Spatial Spillover Effects of Mega-City Lockdown Due to Covid-19 Outbreak

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11 May 2020

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Abstract

With the Covid-19 outbreak, academic studies have been started to calculate the economic effects of the outbreak. Since it is not possible to determine when epidemics/pandemics (or large magnitude earthquakes, etc.) occur, their negative economic effects cannot be precisely predicted. Decreasing consumption and supply at the same time, breaking the supply chain, closing businesses and increasing unemployment are rapidly disrupting economic conditions.

The measures are mostly related to issues at the macroeconomic level. If a full curfew is imposed throughout the country, economists are working on how it will have an impact on the economy of the whole country. However, the analysis of the effects at the regional level is discussed secondarily. The aim of this study is to simulate the effects of an economic lock-down that might take place in two important mega cities such as Istanbul and Izmir.

As a result of this analysis made using spatial econometrics tools; in the event of a lockdown (or earthquake) in mega cities such as İstanbul and/or İzmir, there will be major economic difficulties that will spread wave by wave to the neighboring cities and then eventually to the whole country.

Key words: Covid-19, Mega-city, Lockdown, Spatial Econometrics, Spillover Effects

JEL Codes: R11, R12, O20

1. Introduction

Covid-19 pandemic is affecting all the countries in the world. WHO (2020) declared that as of May 01, 2020, the total number of confirmed globally cases of COVID-19 reached 3.175.207, whereas the total number of deaths was 224.172.

With the emergence of the Covid-19 outbreak in Wuhan (China) and its rapid spread to throughout the world, governments in all countries implemented curfews and took measures to restrict economic activities. As a result, economic growth is expected to decline and unemployment will increase rapidly.

Although the outbreak began in December 2019, it was declared by the World Health Organization (WHO) as a pandemic on March 11, 2020. After a short time after the first cases seen in Turkey on March 10, 2020, the measures were increased. Curfew was imposed on people aged over 65 and under 20. Despite much controversy, the curfew was not fully implemented. Outbreak in Turkey was more effective in metropolitan cities where the population density is high. The data[2] of the Ministry of Health show that İstanbul and İzmir[3] lead the way.

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[2] Although the Ministry of Health did not regularly publish data at the provincial level, it was announced by the Minister that Istanbul and Izmir were in the first two places. Please see: https://tr.euronews.com/2020/04/03/turkiye-de-en-cok-koronavirus-covid-19-vakasinin-goruldugu-10-kent

[3] Please see the map that shows geographically all provinces of Turkey in the appendix.

Why does the Turkish government not willing to implement a long-term curfew in metropolitan cities instead of a short-term and limited curfew? The most important reason is that these cities are Turkey's economic centers. Any sort of economic lock-down in these cities, due to an outbreak or other reasons (for example, the large magnitude Istanbul earthquake that has been expected for years), will result in huge losses of province level gross domestic income for the rest of the country. Because of these cities have a great purchasing power from other cities for their own production and consumption; they are the source of income for other cities.

The main purpose of the paper is to explain the spatial spillover economic effects of mega-city lockdown due to Covid-19 outbreak in Turkey.

2. Literature

Since the Covid-19 outbreak began to spread around the world, many economists quickly began to publish studies analyzing the economic effects of the epidemic.

The vast majority of these studies focus on scenarios, the possible macroeconomic effects, and commodity prices as a result of the Covid-19 outbreak (McKibbin and Fernando, 2020/a and 2020/b; Arezki and Nguyen, 2020; Fernandes, 2020; Ozili and Arun, 2020). On the other hand, Baldwin and Tomiura (2020) analyze the problems arising in national and international trade in goods and services due to the epidemic. Beck (2020) works on global financial side and Toda (2020) studies on stock pricing and labor supply shock based on asset pricing model. Voth (2020) focuses on relations between trade and travel in the time of epidemics. Elgin et al. (2020) develops Covid-19 Economic Stimulus Index (CESI). Lustig and Mariscal (2020) compare the economic effects of the outbreak to the 2008 global crisis. Sumner et al. (2020) focus on the estimates of the impact of COVID-19 on global poverty. Atkeson (2020) works on economic impact of Covid-19 in the US economy. Guerrieri et al. (2020) want to response about whether or not negative supply shocks cause demand shortages.

