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EVALUATION NOTE

Nitrogen Dioxide (NO2) Level Changes in Turkey's 81 Provinces During the COVID-19 Period

Different measures are taken to curb the spread of the COVID-19 outbreak all across Turkey. Resulting from these measures, the economy is expected to shrink from the perspective of both supply and demand dynamics. Yet, as the spread rate of COVID-19 eventually decreases, the process of normalization will initiate. In the normalization process, a gradual re-emergence of the economy is expected.

Sound normalization stages following the COVID-19 require a formidable policy design process. First of all, it is necessary to understand the varying needs of the 81 provinces, find out to what extent they are affected by the pandemic and through which channels. Some of these answers, regarding the economic effects on each province, will be given when the Gross Domestic Product (GDP) figures are announced. However, GDP figures are measured long after production activities take place and the post-COVID normalization period requires short-term policy options due to its nature. Data sets announced at frequent intervals, such as credit card expenditures and electricity consumption, are essential tools in keeping track of which provinces are affected by which channels from COVID-19 measures. This study evaluates the concentration levels of Nitrogen Dioxide (NO2) emissions produced by vehicle traffic, power plants, and factories via satellite images, essentially enabling the tracking of the effects of COVID-19 measures in Turkey's 81 provinces.

The research has revealed that the provinces with the most year-over-year decreases in NO2 levels for April 2020, are: Yalova, Istanbul, Zonguldak, Bursa, Kocaeli, Bartin, Kirklareli, Tekirdag, Adana, and Edirne. Policy designs for the COVID-19 normalization period must factor into account that industrial activities and human mobility in these provinces substantially decreased at a higher rate than in other provinces.

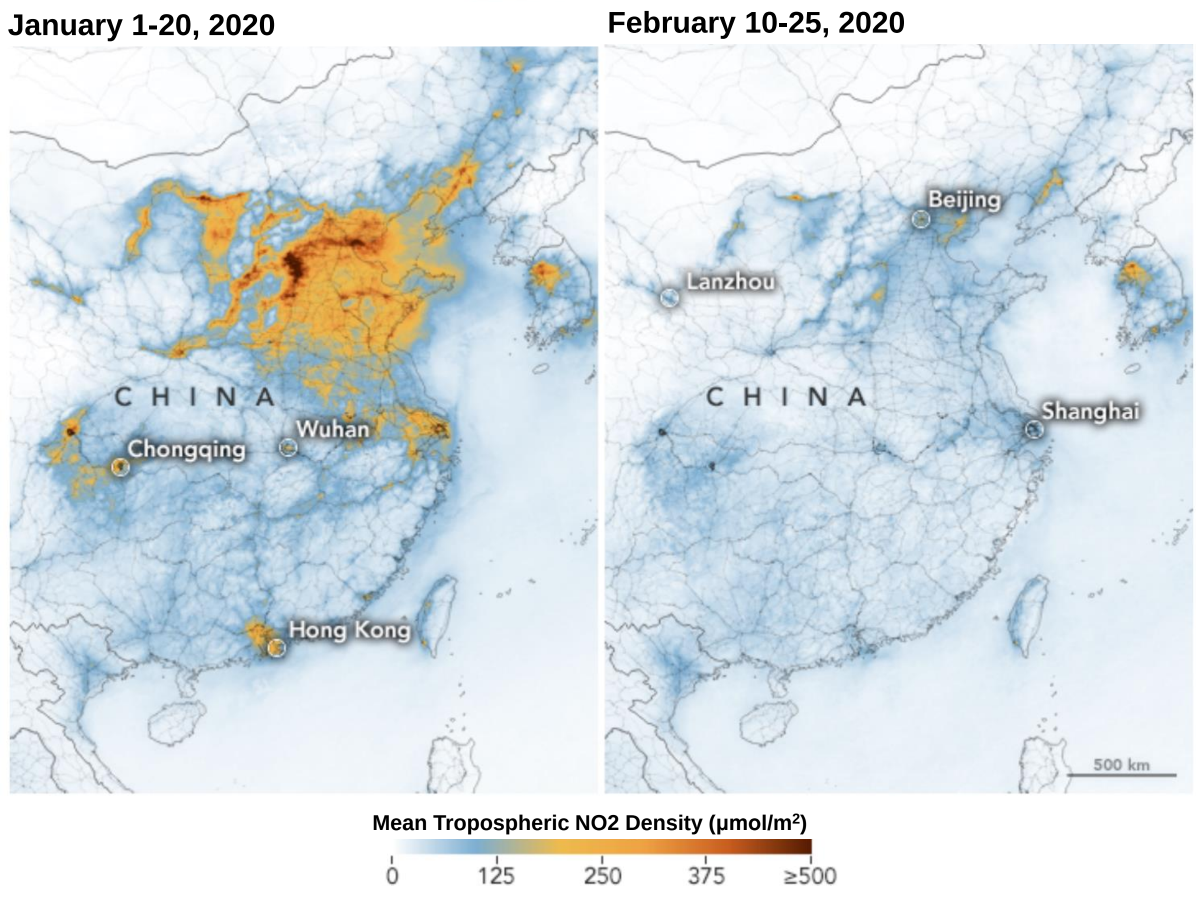
[1] https://www.tepav.org.tr/en/ekibimiz/s/1336/Aysegul+Tasoz+Dusundere

