	Parameter	Std. Err.	t-stat	p-value	Lower CI	Upper CI
Strg. Index lag 1	0.0022	0.0016	1.3584	0.1744	-0.0010	0.0054
Strg. Index lag 2	-0.0041	0.0015	-2.7418	0.0061[a]	-0.0071	-0.0012
Strg. Index lag 3	-0.0002	0.0005	-0.4003	0.6890	-0.0011	0.0007
Strg. Index lag 4	-0.0011	0.0005	-2.0153	0.0439[b]	-0.0021	-2.9e-05
Strg. Index lag 5	-0.0004	0.0004	-1.0666	0.2862	-0.0011	0.0003
Govt. Resp. Index lag 1	-0.0039	0.0021	-1.8311	0.0672[c]	-0.0081	0.0003
Govt. Resp. Index lag 2	0.0073	0.0022	3.2998	0.0010[a]	0.0030	0.0117
Strg. Index	0.0251	0.0130	1.9313	0.0535[c]	-0.0004	0.0505
Govt. Resp. Index	-0.0115	0.0077	-1.4958	0.1348	-0.0266	0.0036
Confirmed Cases	0.0171	0.0085	2.0161	0.0438[b]	0.0005	0.0338
City Gwangju	0.0201	0.0070	2.8647	0.0042[a]	0.0063	0.0339
City Daegu	0.0213	0.0073	2.9264	0.0034[a]	0.0070	0.0355
City Daejeon	0.0141	0.0068	2.0836	0.0373[b]	0.0008	0.0274
City Busan	0.0215	0.0080	2.6989	0.0070[a]	0.0059	0.0372
City Seoul	0.0220	0.0079	2.7713	0.0056[a]	0.0064	0.0375
City Ulsan	0.0232	0.0101	2.2979	0.0216[b]	0.0034	0.0430
City Incheon	0.0267	0.0072	3.6958	0.0002[a]	0.0126	0.0409

[a] significant at $p < 0.01$
[b] significant at $p < 0.05$
[c] significant at $p < 0.1$

summary provides several crucial statistics and diagnostics that inform the interpretation of the model's effectiveness and the reliability of the findings.

- Dependent Variable: *Arrears Delay Amount* indicates the binary status of firms being in arrears.
- Overall R-squared (0.0680): This value is relatively low, suggesting that only 6.8% of the variability in the firms' arrears status is explained by the independent variables included in the model. It indicates a weak fit of the model to the data.
- Between R-squared (0.8166): Contrasting the overall R-squared, the *between* R-squared is substantially higher, which implies that the model better explains the variation between different entities (firms) than it does within the same entity over time.
- Within R-squared (0.0313): This value suggests that the model may not effectively capture the temporal dynamics or variations within individual entities across different periods.
- F-statistic (18.459 with p-value 0.0000): The F-statistic is highly significant, indicating that the model as a whole has statistical merit and that the explanatory variables collectively influence the dependent variable.
- Robust F-statistic (41.785 with p-value 0.0000): The robust F-statistic, which adjusts for potential heteroscedasticity and autocorrelation within the panel data, also indicates a significant model fit.

The following can be noted.

- Model Fit and R-Squared Discrepancy: The overall R-squared value of 0.068 indicates that the model explains only 6.8% of the total variance in the arrears status. In contrast, the *between* R-squared value is significantly higher at 0.8166, suggesting the model is more effective in capturing cross-sectional differences between firms rather than temporal variations within firms. The low *within* R-squared value of 0.0313 further highlights the model's limited ability to explain changes over time within individual firms. This discrepancy likely reflects the dominance of firm-specific factors, such as inherent characteristics or industry-related conditions, over time-variant predictors in influencing arrears status. Additionally, the limited temporal variation in explanatory variables may contribute to the low *within* R-squared.
- Model Robustness: Despite the low R-squared values, the F-statistic (18.459, p-value < 0.0001) and robust F-statistic (41.785, p-value < 0.0001) confirm the model's overall statistical significance, indicating that the included predictors collectively influence the likelihood of arrears.
- Implications of the Discrepancy: The results underscore the importance of firm-specific characteristics in explaining cross-sectional differences in arrears status. However, the model's inability to capture within-firm temporal dynamics suggests potential omitted variables or limited variation in existing predictors. Future refinements could address this by incorporating more dynamic variables or interaction terms, though these modifications are outside the scope of the current analysis.

Nevertheless, the Panel OLS estimation results suggest that while the within-entity variation explained by the model is relatively low, the between-entity variation is substantially captured, indicating significant differences across entities in terms of their arrears delay behavior. The overall significance of the model and the robustness of the results provide a solid foundation for further interpretation of the individual coefficients and their implications.

B. Variable Interpretations

Stringency Index lag 1 to lag 5 represent the lagged effects of stringency measures on arrears. The coefficients suggest varying impacts. For instance, lag 2 (-0.0041) and lag 4 (-0.0011) are statistically significant with negative coefficients, indicating that higher stringency levels two and four months prior are associated with a decrease in the likelihood of

arrears. This might reflect the delayed effect of stringent measures improving firm stability or market conditions. lag 1, lag 3, and lag 5 show non-significant effects, suggesting no clear or consistent influence from stringency measures during these periods on arrears. Government Response Index lag 2 (0.0073) shows a positive and significant effect, implying that a higher governmental response two months earlier increases the likelihood of arrears. This might suggest that some government interventions, possibly restrictive ones, have a delayed adverse impact on firm liquidity or market conditions. lag 1 (-0.0039), though negative, is not statistically significant, indicating inconclusive effects from government actions one month prior. The confirmed cases coefficient is positive and significant, suggesting that higher confirmed cases of COVID-19 are associated with an increased likelihood of arrears, likely due to the direct and indirect impacts of the pandemic on business operations.