Guliyev (2020) examines the factors affecting COVID-19 together with the spatial effects, and use spatial panel data models to determine the relationship among the variables including their spatial effects. Using spatial panel models, he analyses the relationship between confirmed cases of COVID-19, deaths thereof, and recovered cases due to treatment.

Although there are studies (Huang et al., 2020; Kang et al., 2020) analyzing the spatial spread of Covid-19, there are no publications addressing the spatial economic effects of the epidemic.

One of the rare studies based on city/province was on Tokyo. Inoue and Todo (2020) focus on the economic effects of a possible lockdown of Tokyo to prevent spread of COVID-19. Applying an agent-based model to the actual supply chains of nearly 1.6 million firms in Japan, they simulate what would happen to production activities outside Tokyo when production activities that are not essential to citizens' survival in Tokyo were to shut down for a certain period. They find that when Tokyo is locked down for a month, the indirect effect on other regions would be twice as large as the direct effect on Tokyo, leading to a total production loss of 27 trillion yen in Japan, or 5.3% of its annual GDP. Although the production shut down in Tokyo accounts for 21% of the total production in Japan, the lockdown would result in a reduction of the daily production in Japan by 86% in a month.

Although limited in number, some analyses on this subject were made on Turkey. Özatay and Sak (2020/a) work on managing the economic consequences (especially tourism, unemployment and SMEs) of COVID-19. Açıkgöz and Günay (2020) explain potential impacts of the Covid-19 pandemic on the Turkish Economy and try to put forth possible economic and political scenarios for the post-pandemic world.

Özatay and Sak (2020/b) try to answer how national income and economic growth would be affected, if the epidemic lasted long. According to their calculations, for a six-month epidemic, Turkish economy needs support up to 19 percent of GDP. If the duration of the outbreak increases to nine months, this value becomes 27 percent. Taymaz (2020) examines the impacts of the Covid-19 measures the on Turkish economy using by input-output analysis. He makes estimation about the sectors whose activities are restricted and not restricted based on economic relations between the sectors. Relations between Covid-19 cases and the city sizes in Turkey were examined by Yigit (2020). Özatay and Sak (2020/c) focus on the cost of it to the economy, if a curfew is imposed due to COVID-19.

Akcigit and Akgunduz (2020) present some evidence on the size and likely consequences of the sharp decline in demand that followed the beginning of the Covid-19 pandemic in Turkey. They use daily data on province-level credit card spending to estimate the size of the demand shock in each Turkish province. Their results show that the demand shock was sizeable, particularly in large cities like Istanbul. Assuming that the demand shock will last three months, they find an annual decline in total firm sales of 10% with considerable variation across provinces.

As can be seen in these studies, many economists focus on the effects of the epidemic at the macroeconomic level (inflation, GDP, growth rate, unemployment rate, current accounts, budget deficit etc.). However, there is not enough work on what regional economic impact will occur if mega-cities are locked down due to the epidemic. This study aims to fill the gap in this field.

3. Importance of İstanbul and İzmir

Turkey is a country with large regional disparity (Gezici and Hewings, 2004; Celebioglu and Dall'erba, 2010). In particular, the west of Turkey is in a better situation than other regions in terms of economic development. This situation of Western Anatolia can be clearly seen from all kinds of economic and social data. Especially Marmara and Aegean region are different from the others. Marmara region is the economic, financial and industrial epicenter of Turkey. Revenues are higher in these regions due to the population density, the development of trade and industrial sectors, and the impact of tourism (Celebioglu, 2010). According to the Socio-Economic Development Index (SEGE, 2017), Istanbul ranks first and İzmir is third among the most developed provinces.

According to Turkish Statistical Institute - TURKSTAT (2020), population of provinces (first 10) in Turkey, can be seen on Table 1. As seen in Table 1, İstanbul is the most populous city. The second city is capital of Turkey, Ankara and İzmir is in the third rank.

