Understanding the Impact of COVID-19 on Economy and Environment in the Asia-Pacific Region

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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***Abstract*—The COVID-19 pandemic has provoked longstanding and competing interests of the economy and environment. In January 2020, countries across the globe began implementing various levels of safety measures to slow the spread of the virus. Safety measures have run the gamut of restrictions: physical distancing guidelines, proper handwashing practices, and the use of face masks are on the lower end of the restriction spectrum, while travel restrictions, business closures, and country-wide lockdowns are instances of more stringent measures. Policy responses have drastically differed among governments across the globe, but the economic strife has plagued countries regardless of their COVID-19 response plan. Lockdowns in the first half of 2020 impeded economic activity, leading to a reduction in industrial activity and hence emissions. During this time period, observations from publicly available satellite sensors have shown that concentrations of various atmospheric pollutants, nitrogen dioxide especially, have decreased. The Asia-Pacific region was no exception, with China, Japan, South Korea, Australia, and New Zealand all experiencing slowdown in growth and large reductions in various economic sectors. Using these five Asia-Pacific countries, we will analyze how government policy, lockdowns, and travel restrictions implemented during the COVID-19 outbreak have slowed economic growth in the transportation, manufacturing, and agriculture sectors, and in turn, impacted air quality and water quality. Conclusions and statistical significance of our analysis comparing coronavirus-related policies and their effect on economic growth and environmental health will help drive future decisions made by policymakers should another pandemic or similar global crisis arise.**

Keywords—COVID-19, economy, environment, China, South Korea, Japan, New Zealand, Australia

I. INTRODUCTION

The spread of COVID-19 was largely influenced by government containment policies. Restrictions have varied by timing and intensity among countries but can generally be organized into common categories. The University of Oxford's Blavatnik School of Government has developed a methodology to track and compare government responses. The Oxford COVID-19 Government Response Tracker (OxCGRT) collects publicly available information on 20 indicators of government response, which are aggregated into overall government response, containment and health, economic support, and lockdown stringency indices [3]. These metrics were considered to understand differences in government responses and their impacts on the economies and environments of countries in the Asia-Pacific region.

In late December 2019, health authorities in the Wuhan province of China detected several pneumonia cases from an unknown source with links to the Huanan Seafood Market, which led to a strict 76-day lockdown throughout China and ultimately the outbreak of a global pandemic. New Zealand's response to the virus shared similarities with that of China. Beginning on March 25, 2020, New Zealand entered a full-scale lockdown, which lasted over a month and included cancelations of all public gatherings, non-essential business and educational facility closures, and strict stay-at-home orders [6]. Strict responses seen in China and New Zealand were successful in containing the virus.

In other countries, nationwide lockdowns were not employed. Australia, which benefits from geographic isolation and lower population densities, succeeded in curtailing outbreaks by employing short-term, snap lockdowns on a regional basis. Overall, swift government response and bipartisan leadership have allowed Australians to return to some semblance of normalcy [5]. In South Korea, prioritization of detection, containment, treatment, transparency and communication with the public proved effective in limiting infections. By the end of 2020, total deaths were held to under 1,000 [3].

In comparison to the rest of Asia-Pacific region, Japan followed a relatively relaxed set of virus containment measures. In April 2020, the government recommended a State of Emergency in heavily populated areas. Japan tested only .2% of its population, allowed public transportation to operate normally, and relied on local governors in less densely populated regions to institute virus containment measures as seen fit [19]. These relatively mild measures allowed for higher transmission of the virus.

Inherent characteristics of individual countries, which are out of government control, have also played a significant role in shaping the spread of the virus. Population sizes vary widely among the countries considered; thus, absolute numbers can be misleading. Geography and population densities influence transmission rates, which affect the development of the pandemic on a localized scale. Deficiencies in testing limit the government's ability to properly respond. When comparing government responses in the time domain, the virus did not arrive in all countries simultaneously, so specific dates are not a useful method of comparison. For these reasons, there are limitations to comparing the effectiveness of government response between countries [4].