1- Background Information

Known to be harmful to human health, NO2 gas, as stated, is mainly produced by vehicle traffic, power plants, and factories.[i] The drop in toxic gas rates, especially NO2, is a positive improvement for the global environment.[ii] Nevertheless, the decreases observed worldwide in the last couple of months are not caused by the abrupt shift of individuals becoming environmentally conscious. Recent declines in NO2 are intimately connected to reduced vehicle use and industrial production at the onset of temporary measures taken to combat the COVID-19 outbreak.[iii] [iv]

Following the decrease in economic activity and human mobility due to COVID-19 measures, lockdown periods in Italy and numerous other countries depict a significant drop in NO2 levels.[v] Another example with readily available data and visualizations, as seen below in Figure 1, are the NO2 concentration decreases witnessed in China. When compared over the years, the decline in NO2 levels in some parts of China was reported to be around 20-30 percent.[vi]

Figure 1 - Comparison of NO2 Concentrations in China, January 1-20 and February 10-25, 2020



Source: *Earth Observatory. (2020). Airborne Nitrogen Dioxide Plummets over China.*[vii]

NO2 values can be compiled from a number of satellite systems. The data collected by the Sentinel-5 Precursor (S5p), a polar satellite system that works to compile information about the air quality, climate, and ozone layer in the world, is utilized in this evaluation note.[2] The S5p was developed to track air quality between 2017 and 2023, and is part of the European

[2] With the S5p satellite, daily global observations of the primary atmospheric composition of ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, methane, formaldehyde, cloudiness, and aerosol levels are compiled.

Union (EU)'s earth observation program, Copernicus.[viii] [3] With passive remote sensing techniques, the S5p routinely performs measurements at around 13:30 local time.[ix]

Furthermore, NO2 is known to be a short-lasting pollutant. In that NO2 may stay in the atmosphere approximately for a day without spreading or reacting with other gases. The short life of NO2 means that the measured amount of gas is produced very close to the region where the measurements takes place and to the measurement date.[x] As such, NO2 measurements are an important tool for determining air quality at the regional, national, and global scale.

There are a few issues to consider when studying NO2 data analytically. The relevant data is viewed in pixels and for each pixel there is a quality indicator. The corresponding "quality assurance value" is a continuous variable that takes a value between 0 (meaning there is an error) and 1 (no error or no warning). It contains information on the pixel where the measurement occurred regarding whether there is snow or ice on the surface, whether data errors are detected, and the level of cloudiness. Out of the various filters that could be used to analyze the data, it is recommended to use the 0.75-pixel filter.[4] [xi] Moreover, although controlled by the quality assurance value, satellite data shows high volatility in day-to-day data. For example, this could be due to natural weather conditions, or weekday and weekend concentration differences.[xii] For these reasons, a one month range is compared for further analytical accuracy.[xiii] Besides, it is not possible to linearly distinguish whether the change in raw NO2 values is due to the change in metrological changes on the basis of a few daily comparisons.[xiv] [xv] Therefore, for this study, a wide-ranging index of 81 provinces processing NO2 data was created to partially exclude meteorological variability and evaluate the effect of changes related to human activity.[5] [xvi] For comparing the 2019 and 2020 periods, the analytical steps for an accurate reading on NO2 levels is shared in the "ANNEX" section at the end of the evaluation note.

2- Results from Analysis

The geographical distribution of average NO2 levels for April 2020 -the period with the strictest measures taken during the COVID-19 outbreak for Turkey- alongside a year-over-year comparison is shared in Figure 2. The following observations can be listed regarding the NO2 data:

1- Under normal conditions, the highest density of NO2 is observed in the Marmara region. According to the April 2019 averages, the provinces with the highest NO2

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[3] S5p satellite launched on October 13, 2017, and following a trial compilation of 6 months of data, the satellite became operational after April 2018.

[4] The 0.75 filter in the case of quality assurance value, removes cloud-covered scenes, part of the scenes covered by snow/ice, errors, and problematic retrievals.

[5] As an example of the different approaches followed to exclude meteorological variations, the following studies can be shown:

Air Quality Consultants. (2020). The Effect of COVID-19 Social and Travel Restrictions on UK Air Quality - 06 April Update. 6 April 2020.

Carslaw, D.C. ve K. Ropkins, (2012). openair- An R Package for Air Quality Data Analysis. Environmental Modelling & Software. Volume 27-28, 52–61.

Carslaw, D. (2015). The openair Manual Open-Source Tools for Analysing Air Pollution Data. King's College London. Version: 28th January 2015.

Earthsense. (2020). COVID-19 & Air Quality: Learning Painful Lessons to Deliver Long-Term Benefit, 15 Nisan 2020.