Coefficients for different cities are all positive and significant, indicating that firms located in these cities are more likely to experience arrears compared to the baseline city. This could be due to regional economic variations, differing local government responses, or varying levels of pandemic impact. P-values indicate the probability that the observed coefficient is due to chance if the null hypothesis (that the coefficient is zero) is true. Significant p-values (<0.05) like those for most city variables and certain lagged variables indicate evidence against the null hypothesis, suggesting a real effect. Non-significant p-values (e.g., for some lagged stringency indices and the Government Response Index) suggest that the effects observed could be due to chance, and these variables might not reliably predict arrears.

These underscore the complexity of the relationship between regulatory responses, pandemic conditions, and economic outcomes. They suggest significant regional differences in the impacts of these factors. The negative coefficients on certain lagged stringency measures might indicate the beneficial effects of strict regulations over time, while the positive coefficients associated with confirmed cases and some government responses suggest challenges in managing economic impacts during health crises. These findings can inform policymakers about the delayed effects of their interventions and help in planning more effective responses for future crises. The city-specific effects show that firms located in these cities generally have a positive and significant effect on the arrears delay amount. This indicates regional variations in the likelihood of arrears.

Overall, the model indicates that certain lagged stringency and government response indices, as well as confirmed COVID-19 cases, significantly influence the likelihood of arrears delay among firms in the food sector in Korea. The effects of these variables vary by lag period and city, highlighting the importance of considering both temporal and regional factors in analyzing arrears behavior during the COVID-19 pandemic.

VI. Hypotheses Evaluation

Hypothesis: Government intervention through stringency measures has a statistically significant effect on the likelihood of arrears in food sector firms in South Korea. More stringent measures are expected to reduce the probability of arrears.

- **Variables of Interest:** The lagged and current values of the Stringency Index (Stringency Index lag 1 to Stringency Index lag 5, and Stringency Index).
- **Findings:**
  - **Stringency Index lag 1:** The coefficient is 0.0022 with a p-value of 0.1744. This indicates a positive effect on arrears delay amount but is not statistically significant at the 5% level.
  - **Stringency Index lag 2:** The coefficient is -0.0041 with a p-value of 0.0061. This suggests a significant negative effect on arrears delay amount at the 1% level, supporting the hypothesis.
  - **Stringency Index lag 3:** The coefficient is -0.0002 with a p-value of 0.6890, indicating no significant effect.
  - **Stringency Index lag 4:** The coefficient is -0.0011 with a p-value of 0.0439, showing a significant negative effect at the 5% level.
  - **Stringency Index lag 5:** The coefficient is -0.0004 with a p-value of 0.2862, indicating no significant effect.
  - **Stringency Index:** The coefficient is 0.0251 with a p-value of 0.0535, suggesting a marginally significant positive effect at the 10% level.

The hypothesis is partially supported. While some lagged stringency indices (lag 2 and lag 4) show significant negative effects, indicating that more stringent measures reduce the likelihood of arrears, other indices do not show substantial effects or positive effects. The overall impact of stringency measures appears mixed, with more stringent measures potentially reducing arrears with a delayed effect.

While some lagged stringency measures support our Hypothesis by showing a significant reduction in arrears, the overall evidence is mixed. Further analysis with additional control variables or interaction terms might provide a clearer picture of the effects.

VII. Conclusion

Our study employs firm-level panel data from South Korea from 2020 to 2022 to estimate firms' responses to COVID-19 policies before and after the introduction of the pandemic. The results from our pooled model indicate that firms subject to higher stringency measures experienced a decrease in late payments, particularly with a two-month lag (coefficient -0.0041, $p<0.01$) and a four-month lag (coefficient -0.0011, $p<0.05$). Additionally, our analysis reveals significant regional variations, with all studied cities showing positive coefficients (ranging from 0.0141 to 0.0267, $p<0.05$), suggesting that urban areas experienced systematically higher probabilities of payment delays compared to other regions. These findings

align with prior research, demonstrating that targeted COVID-19 policies can effectively reduce payment delays when properly implemented while acknowledging the importance of regional economic contexts.

However, despite identifying significant relationships, a considerable portion of the variance in *Arrears Delay Amount* remains unexplained. This observation suggests potential omitted variable bias or key variables may be missing from our model. To improve the explanatory power of our analysis, future efforts could include integrating more comprehensive economic indicators such as regional GDP growth rates, industry-specific performance metrics, supply chain disruption indices, and firm-level financial health indicators (e.g., liquidity ratios, and operating margins). Additionally, examining non-linear relationships and interaction effects between policy measures and economic conditions could provide deeper insights. Applying fixed or random effects models might better capture unobserved heterogeneity, thus fully exploiting the advantages of our panel data.

Finally, given the complex nature of COVID-19 regulations compared to traditional measures regulating late payments, it is crucial to explore how firms internally adapt to such policies. Future research should delve into firms' internal strategies, such as adjustments in their approach to the mobility credit market or the challenges they face in trading mobility credits. Particular attention should be paid to how firms in different regions develop varying coping mechanisms in response to both local policy implementations and economic conditions. This will provide a more nuanced understanding of the pandemic's impact on business operations and financial practices while accounting for the regional heterogeneity observed in our study.

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