On November 16, 2020, these five nations (along with ten Southeast Asian countries) finalized the formation of the world's largest trading bloc, the Regional Comprehensive Economic Partnership, warranting a closer look at the implications of the pandemic for this regional economy [7].

II. DATA

To understand how the pandemic has affected economic development, weekly GDP year-on-year growth estimates were obtained from the Organization for Economic Cooperation and Development (OECD) [27]. The OECD's estimates are based on Google trends data related to consumption, trade, industrial activity, uncertainty, and other economic factors. For China, weekly GDP estimates were not available, so quarterly GDP data was utilized for analysis. Japan's monthly electricity production volume was also analyzed [23]. Furthermore, daily air quality data was obtained from the World Air Quality Index (WAQI) project to study potential environmental changes. WAQI's measurements are taken across multiple ground monitoring stations, and include measurements, in parts per million of NO_2, SO_2, CO, O_3, PM 2.5, and PM 10 [15]. Data was obtained from stations in Seoul, Shanghai, Tokyo, and Wuhan. New Zealand was the only country for which water quality analysis was performed. To examine potential improvements to water quality, various pollutants including biochemical oxygen demand, E. coli concentrations, nitrogen (NH_4, Nitrate Nitrogen, NNN, NO_3, and TKN), and phosphorus were analyzed in conjunction with changes in livestock slaughter, agricultural GDP, and other potential predictors [21].

III. METHODOLOGY

A. GDP Growth

R Studio was used as the primary software in GDP analysis. We examine the impact of COVID-19 on the economy of each country as a whole using time series analysis and predictive modeling. Past year-on-year, weekly GDP growth rates from each country were used to create models that predict how each economy might have functioned in 2020 had COVID never occurred. As economic data is serially correlated, time series analysis was implemented using data from years 2018 and 2019. To ensure stationarity of the data, spectral analysis was used to include trend and seasonality components. This method captures the time-related structure in the data by including a trigonometric function with unique periodicity, measured visually with a periodogram and validated quantitatively in R with sorting methods. An autoregressive moving average (ARIMA) model was used on the residuals. This produced sufficient models that accurately captured the time-related components within the GDP data based on the respective autocorrelation functions and partial autocorrelation functions (ACF and PACF). These models, based on each country's GDP estimates from 2018 to 2019, then predicted weekly GDP growth rates throughout 2020 along with 95% confidence intervals. In order to evaluate statistical differences between actual and predicted values, paired sample Wilcoxon Signed-Rank tests were used as data was not normally distributed.

B. Air Quality

Similar to GDP analysis, R Studio was the primary software used for air quality analysis. A time series was first created for NO_2, SO_2, CO, O_3, PM 2.5, and PM 10 during 2019 and 2020. Then, linear regression models were built for each pollutant, with the pollutant as the dependent variable and time, the Oxford Stringency Index, and transportation trends from Apple mobility data as predictors. Stepwise regression was then performed on each linear model, which produces a model that minimized the Akaike Information Criterion (AIC). This maximizes predictive power while simultaneously minimizing the models' complexity by eliminating unnecessary predictors. The aforementioned modeling uncovered statistically significant conclusions regarding the predictors' impact on greenhouse gas levels. For industry specific analyses related to air quality, ad-hoc statistical tests, such as a paired t-test, were used.

C. Water Quality

The methodology performed on the water quality data closely followed that of air quality analysis. Using a time series of total pollution, mostly consisting of nitrogen and phosphorus, linear and stepwise regression models were constructed with various pollutants as the dependent variables, and livestock slaughter numbers — cattle, sheep, goats, and pigs, the Oxford Stringency Index, agricultural GDP, and a binary lockdown indicator as predictors. Statistically significant conclusions regarding the predictors' impact on water pollution, specifically nitrogen and phosphorus levels were drawn.

IV. RESULTS

A. GDP Growth

As seen in Figure 1, regardless of government stringency, each country's economy suffered throughout 2020, especially during the second quarter. For Australia, New Zealand, South Korea, and Japan, real GDP growth estimates reported by the OECD throughout 2020 were significantly lower than what each model predicted based on previous years ($p < .001$). Japan, Australia, and South Korea's economies saw the heaviest impacts to overall 2020 GDP growth, with significant declines of ~4.0%, ~2.6%, and ~0.69% ($p<.001$, $p<.01$, $p<.05$). Quarterly analysis revealed that during the first quarter, Australia and New Zealand experienced slight economic growth while Japan was the only country with a median negative growth rate for this period.