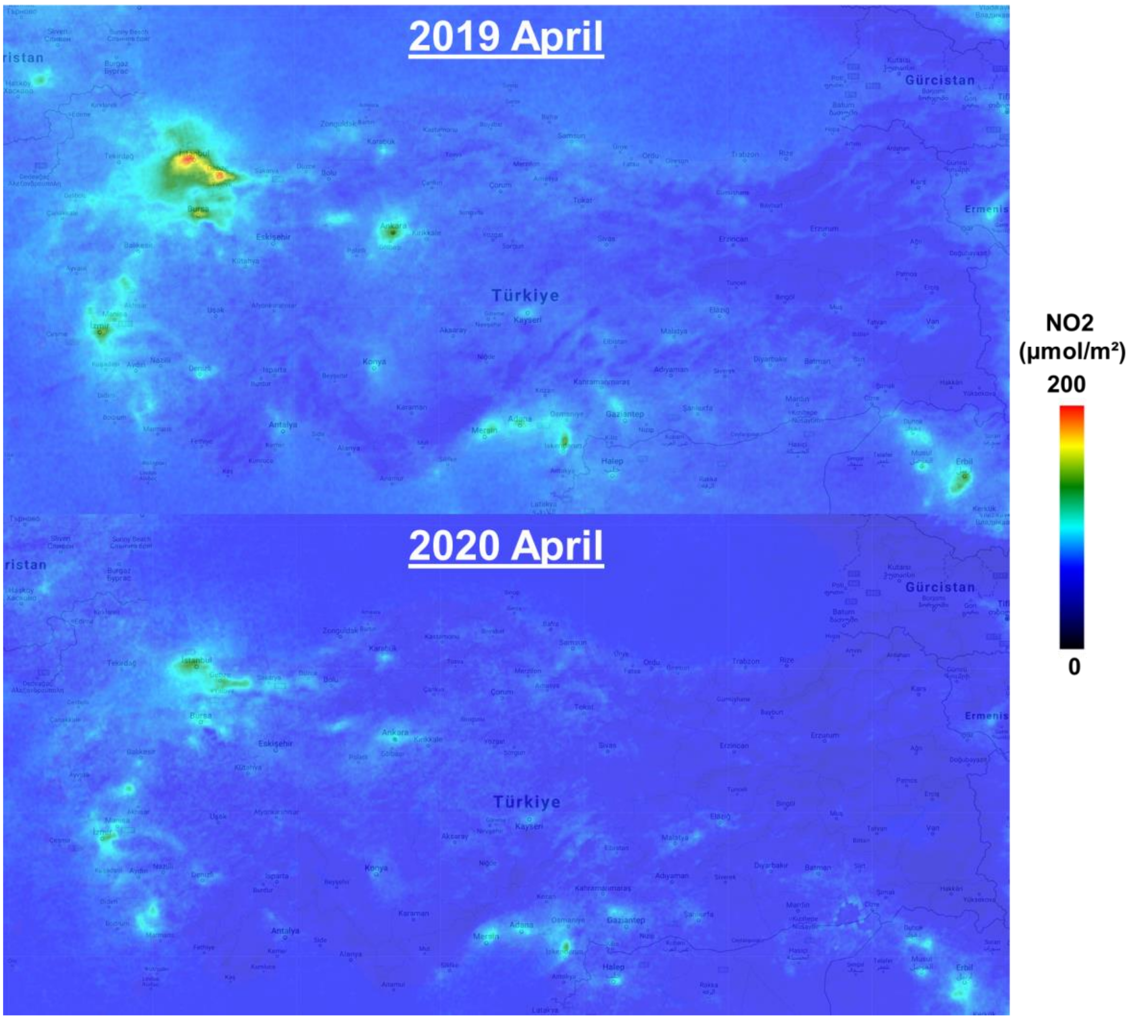
levels, in descending order, are Yalova, Istanbul, Kocaeli, Bursa, Zonguldak, Sakarya, Izmir, Bilecik, Hatay, Manisa, Tekirdag, Balikesir, Duzce, Adana, Kirklareli, Aydin, Canakkale, Ankara, Osmaniye, and Edirne. In 2018, these provinces produced 73 percent of all industrial production in Turkey.[6]

2- Among the top 10 provinces- Istanbul, Ankara, Izmir, Kocaeli, Bursa, Tekirdag, Gaziantep, Manisa, Adana, and Konya- producing 66 percent of all industrial production in Turkey, 8 out of 10 of them also possessed high NO2 levels. The exceptions being Gaziantep and Konya.

3- NO2 pollution levels, especially in the Eastern region of Turkey is much lower when compared to other regions. The provinces with the lowest NO2 levels are Ardahan, Erzurum, Bingol, Bayburt, and Hakkari.

4- Mean values for cities across Turkey vary between 104 and 58 µmol/m^2. In other words, there are almost two-fold differences between provinces with the lowest NO2 levels and provinces with the highest NO2 levels.