Table 1: Population Numbers of Provinces in Turkey (2019)

Provinces	Population Numbers
İstanbul	15 519 267
Ankara	5 639 076
İzmir	4 367 251
Bursa	3 056 120
Antalya	2 511 700
Adana	2 237 940
Konya	2 232 374
Şanlıurfa	2 073 614
Gaziantep	2 069 364
Kocaeli	1 953 035

Source: TURKSTAT (2020)

Turkish Exporters Assembly-TİM (2020) dataset explains that the most powerful exporter city is İstanbul in 2019 in Turkey. İzmir is the fourth city in Turkey.

Table 2: Export Numbers of Provinces in Turkey (2019)

Provinces	Export Numbers (thousand dollars)
İstanbul	70 101 911
Kocaeli	15 240 493
Bursa	14 987 146
İzmir	9 770 278
Ankara	8 303 474
Gaziantep	7 471 843
Sakarya	5 177 176
Manisa	4 450 434
Denizli	3 185 780
Hatay	2 841 678
Kayseri	2 050 133
Konya	2 013 869
Adana	1 918 852
Mersin	1 797 162

Source: TİM (2020)

İstanbul can be considered as the economic capital of Turkey. Factors such as population, commercial and financial data, industrial production, and intercontinental location support this claim. Although İstanbul has a special status, the status of İzmir, Turkey's 3rd-biggest metropolitan city, is similar to İstanbul.

4. Data

Province based gross domestic products (year 2018) dataset[4] comes from Turkish Statistical Institute of Turkey. We use LN of provincial GDP (see at tables as LN_G).

Inter-city trade dataset[5] (year 2017) of İstanbul and İzmir comes from Entrepreneurial Information System of the Ministry of Industry and Technology. We consider the ratio of the purchases of Istanbul and Izmir from each province within the total purchases (see at tables as IST_BUY and IZ_BUY).

We have some limitations about the datasets. The institutions have not published the new versions of datasets after 2017 and 2018. However, the datasets we used as the economic weight of the provinces will not change in a short time. We use GeoDa Program to analyze spatial effects.

5. Methodology

In this section, we will explain spatial neighbors and spatial weight matrix, spatial autocorrelation, Moran's I value and bases of spatial econometric analysis.

5.1. Spatial Weight Matrix and Spatial Neighbors

Following Anselin (1988), spatial weight matrix is the necessary tool to impose a neighborhood structure on a spatial dataset. As usual in the spatial statistics literature, neighbors are defined by a binary relationship (0 for non-neighbors, 1 for neighbors). We have used two basic approaches for defining neighborhood: contiguity (shared borders) and distance. Contiguity-based weights matrices include rook and queen. Areas are neighbors under the rook criterion if they share a common border, not vertices. Distance-based weight matrices include distance bands and k nearest neighbors. Based on these two concepts, we tried all the neighborhood criteria of Queen, Rook, Distance 200 km, Distance 250 km and Distance 300 km. Since we found the best results in a distance 250 km neighborhood, we decided to use the "distance 250 km" weight matrix which defines as neighbors all

[4] Please see on the website: http://www.tuik.gov.tr/UstMenu.do?metod=temelist
[5] Please see on the website: https://gbs.sanayi.gov.tr/AnaSayfa.aspx

the provinces located within a great circle distance with a cutoff of 250 km. Distance metric is based on ARCDISTANCE (km).

$$w_{ij} = \begin{cases} 1\,, & 0 \leq d_{ij} \leq d \\ 0\,, & d_{ij} > d \end{cases} \qquad (1)$$

where d_{ij} is great circle distance between centroids of region *i* and *j.* The weight matrices are based on the *centroid distances*, d_{ij} , between each pair of spatial units *i* and *j*.

5.2 Moran's I for Global Spatial Autocorrelation

Anselin and Berra (1998) describe spatial autocorrelation as coincidence of value similarity with locational similarity. In other words, high or low values for a random variable tend to cluster in space (positive spatial autocorrelation), or locations tend to be surrounded by neighbors with very dissimilar values (negative spatial autocorrelation). Positive spatial autocorrelation operationalizes Tobler's First Law of Geography whereby closer areas are more similar in value than distant ones. Negative spatial autocorrelation exists when high values correlate with low neighboring values and vice versa.