As global COVID cases increased and government restrictions tightened, each country's domestic productivity fell in the second quarter ($p < .01$). Compared to previous years in the same period, Japan experienced the lowest average GDP growth of 10.5%. New Zealand and Australia's GDP both fell by 4.9%. South Korea's economy experienced the least impact, with a GDP decline of about only 2.2% throughout the second quarter. Although New Zealand and Australia only had relatively modest declines in each quarter, they both experienced the lowest GDP weekly growth rates across all countries near the end of the first quarter, with respective declines of 21.1% and 15.1%. However, New Zealand's economy was able to recover quickly within 11 weeks but Australia took 30 weeks to recover. Analyzing GDP growth over the first half of 2020 revealed that New Zealand's economy, even with the lowest

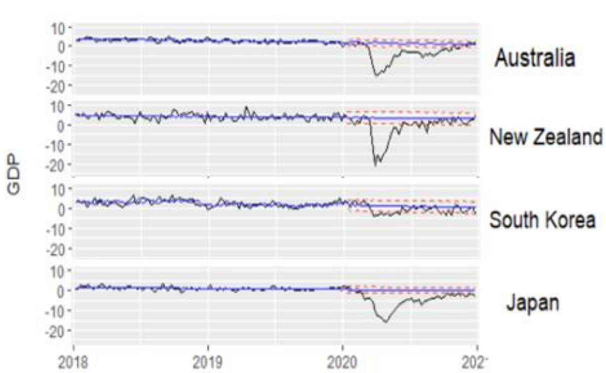

Fig. 1. Forecasted versus actual GDP growth

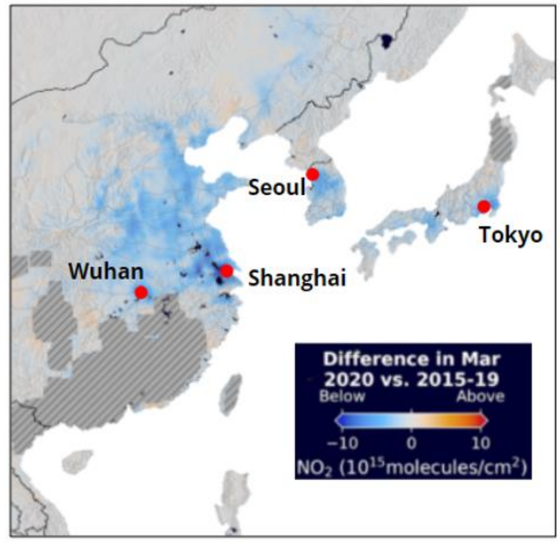

Fig. 2. Differences in NO_2 in the Asia-Pacific Region

GDP rate recorded in the first period, only experienced an average decline of 0.09%.

Korea's GDP growth was not significantly different from what the model predicted for the first quarter but was in the second quarter.

China is currently regarded as the second-largest economy. As the coronavirus epidemic spread worldwide, China's economic growth hit its lowest point since 1976. In the first quarter of 2020, China's economy recorded its first sharp decline in decades. In the fourth quarter of 2020, China reported a 6.5% year-on-year increase in their GDP and a 2.3% increase for all of 2020, which made China the only major economy that documented positive economic growth in 2020. Because China is a primary global importer of vital medical supplies, such as face masks, China's growth was concentrated in the pharmaceutical industry [13]. Additionally, due to its tense relations with Australia, most exported goods from Australia for coal, gold, iron ore, and liquefied natural gas are at risk [20]. Oxford Economics predicts that China will become the world's largest economy in 2029 due to China's domestic economic rebound [4].