Figure 2 - Comparison of NO2 Concentrations in Turkey, April 2019 and April 2020

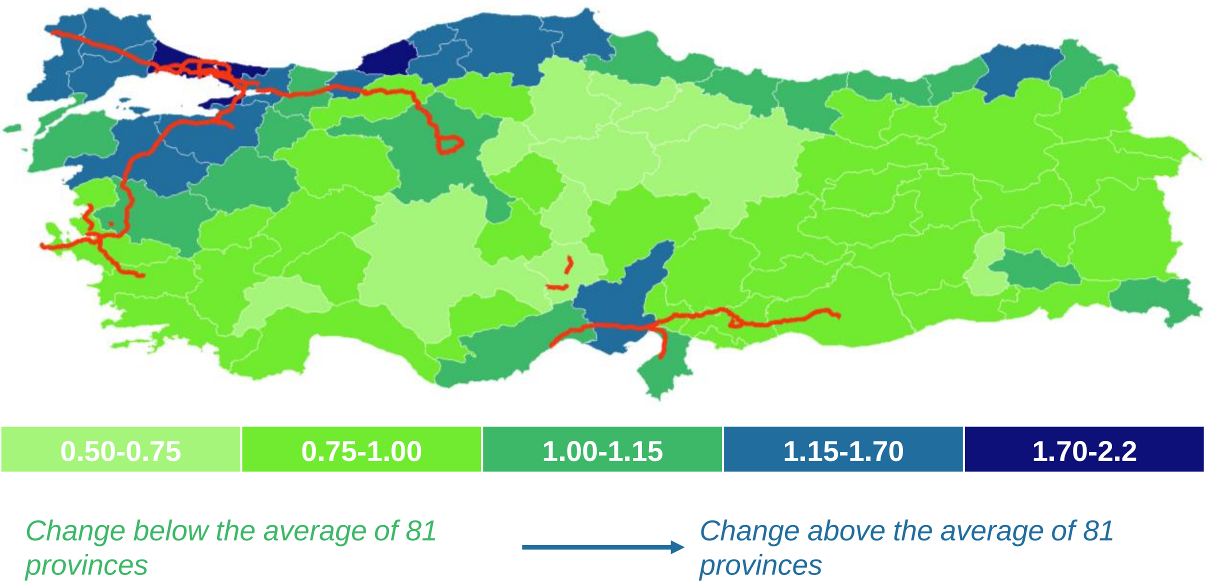


Source: *GEE, S5p ESA, TEPAV visualizations*

[6] Source: TURKSTAT, TEPAV calculations

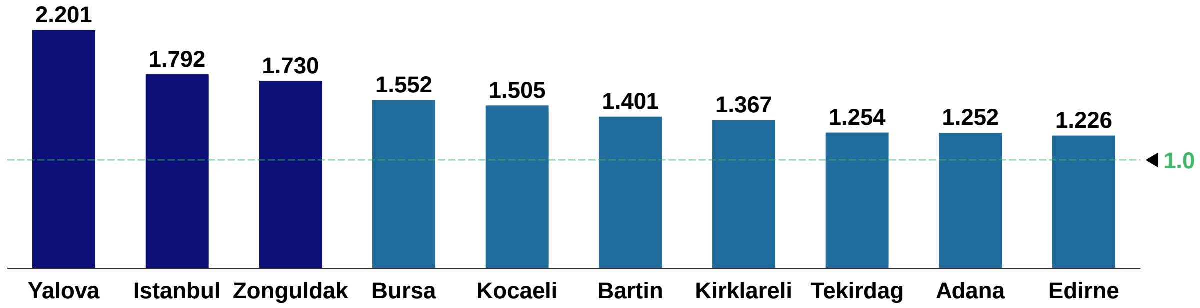
Comparison of the NO2 index values, with the average for 81 provinces in 2019 and 2020, is visualized in Figure 3. Accordingly, from April 2019 to April 2020, the average NO2 value of 81 provinces decreased by 10.5 percent. The change in the average of 81 provinces within the scope of the index value is taken as 1- with an index value below 1 indicating a change in NO2 levels below the national average and above 1 for values above the national average. In April 2020, the most significant difference compared to the previous year is found in Yalova with an index value of 2.2. In short, Yalova became the province with the sharpest decline of NO2 levels. Yalova was trailed by Istanbul with an index value of 1.8 and then Zonguldak with 1.7. These provinces can be considered as the 1st tier provinces in terms of the most reduction in NO2 values. Following these 1st tier provinces, those in the 2nd tier (Bursa, Kocaeli, Bartin, Kirklareli, Tekirdag, Adana, and Edirne) were mostly located in the Marmara and Black Sea regions. An exception in the 2nd tier, being out of these two regions, was Adana. The 3rd tier provinces are found to be in close geographic proximity to provinces listed within the 2nd tier. Furthermore, many of the provinces in the 1st and 2nd tiers either have or are near highways.

Figure 3 - NO2 Change Index and Highway Infrastructure in Turkey, April 2019 and April 2020



Source: *S5p ESA, TEPAV calculations*
Note: Red lines correspond to highways.

Figure 4 - Comparison of Top 10 Provinces with the Most Changes in NO2 Index Values, April 2019 and April 2020



Source: *S5p ESA, TEPAV calculations*

For the provinces experiencing a significant decrease in NO2 levels compared to the national provincial average, it can be interpreted that these provinces were most affected by various

COVID-19 measures in place. To name a few, heightened social distancing, transitioning to working at home, the decrease in urban and intercity traffic, and temporary suspension of factories. Of course, the provinces that have the most decrease in NO2 levels are also centers for Turkey's economic activity and industrial production. Nevertheless, the data is limited in explaining the impact channels such as tourism and agriculture. Other methods are required to evaluate which provinces and to what extend these provinces are affected via these channels.