Spatial autocorrelation refers to the correlation of a variable with itself in space. It can be positive (when high values correlate with high neighboring values or when low values correlate with low neighboring values) or negative (spatial outliers for high–low or low–high values). Note that positive spatial autocorrelation can be associated with a small negative value (e.g., −0.01) since the mean in finite samples is not centered on 1. Spatial autocorrelation analysis includes tests and visualization of both global (test for clustering) and local (test for clusters) Moran's I statistic (Anselin et al. 2006).

Global spatial autocorrelation is a measure of overall clustering and it is measured here by Moran's I. It captures the extent of overall clustering that exists in a dataset. It is assessed by means of a test of a null hypothesis of random location. Rejection of this null hypothesis suggests a spatial pattern or spatial structure, which provides more insights into data distribution, that what a quartile map or box plot does. For each variable, it measures the degree of linear association between its value at one location and the spatially weighted average of neighboring values (Anselin et al. 2007; Anselin 1995) and is formalized as follows:

$$I_t = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} \dot{w}_{ij}(k) x_{it} x_{jt}}{\sum_{i=1}^{n}\sum_{j=1}^{n} x_{it} x_{jt}} \qquad (2)$$

Where $\dot{w}_{ij}$ is the (row-standardized) degree of connection between the spatial units *i* and *j* and x_{ij} is the variable of interest in region *i* at year *t* (measured as a deviation from the mean value for that year). Values of I larger (smaller) than the expected value *E(I)* = −1/*(n* − 1*)* indicate positive (negative) spatial autocorrelation.

5.3. Spatial Econometric Analysis

We explain spatial econometrics dimensions of economic lockdown of İstanbul and İzmir due to Covid-19 or large magnitude earthquake. For this reason, spatial lag and spatial error models are tested for the variables.

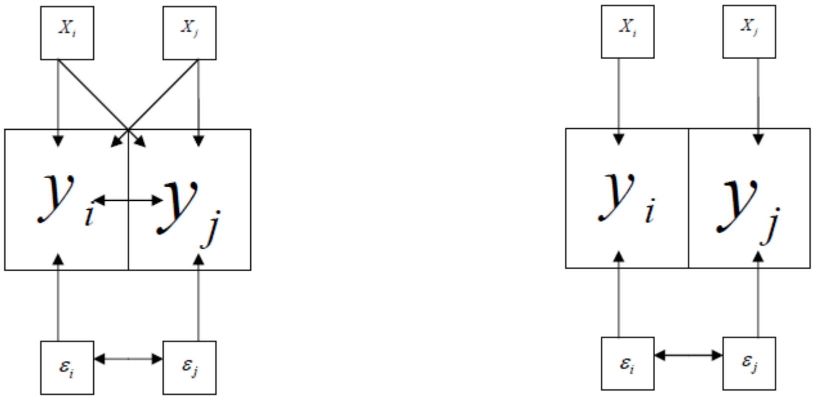
Spatial autocorrelation analysis is completed by means of composing spatial weights. Evaluation of spatial autocorrelation is applied to ordinary least-squares regression. Maximum likelihood analysis is used to measure spatial error and lag models (Anselin et al. 2006; Altay and Çelebioğlu, 2015) are the two main types of spatial regression models.

According to the spatial lag model, the degree of dependent variable "a" at a region "X" is affected by the degree of that same dependent variable at the bordering region "Y". Beside the dependent variable y in place i is affected by the independent variables in both place i and j. This is a statistical expression of "spatial spillover". For instance, the rate of unemployment in a region may be affected by the rate of unemployment at a bordering region. Following Anselin (2003), incorporates spatial effects by including a spatially lagged dependent variable as an additional predictor:

$$y = \rho W y + x\beta + \varepsilon \qquad (3)$$

where w_y is spatially lagged dependent variable for weights matrix W , x is a matrix of observations on explanatory variables, ε is a vector of error terms, ρ is the spatial coefficient. If there is no spatial dependence, and y does not depend on neighboring y values, $\rho = 0$.

Figure: Spatial Lag Model (on left) and Spatial Error Model (on right)



Source: Spatial Structures in the Social Sciences, GeoDa: Spatial Regression, https://s4.ad.brown.edu/Resources/Tutorial/Modul2/GeoDa3FINAL.pdf , Date Accessed: February 20, 2020.