B. Air Quality

The economic downturns and COVID-19 lockdowns caused significant reductions in vehicle traffic across all five countries [17] [26]. As a result, the decline in daily vehicle traffic led to significant reductions in nitrogen dioxide (NO_2), a greenhouse gas produced during the burning of fossil fuels. This reduction in NO_2 can be observed in NASA's satellite image taken of the Asia-Pacific region, as seen in Figure 2. Linear regression analysis revealed that daily vehicle traffic was a significant predictor ($p < 0.1$) of NO_2 in the major cities across all countries except for Japan, which was likely due to its more relaxed containment measures and travel restrictions. New Zealand, Australia, South Korea, and Japan's daily traffic all had a positive correlation with NO_2 levels of ~7.6 e-7, ~0.12, ~0.07, and ~0.07 at significant levels of $p = 4.8$ e-5, $p = 0.003$, $p = 0.08$, and $p = 0.48$. Moreover, the significance of the p-values for daily traffic and its predictiveness of NO_2 match the relative decline in traffic for each country shown in Figure 3. Traffic in New Zealand was the most predictive of NO_2 and also saw the greatest relative decline during its lockdown, whereas traffic in Japan, which was not significantly predictive of NO_2, declined the least compared to the other countries. There were several additional greenhouse gases in which traffic was significantly predictive. New Zealand's traffic was correlated with SO_2 levels ($p = 0.055$), and Australia's traffic was predictive of PM 2.5 (0.02), PM 10 ($p = 0.03$), and CO ($p = 0.003$).

Regional wind patterns also affect air quality in the Asia-Pacific region. Levels of particulate matter in South Korea are negatively impacted by eastward traveling winds that carry pollutants generated by Chinese industries. Particularly in the springtime, industrial and agricultural production in Shanghai emit fine dust particles, known as Yellow Dust, onto the Korean Peninsula. Yellow Dust storms have occurred in South Korea for over 2,000 years, and China's dependence on the coal industry has worsened both nations' air quality. It is approximated that China contributes up to 68% of the PM2.5 in South Korea [1]. Although the pandemic occurred during a season of

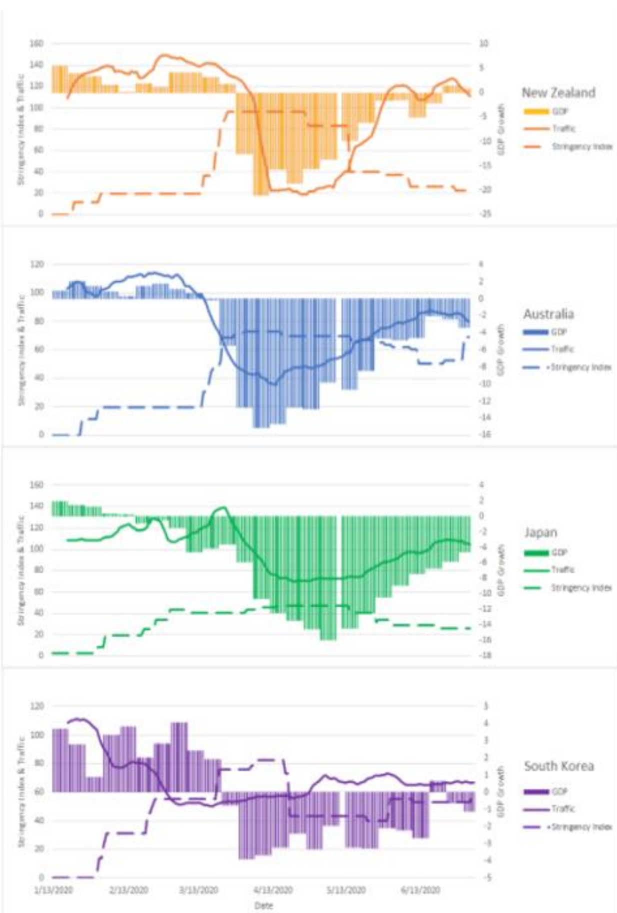

Fig. 3. Cross-country comparison of mobility, stringency index, and GDP

typically high PM levels, compared to the past three years, mean PM2.5 and PM10 concentrations in March 2020 decreased by 36% and 25% in Seoul, respectively. China's mean PM2.5 and PM 10 concentrations decreased 13.1% and 15.3% in Shanghai and Wuhan, respectively [8]. Because PM levels from both countries had been falling since January, Korea's significant decrease in PM is likely due to China's earlier lockdown limiting industry pollutants rather than South Korea's social distancing efforts in March. While annual average concentrations of fine dust in Korea have decreased consistently over the past 20 years, it is still nearly twice as high as in developed countries such as the US and Europe [12]. Air quality will remain a top priority in Korea, and because social distancing measures have successfully proved to decrease pollutant levels, especially PM levels during the Yellow Dust season, similar measures may be taken in the future to combat air pollution.