For now, while life comes to a semi-halt to fight COVID-19, we must employ creative methods for understanding how the various measures have affected the economy. Analyzing the NO2 levels in Turkey reveals that there is a sharp decrease of industrial activity in provinces that would under normal circumstances be in mass production and movement. Satellite datasets on the environment is another tool for us to utilize in understanding these current shifts in the environment and economy. Furthermore, the results make a compelling case for the benefit of remote working for the sake of the environment and should be evaluated as an option in the long-term in the post-COVID era.[xvii]

Table 1 - NO2 Change Index Scores by Provinces, April 2019 and April 2020

81 Provinces' Average = 1

Province	Index Score	Province	Index Score	Province	Index Score
Adana	1.252	Edirne	1.226	Malatya	0.763
Adiyaman	0.941	Elazig	0.827	Manisa	1.081
Afyonkarahisar	0.829	Erzincan	0.925	Mardin	0.876
Agri	0.880	Erzurum	0.923	Mersin	1.036
Aksaray	0.778	Eskisehir	0.879	Mugla	0.835
Amasya	0.697	Gaziantep	0.879	Mus	0.805
Ankara	1.013	Giresun	1.060	Nevsehir	0.575
Antalya	0.996	Gumushane	0.895	Nigde	0.635
Ardahan	1.049	Hakkari	1.120	Ordu	1.109
Artvin	1.189	Hatay	1.076	Osmaniye	0.864
Aydin	0.845	Igdir	0.752	Rize	1.097
Balikesir	1.158	Isparta	0.930	Sakarya	1.013
Bartin	1.401	Istanbul	1.792	Samsun	1.056
Batman	0.716	Izmir	0.868	Siirt	1.077
Bayburt	0.798	Kahramanmaras	0.800	Sinop	1.151
Bilecik	1.068	Karabuk	1.194	Sivas	0.664
Bingol	0.770	Karaman	0.833	Sanliurfa	0.994
Bitlis	0.976	Kars	0.772	Sirnak	0.953
Bolu	0.990	Kastamonu	1.212	Tekirdag	1.254
Burdur	0.744	Kayseri	0.832	Tokat	0.596
Bursa	1.552	Kirikkale	0.525	Trabzon	1.095
Canakkale	1.032	Kirklareli	1.367	Tunceli	0.777
Cankiri	0.810	Kirsehir	0.764	Usak	0.925
Corum	0.658	Kilis	0.787	Van	0.909
Denizli	0.903	Kocaeli	1.505	Yalova	2.201
Diyarbakir	0.763	Konya	0.728	Yozgat	0.689
Duzce	1.150	Kutahya	1.088	Zonguldak	1.730

Source: *S5p ESA, TEPAV calculations*

APPENDIX – Steps for Processing NO2 Data

Instead of interpreting NO2 level changes with raw data, the procedures listed below was followed to partially exclude meteorological variability and concentrate on changes due to human activity.

1- **Downloading NO2 data:** For 2019 and 2020, data points on NO2 levels for January, February, March, and April were accessed through the European Space Agency (ESA). In the S5p mission interface, part of the EU's earth observation program Copernicus, NO2 data from each orbit is presented on a daily basis. In any given day, there may be multiple orbits that cross Turkey's boundaries and the unique id of orbits tend to fluctuate. For this study, data was downloaded by designating Turkey's geographic boundaries in the shape of a polygon framework spanning from 35 to 43 degrees latitude and from 25 to 46 degrees longitudes. The reason for this being the sheer size of the raw data. The data compiled within the scope of the study exceeded 200 Gigabytes. There are indeed programs like the Google Earth Engine, where raw S5p data can be accessed without downloading.[7] [xviii] Or, for example, an interface that includes NO2 analyzes, which has recently begun presenting COVID-19 analyzes as well, is offered by Copernicus Atmosphere Monitoring Service (CAMS).[xix] Nonetheless, data processed in such interfaces may be subject to unwanted additional operations. Thus, within the scope of the study, the research process began with accessing raw data in order to control all the stages leading up to the analysis results.

2- **NO2 data specifications:** NO2 values of S5p are shared with three versions. The first of these versions, offline data is accessible with a certain delay after the input of measurement dates. In addition to the offline data, announced following the related cleaning procedures, NRTI (Near Real Time) data, which are partially data deficient, can be accessed within a few hours following the measurements made by the satellite. The third version, reprocessing data, on the other hand, is not available through the data download channels, which were used in this study. Still, this version is between NRTI and offline data in terms of release duration and quality.[xx] Within the scope of the study, offline data, which was available between January 1 - April 30, 2019, and January 1 - April 25, 2020, was downloaded with 'L2' specification. For NRTI data, the files for the accessible period between March 23, 2020, and April 30, 2020, were also downloaded. Under normal conditions it is not recommended to combine offline data with NRTI data. In order to cover the widest period within the scope of the study, the offline and NRTI data was used together after the first controls since the offline data were insufficient to cover the period as close as possible, and NRTI did not provide access to the past as offline data did.