Incorporates spatial effects through error term;

$$y = x\beta + \varepsilon \qquad (4)$$

$$\varepsilon = \lambda W \varepsilon + \zeta \qquad (5)$$

Where ε is the vector of error terms, spatially weighted using the weight matrix (W), λ is the spatial error coefficient and ζ is a vector of uncorrelated error terms. If there is no spatial correlation between the errors, then λ=0.

The model then changes to:

$$y = x\beta + (I - \lambda W)^{-1}\zeta \qquad (6)$$

According to (Anselin, 2005), spatial regression model selection begins considering the standard (i.e., not the robust forms) LM-Error and LM-Lag test statistics. If neither rejects the null hypothesis, stick with the OLS results. It is likely that in this case, the Moran's I test statistic will not reject the null hypothesis either. If one of the LM test statistics rejects the null hypothesis, and the other does not, then the decision is straightforward as well: estimate the alternative spatial regression model that matches the test statistic that rejects the null. If LM-Error rejects the null, but LM-lag does not, estimate a spatial error model, and vice versa. When both LM test statistics reject the null hypothesis, proceed to the bottom part of the graph and consider the robust forms of the test statistics. Typically, only one of them will be significant or one will be orders of magnitude more significant than the other (e.g., $p < 0.00000$ compared to $p < 0.03$). In that case, the decision is simple: estimate the spatial regression model matching the (most) significant statistic. In the rare instance that both would be highly significant, go with the model with the largest value for the test statistic.

6. Findings

If a lockdown takes place in Istanbul and Izmir due to Covid-19, these mega-cities cannot purchase goods and services from other provinces. In this case, a decrease will occur in the incomes of the provinces other than these two mega cities. We can see this in OLS estimates. First, we can look at the OLS estimates of Istanbul. In OLS regressions, the level of significance of independent variables in regressions (p = 0.000) is quite high.

As seen in Table 3, the purchases (also including intra-İstanbul purchases) made by Istanbul from the provinces within one year contribute 6.9% to the gross domestic product of those provinces. The opposite can also be said. In other words, if the economy of Istanbul experiences a lockdown, the gross domestic product of other provinces decreases by 6.9%.

Table 3: OLS Regression Results for İSTANBUL

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SUMMARY OF OUTPUT: ORDINARY LEAST SQUARES ESTIMATION
Data set            :  turkey81
Dependent Variable  :        LN_G  Number of Observations:   81
Mean dependent var  :     16.7372  Number of Variables   :    2
S.D. dependent var  :     1.10316  Degrees of Freedom    :   79

R-squared           :    0.242657  F-statistic           :      25.312
Adjusted R-squared  :    0.233070  Prob(F-statistic)     :2.99171e-006
Sum squared residual:     74.6542  Log likelihood        :     -111.63
Sigma-square        :     0.94499  Akaike info criterion :      227.26
S.E. of regression  :    0.972106  Schwarz criterion     :     232.049
Sigma-square ML     :    0.921657
S.E of regression ML:     0.96003

-----------------------------------------------------------------------------
       Variable      Coefficient      Std.Error    t-Statistic   Probability
-----------------------------------------------------------------------------
          CONSTANT       16.6507        0.10937        152.242     0.00000
           IST_BUY     0.0699846      0.0139104        5.03111     0.00000
-----------------------------------------------------------------------------

REGRESSION DIAGNOSTICS
MULTICOLLINEARITY CONDITION NUMBER   1.171648
TEST ON NORMALITY OF ERRORS
TEST                  DF           VALUE             PROB
Jarque-Bera            2             2.7328          0.25502

DIAGNOSTICS FOR HETEROSKEDASTICITY
RANDOM COEFFICIENTS
TEST                  DF           VALUE             PROB
Breusch-Pagan test     1             0.0868          0.76822
Koenker-Bassett test   1             0.0911          0.76275
============================== END OF REPORT ================================
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According to Table 4, the purchases of goods and services from İzmir (including intra-Izmir purchases) affect the gross domestic product of the provinces by 9%. Therefore, a lockdown process that İzmir will experience can decrease the gross domestic product level of other provinces by 9%.