As Japanese air quality is also affected by the eastward winds from China, Japan also experienced a decrease in PM2.5 emissions due to a reduction in the electricity production industry. Linear regression modeling of PM2.5 measured in Ibaraki, Japan, a critical city for electricity production, showed the strongest positive relationship with electricity production. Additionally, paired T-test analysis revealed that decreases in national electricity production and PM2.5 levels were significant during the lockdown period at a 5% level ($p=.03$). This relationship between emissions and electricity production provides insight as to why a 4% reduction of average national power production for the month of April resulted in a 35% reduction of average PM2.5 emissions in Ibaraki.

C. *Water Quality*

New Zealand's Waikato River is the country's longest river, running for over 250 miles through the Waikato region. With an economy driven by dairy farming and agriculture biotechnology, the Waikato region has the highest density of livestock per km^2 in the country [11]. Linear regression analysis of nitrogen and phosphorus pollutants, the most critical runoff pollutants from animal byproducts, reveals that New Zealand's lockdown during April 2020 was a significant predictor of pollution levels. Samples collected at the Tuakau Bridge, the most downstream sampling site on the Waikato River, recorded a total 1.253 g/m^3 of biochemical oxygen demand, nitrogen (NH_4, Nitrate Nitrogen, NO_3, TKN), and phosphorus during April of 2020, which was the lowest level of pollution during all of 2019 and 2020. Linear regression confirms the lockdown's role in reducing water pollution with a significance level of $p = 0.022$. However, when comparing pollution levels before and after the lockdown, linear regression reveals no statistical difference ($p = 0.11$) in water quality. This rebound to normal pollutant levels after April was likely due to New Zealand's sharp rebound in agricultural activity, travel, and industry related activities immediately after the lockdown was lifted in early May [10].

V. CONCLUSION

Our analysis aims to provide a descriptive study of the COVID-19 pandemic's impact on the economy and environment in the Asia-Pacific region. Individual analysis of the economy, air quality, water quality, and mobility trends in New Zealand, Australia, China, Japan, and South Korea reveal significant declines in GDP growth, NO_2 levels, particulate matter, and water pollution; however, the critical aspect of comparison lies in understanding the relationship between the economy, transportation, and the environment in each of these countries [14] [17] [27]. Figure 3 provides a visual representation of how COVID-19 restrictions (dashed line), weekly GDP growth (bar graph), and daily vehicle traffic (solid line) simultaneously change and influence each other. As shown through the linear regression analysis on transportation and NO_2 emissions, transportation is significantly predictive of NO_2 in all countries but Japan and is therefore an accurate predictor of overall air quality. Starting with New Zealand, shortly after COVID-19 restrictions increased and the country entered its month-long lockdown, GDP growth and daily traffic both experienced sharp declines. However, once restrictions were lifted, the economy and transportation quickly returned to pre-COVID levels. Similar trends can be observed in both Australia and Japan, however the return to normal traffic activity and GDP growth is much more gradual, as government restrictions were not lifted as quickly as New Zealand and remained implemented for longer. Lastly, as seen in Figure 3, South Korea's stringency showed a relatively incremental increase. Because they managed to contain the virus without a government-mandated lockdown, their economy initially experienced a modest recession compared to New Zealand, for example, where the lockdown drastically reduced GDP as restriction levels soared near the end of March. Comparison of these four countries reveal that as government restrictions on business, transportation, and gathering size increases, GDP growth and daily traffic both decrease, therefore leading to an improvement in air quality. These results can be used to aid future policymaking regarding the balance of public health, environmental, and economic interests.

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