3- **First stage of cleaning NO2 data:** "nitrogendioxide_total_column," latitude, longitude, and quality assurance values were compiled from each 'nc' file downloaded from S5p. Although the data was chosen by matching the orbits with a frame polygon of Turkey, data related to all the geographical locations in the relevant orbit come within the same file. Keeping data size and the required duration of the process in mind, the downloaded

[7] For alternatives to access NO2 data, please see Earthdata NASA. (2020). How to Find and Visualize Nitrogen Dioxide Satellite Data. 26 March 2020.

data was kept for the latitude and longitude values of Turkey's frame polygon. Coordinates falling outside of the specified area were excluded. In the data presented with latitude and longitude pairs, observations with a quality assurance value equal to or more than 0.75 were kept. While these steps were performed for each nc file downloaded, the data files that passed through these operations in the following stage were converted into two separate data sets, including latitude, longitude, NO2 value, and date information, one for offline data and one for NRTI data.

4- **Processing of NO2 data with grids:** The area between 25 and 46 longitudes and 35 and 43 latitudes were divided into 2.5 square kilometer polygonal grids. Based on the administrative boundaries of 81 provinces, a total of 141,801 polygonal grids were made. At this stage, a single grid could be assigned to more than one province if it contains the areas of different provinces close to each other. NO2 data collected with coordinate information was paired with Turkey's grid polygons. With this transformation, if there were more than one observation within a minimal geographic distance, the proximity information between the observations was not lost. Thanks to this approach, in the average calculations, to be carried out in the next stages, instead of the individual coordinates that are close to each other, which can take different values, 2.5 square kilometers can be represented by equal weights. At the same time, with this approach, data on NO2 values that can be carried due to different meteorological weather conditions, such as wind, were tried to be kept in the evaluation. Then, grid, province, and day information were held, and the average of NO2 data was calculated. The grid-based average approach also attempted to compensate for the lack of information resulting from observations that had a quality assurance value below the threshold value.

5- **Combining offline and NRTI data together and the conversion to index values that allows for geographic transitivity:** Relevant offline data and NRTI data was collected in two files by going through stages three and four separately. The separately possessed data was then combined into a single dataset for each day and province, with the combination of offline and NRTI data at the last stage. The intersections of NRTI and offline data available for the same period were compared. No significant difference was observed between the two-corresponding data sets in different provinces and over time. The dataset was combined to include offline data for days when offline data was available, and NRTI data when offline data was not available. Monthly averages were obtained at the provincial level for 2019 and 2020 through combined data. After that, the monthly change of gridded NO2 levels were calculated for each province considering 2019 and 2020 data. The same calculation approach was repeated for the artificial row created with an average of 81 provinces. The index value was created by the ratio of the individual change rates to this artificial average. One of the main points where the obtained index value differs from the average of raw NO2 values obtained is when matching administrative boundaries and coordinates without additional calculations is in the use of grids allowing NO2 transitions instead of administrative boundaries.

6- **Controlling of temperature change:** The higher and lower temperature values compared to the previous year directly affect the consumption of fuel and electricity, which may cause a difference in NO2 values for seasonal reasons. To control this effect, the hourly air temperature data measured at 2 meters above the land or sea surface within the designated polygon for Turkey for January, February, March, and April in 2019 and 2020, are compiled through the Copernicus Climate Change Service (C3S) interface with a 2.5 square kilometers grid specification. In the compiled dataset, latitude, longitude, measurement date, and average temperature data are collected. After converting the average hourly temperature data shared with Kelvin to Celsius, the average values for daily temperature values were obtained from hourly data at the coordinate level. Since the data were shared with 2.5 square kilometers grid specification, the corresponding coordinate points were converted to 2.5 square kilometers polygons. Polygons for temperature grids and the polygons covering the provincial administrative border of Turkey were merged. In the merging process, if a grid with a specific coordinate intersects with multiple provinces, this grid is then matched with all relevant provinces. This approach was followed by the assumptions that values such as temperature values could not be distinguished sharply at the provincial administrative boundaries and that data could be distributed evenly since the data offered with grids specification. In the next stage, the monthly average temperature values in each province were calculated with the relevant daily data. Monthly rates were compared for 2019 and 2020. In addition to the monthly comparisons, the two-month averages for the March-April period was also measured for 2019 and 2020 to compare. As a result, a data set has been obtained at the provincial level that shows how much the average temperature values have changed in the relevant months compared to the previous year. This dataset was taken into account when interpreting NO2 results. If a province presented a sudden increase or decrease in NO2 values, it was examined whether this situation correlated with the temperature value. On the other hand, by comparing the periods of April 2019 and April 2020, the highest decrease in 81 provinces was 0.67 ℃, and the highest increase was calculated as 1.08 ℃ (see Table 2). The temperature value did not change significantly in 81 provinces after the relevant grid approach. Even though a different approach was taken with grid mapping compared to the official statistics announced throughout the province, the average temperature values of the General Directorate of Meteorology for provinces between the months of 1961-2019 was compared for cross-examining.[xxi]