Table 4: OLS Regression Results for İZMİR

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SUMMARY OF OUTPUT: ORDINARY LEAST SQUARES ESTIMATION
Data set            :  turkey81
Dependent Variable  :        LN_G  Number of Observations:   81
Mean dependent var  :     16.7372  Number of Variables   :    2
S.D. dependent var  :     1.10316  Degrees of Freedom    :   79

R-squared           :    0.254035  F-statistic           :     26.9031
Adjusted R-squared  :    0.244592  Prob(F-statistic)     :1.61114e-006
Sum squared residual:     73.5326  Log likelihood        :    -111.017
Sigma-square        :    0.930793  Akaike info criterion :     226.034
S.E. of regression  :    0.964776  Schwarz criterion     :     230.823
Sigma-square ML     :     0.90781
S.E of regression ML:    0.952791

-----------------------------------------------------------------------------
       Variable      Coefficient      Std.Error    t-Statistic   Probability
-----------------------------------------------------------------------------
          CONSTANT       16.6257       0.109331        152.067     0.00000
            IZ_BUY      0.090333      0.0174159        5.18682     0.00000
-----------------------------------------------------------------------------

REGRESSION DIAGNOSTICS
MULTICOLLINEARITY CONDITION NUMBER   1.220419
TEST ON NORMALITY OF ERRORS
TEST                  DF           VALUE             PROB
Jarque-Bera            2             1.8250          0.40152

DIAGNOSTICS FOR HETEROSKEDASTICITY
RANDOM COEFFICIENTS
TEST                  DF           VALUE             PROB
Breusch-Pagan test     1             2.9717          0.08473
Koenker-Bassett test   1             3.2450          0.07164
============================== END OF REPORT ================================
```

Although İzmir has a smaller economic volume than Istanbul, it has a greater impact on other provinces through its acquisitions. The main reason for this can be attributed to the fact that intra-Istanbul purchases are larger than intra-Izmir purchases.

Table 5: OLS Regression Results with Weight Matrix (Dis_250) for İstanbul

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SUMMARY OF OUTPUT: ORDINARY LEAST SQUARES ESTIMATION
Data set            :  turkey81
Dependent Variable  :        LN_G  Number of Observations:   81
Mean dependent var  :     16.7372  Number of Variables   :    2
S.D. dependent var  :     1.10316  Degrees of Freedom    :   79

R-squared           :    0.242657  F-statistic           :      25.312
Adjusted R-squared  :    0.233070  Prob(F-statistic)     :2.99171e-006
Sum squared residual:     74.6542  Log likelihood        :     -111.63
Sigma-square        :     0.94499  Akaike info criterion :      227.26
S.E. of regression  :    0.972106  Schwarz criterion     :     232.049
Sigma-square ML     :    0.921657
S.E of regression ML:     0.96003

-----------------------------------------------------------------------------
       Variable      Coefficient      Std.Error    t-Statistic   Probability
-----------------------------------------------------------------------------
          CONSTANT       16.6507        0.10937        152.242     0.00000
           IST_BUY     0.0699846      0.0139104        5.03111     0.00000
-----------------------------------------------------------------------------

REGRESSION DIAGNOSTICS
MULTICOLLINEARITY CONDITION NUMBER   1.171648
TEST ON NORMALITY OF ERRORS
TEST                  DF           VALUE             PROB
Jarque-Bera            2             2.7328          0.25502

DIAGNOSTICS FOR HETEROSKEDASTICITY
RANDOM COEFFICIENTS
TEST                  DF           VALUE             PROB
Breusch-Pagan test     1             0.0868          0.76822
Koenker-Bassett test   1             0.0911          0.76275

DIAGNOSTICS FOR SPATIAL DEPENDENCE
FOR WEIGHT MATRIX : dis_250
   (row-standardized weights)
TEST                          MI/DF        VALUE          PROB
Moran's I (error)             0.2051        5.3850        0.00000
Lagrange Multiplier (lag)       1          22.8481        0.00000
Robust LM (lag)                 1           3.2364        0.07202
Lagrange Multiplier (error)     1          19.6255        0.00001
Robust LM (error)               1           0.0138        0.90635
Lagrange Multiplier (SARMA)     2          22.8620        0.00001
============================== END OF REPORT ================================
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When Tables 5 and 6 are examined, it is seen that Spatial Lag Model comes to the fore as a result of both regression analysis. Because the level of significance (p = 0.00002) of Lagrange Multiplier-LAG is higher than that of Lagrange Multiplier-ERROR (p = 0.00062). For this reason, Spatial Lag Model is run for both İstanbul and İzmir.

Table 6: OLS Regression Results with Weight Matrix (Dis_250) for İzmir

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SUMMARY OF OUTPUT: ORDINARY LEAST SQUARES ESTIMATION
Data set            :  turkey81
Dependent Variable  :        LN_G  Number of Observations:   81
Mean dependent var  :     16.7372  Number of Variables   :    2
S.D. dependent var  :     1.10316  Degrees of Freedom    :   79

R-squared           :    0.254035  F-statistic           :     26.9031
Adjusted R-squared  :    0.244592  Prob(F-statistic)     :1.61114e-006
Sum squared residual:     73.5326  Log likelihood        :    -111.017
Sigma-square        :    0.930793  Akaike info criterion :     226.034
S.E. of regression  :    0.964776  Schwarz criterion     :     230.823
Sigma-square ML     :     0.90781
S.E of regression ML:    0.952791

-----------------------------------------------------------------------------
       Variable      Coefficient      Std.Error    t-Statistic   Probability
-----------------------------------------------------------------------------
          CONSTANT       16.6257       0.109331        152.067     0.00000
            IZ_BUY      0.090333      0.0174159        5.18682     0.00000
-----------------------------------------------------------------------------

REGRESSION DIAGNOSTICS
MULTICOLLINEARITY CONDITION NUMBER   1.220419
TEST ON NORMALITY OF ERRORS
TEST                  DF           VALUE             PROB
Jarque-Bera            2             1.8250          0.40152

DIAGNOSTICS FOR HETEROSKEDASTICITY
RANDOM COEFFICIENTS
TEST                  DF           VALUE             PROB
Breusch-Pagan test     1             2.9717          0.08473
Koenker-Bassett test   1             3.2450          0.07164

DIAGNOSTICS FOR SPATIAL DEPENDENCE
FOR WEIGHT MATRIX : dis_250
   (row-standardized weights)
TEST                           MI/DF        VALUE          PROB
Moran's I (error)              0.1585        4.2486        0.00002
Lagrange Multiplier (lag)         1         18.1909        0.00002
Robust LM (lag)                   1          7.8794        0.00500
Lagrange Multiplier (error)       1         11.7170        0.00062
Robust LM (error)                 1          1.4055        0.23580
Lagrange Multiplier (SARMA)       2         19.5964        0.00006
============================= END OF REPORT ================================
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For İstanbul and İzmir, Table 7 and 8 show Spatial Lag Model results. Table 7 displays that the Lag coefficient (Rho)'s value is 0.509996 and it is highly significant (p=0.00156). This means that when İstanbul's GDP and its purchases increase by one unit, the gross domestic product in the neighboring provinces increases by 0.50%. If we say the opposite, when the GDP and purchases of Istanbul decrease by one unit, the gross domestic product in the neighboring provinces will decrease by 0.50%.

As mentioned above, in the non-spatial OLS regression, the average contribution of Istanbul's purchases to the gross domestic product in 81 provinces were almost 0.07.

Table 7: Spatial Lag Model Results with Weight Matrix (Dis_250) for İstanbul

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SUMMARY OF OUTPUT: SPATIAL LAG MODEL - MAXIMUM LIKELIHOOD ESTIMATION
Data set            : turkey81
Spatial Weight      : dis_250
Dependent Variable  :        LN_G  Number of Observations:   81
Mean dependent var  :     16.7372  Number of Variables   :    3
S.D. dependent var  :     1.10316  Degrees of Freedom    :   78
Lag coeff.   (Rho)  :    0.509996

R-squared           :    0.355546  Log likelihood        :    -106.142
Sq. Correlation     : -            Akaike info criterion :     218.283
Sigma-square        :    0.784275  Schwarz criterion     :     225.467
S.E of regression   :    0.885593

-----------------------------------------------------------------------------
       Variable       Coefficient     Std.Error       z-value    Probability
-----------------------------------------------------------------------------
            W_LN_G      0.509996       0.161258        3.16261     0.00156
          CONSTANT       8.11352        2.69906        3.00605     0.00265
           IST_BUY     0.0659439      0.0126923        5.19557     0.00000
-----------------------------------------------------------------------------

REGRESSION DIAGNOSTICS
DIAGNOSTICS FOR HETEROSKEDASTICITY
RANDOM COEFFICIENTS
TEST                                     DF      VALUE         PROB
Breusch-Pagan test                       1         0.0852      0.77040

DIAGNOSTICS FOR SPATIAL DEPENDENCE
SPATIAL LAG DEPENDENCE FOR WEIGHT MATRIX : dis_250
TEST                                     DF      VALUE         PROB
Likelihood Ratio Test                    1        10.9765      0.00092
============================== END OF REPORT ================================
```