Table 2 - Average Monthly Temperature, Grids of 2.5 Square Kilometers, 2019-2020

	Change		
	March	April	March-April average
Minimum	**-0.61**	**-0.67**	**-0.64**
Duzce	-0.61	-0.67	-0.64
Bingol	-0.38	-0.21	-0.30
Nevsehir	-0.16	-0.30	-0.23
Elazig	-0.22	-0.19	-0.21
Diyarbakir	-0.37	-0.03	-0.20
Antalya	-0.18	-0.22	-0.20
Siirt	-0.15	-0.20	-0.17
Agri	-0.22	-0.10	-0.16
Bursa	-0.22	-0.09	-0.16
Hakkari	0.08	-0.39	-0.15
Afyonkarahisar	-0.10	-0.20	-0.15
Mersin	0.17	-0.42	-0.13
Rize	-0.37	0.13	-0.12
Zonguldak	0.08	-0.32	-0.12
Isparta	-0.20	-0.04	-0.12
Sakarya	0.00	-0.23	-0.12
Karabuk	-0.27	0.09	-0.09
Nigde	-0.13	-0.03	-0.08
Aksaray	0.17	-0.33	-0.08
Kutahya	-0.10	-0.05	-0.08
Samsun	-0.10	-0.06	-0.08
Kars	-0.18	0.02	-0.08
Igdir	-0.07	-0.05	-0.06
Ardahan	0.11	-0.20	-0.05
Kirsehir	0.00	-0.09	-0.04
Amasya	-0.14	0.06	-0.04
Kahramanmaras	-0.09	0.03	-0.03
Konya	-0.03	-0.03	-0.03
Edirne	-0.03	-0.03	-0.03
Sinop	-0.01	-0.03	-0.02
Mardin	-0.37	0.33	-0.02
Sanliurfa	0.02	-0.05	-0.01
Artvin	-0.04	0.02	-0.01
Eskisehir	-0.01	-0.00	-0.01
Manisa	-0.05	0.04	-0.00
Bilecik	-0.16	0.15	-0.00
Osmaniye	-0.07	0.07	-0.00
Burdur	0.07	-0.07	-0.00
Aydin	0.03	-0.03	0.00
Istanbul	-0.22	0.22	0.00
Sivas	-0.06	0.11	0.02
Adana	0.11	-0.06	0.03
Balikesir	0.02	0.04	0.03
Canakkale	0.09	-0.02	0.03
Giresun	0.08	-0.01	0.04
Erzurum	0.08	-0.00	0.04
Adiyaman	-0.27	0.36	0.05
Tekirdag	0.19	-0.09	0.05
Mus	-0.11	0.21	0.05
Gumushane	-0.11	0.21	0.05
Kayseri	0.06	0.04	0.05
Malatya	-0.08	0.18	0.05
Kirklareli	-0.01	0.11	0.05
Karaman	0.25	-0.15	0.05
Van	0.13	-0.00	0.06
Izmir	-0.00	0.16	0.08
Erzincan	-0.00	0.17	0.08
Ankara	0.20	-0.04	0.08
Mugla	-0.12	0.29	0.08
Trabzon	-0.11	0.32	0.10
Kastamonu	0.17	0.04	0.11
Bayburt	0.18	0.04	0.11
Denizli	0.13	0.09	0.11
Bolu	0.01	0.23	0.12
Yozgat	0.08	0.15	0.12
Kirikkale	0.09	0.15	0.12
Corum	0.16	0.08	0.12
Tokat	0.26	-0.00	0.13
Tunceli	0.02	0.25	0.14
Bartin	0.37	-0.09	0.14
Sirnak	0.34	-0.04	0.15
Ordu	0.17	0.25	0.21
Batman	0.28	0.16	0.22
Usak	0.12	0.35	0.24
Cankiri	0.30	0.19	0.24
Bitlis	0.52	-0.02	0.25
Kilis	1.23	-0.51	0.36
Kocaeli	0.48	0.30	0.39
Gaziantep	0.53	0.29	0.41
Hatay	0.44	1.08	0.76
Yalova	1.22	0.32	0.77
Maximum	**1.23**	**1.08**	**0.77**

Source: *C3S, TEPAV calculations*

References (Endnotes)

[i] ESA. (2020). Coronavirus: Nitrogen Dioxide Emissions Drop over Italy. 13 March 2020. https://www.esa.int/ESA_Multimedia/Videos/2020/03/Coronavirus_nitrogen_dioxide_emissions_drop_over_Italy

[ii] World Health Organisation. (2003). Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide. 13-15 January 2003. https://apps.who.int/iris/bitstream/handle/10665/107478/E79097.pdf?sequence=1&isAllowed=y

[iii] Timmer, H., Mercer-Blackman, V., Beyer, R. C. M. (2020). The Economic Impact of COVID-19 on South Asia: 3 Visuals. World Bank Blog. 16 April 2020. https://blogs.worldbank.org/endpovertyinsouthasia/economic-impact-covid-19-south-asia-3-visuals

[iv] Bowler, J. (2020). New Evidence Shows How COVID-19 Has Affected Global Air Pollution. 17 March 2020. https://www.sciencealert.com/here-s-what-covid-19-is-doing-to-our-pollution-levels

[v] ESA. (2020). Coronavirus: Nitrogen Dioxide Emissions Drop over Italy. 13 March 2020. https://www.esa.int/ESA_Multimedia/Videos/2020/03/Coronavirus_nitrogen_dioxide_emissions_drop_over_Italy

[vi] ESA. (2020). COVID-19: Nitrogen Dioxide over China. 19 March 2020. https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/COVID-19_nitrogen_dioxide_over_China

[vii] Earth Observatory. (2020). Airborne Nitrogen Dioxide Plummets over China. https://earthobservatory.nasa.gov/images/146362/airborne-nitrogen-dioxide-plummets-over-china

[viii] ESA. (2020). Coronavirus: Nitrogen Dioxide Emissions Drop over Italy. 13 March 2020. https://www.esa.int/ESA_Multimedia/Videos/2020/03/Coronavirus_nitrogen_dioxide_emissions_drop_over_Italy

[ix] Boersma, A. L. K. F., Eskes H. J., Veefkind, J. P., van Geffen, J. H. G. M., de Zeeuw, M. B., Denier van der Gon H. A. C., Beirle, S. ve Krol, M. C. (2019). Quantification of Nitrogen Oxides Emissions from Build-Up of Pollution over Paris with TROPOMI. Sci Rep 9, 20033 (2019). 27 December 2019. https://www.nature.com/articles/s41598-019-56428-5#citeas

[x] Copernicus Atmosphere Monitoring Service. (2020). Copernicus Confirms a Reduction of NO2 Levels over Northern Italy since the Lockdown. 17 March 2020. https://atmosphere.copernicus.eu/copernicus-confirms-reduction-no2-levels-over-northern-italy-lockdown

[xi] Royal Netherlands Meteorological Institute Ministry of Infrastructure and Water Management. (2019). Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Nitrogendioxide. Eskes, H., van Geffen J., Boersma, F., Eichmann, K.-U., Apituley, A., Pedergnana, M., Sneep, M., Veefkind, J. P., Loyola, D. 27 March 2019. https://sentinel.esa.int/documents/247904/2474726/Sentinel-5P-Level-2-Product-User-Manual-Nitrogen-Dioxide

[xii] Amos, J. (2020). Coronavirus: Lockdowns Continue to Suppress European Pollution. BBC. 27 March 2020. https://www.bbc.com/news/science-environment-52065140

[xiii] Copernicus Atmosphere Monitoring Service. (2020). Flawed Estimates of the Effects of Lockdown Measures on Air Quality Derived From Satellite Observations. 26 March 2020. https://atmosphere.copernicus.eu/flawed-estimates-effects-lockdown-measures-air-quality-derived-satellite-observations?q=flawed-estimates-effects-lockdown-measures-air-quality-satellite-observations

[xiv] Ibid.

[xv] ESA. Coronavirus Lockdown Leading to Drop in Pollution across Europe.27 March 2020. http://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Coronavirus_lockdown_leading_to_drop_in_pollution_across_Europe

[xvi] Air Quality Consultants. (2020). The Effect of COVID-19 Social and Travel Restrictions on UK Air Quality - 06 April Update. 6 April 2020. https://www.aqconsultants.co.uk/CMSPages/GetFile.aspx?guid=1222ff30-3c9f-4189-b353-2f2ee50edab1

Carslaw, D.C. ve K. Ropkins. (2012). openair- An R Package for Air Quality Data Analysis. Environmental Modelling & Software. Volume 27-28, 52–61.

Carslaw, D. (2015). The openair Manual Open-Source Tools for Analysing Air Pollution Data. King's College London. Version: 28th January 2015. https://davidcarslaw.com/files/openairmanual.pdf

Earthsense. (2020). COVID-19 & Air Quality: Learning Painful Lessons to Deliver Long-Term Benefit, 15 April 2020. https://www.earthsense.co.uk/post/covid-19-and-air-quality

[xvii] Earthsense. (2020). Covid-19 & Air Quality: Learning Painful Lessons to Deliver Long-term Benefit, 15 April 2020. https://www.earthsense.co.uk/post/covid-19-and-air-quality

[xviii] Earthdata NASA. (2020). How to Find and Visualize Nitrogen Dioxide Satellite Data. 26 March 2020. https://earthdata.nasa.gov/learn/articles/feature-articles/health-and-air-quality-articles/find-no2-data

[xix] Copernicus Atmosphere Monitoring Service. (2020). European Air Quality Information in Support of the COVID-19 Crisis. https://atmosphere.copernicus.eu/european-air-quality-information-support-covid-19-crisis

[xx] TROPOMI. Data Products. Level 2 Products. http://www.tropomi.eu/data-products/level-2-products

[xxi] T.C. Tarım ve Orman Bakanlığı Meteoroloji Genel Müdürlüğü. Resmi İstatistikler. İllere ait Mevsim Normalleri. (1981-2010). https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=undefined&m=