The neighboring provinces of İstanbul (see the Connectivity Map 1) mostly consist of crowded industrial and touristic cities (Kocaeli, Bursa, Adapazarı, Tekirdağ, Balıkesir, Bilecik etc.). There is a strong interaction among its neighbors and İstanbul. A lockdown to be implemented in İstanbul will have huge negative economic impacts on the neighbors of this mega-city.

Connectivity Map 1: Neighbors of İstanbul (250 km)

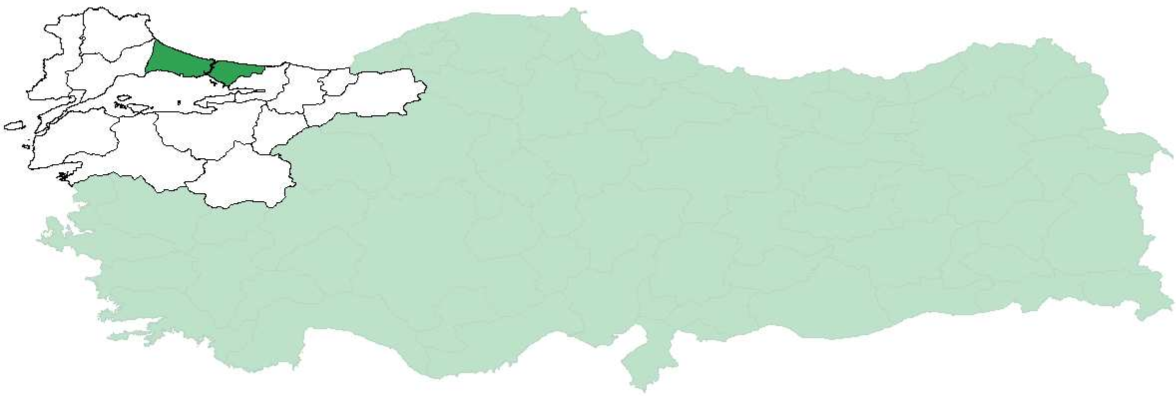

Table 8: Spatial Lag Model Results with Weight Matrix (Dis_250) for İzmir

```
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SUMMARY OF OUTPUT: SPATIAL LAG MODEL - MAXIMUM LIKELIHOOD ESTIMATION
Data set            : turkey81
Spatial Weight      : dis_250
Dependent Variable  :        LN_G  Number of Observations:   81
Mean dependent var  :     16.7372  Number of Variables   :    3
S.D. dependent var  :     1.10316  Degrees of Freedom    :   78
Lag coeff.   (Rho)  :    0.461356

R-squared           :    0.343793  Log likelihood        :    -106.655
Sq. Correlation     : -            Akaike info criterion :     219.311
Sigma-square        :    0.798578  Schwarz criterion     :     226.494
S.E of regression   :    0.893632

-----------------------------------------------------------------------------
       Variable       Coefficient      Std.Error       z-value    Probability
-----------------------------------------------------------------------------
            W_LN_G      0.461356       0.172402        2.67604     0.00745
          CONSTANT       8.90815        2.88155        3.09144     0.00199
            IZ_BUY     0.0822562      0.0161626        5.08931     0.00000
-----------------------------------------------------------------------------

REGRESSION DIAGNOSTICS
DIAGNOSTICS FOR HETEROSKEDASTICITY
RANDOM COEFFICIENTS
TEST                                     DF      VALUE         PROB
Breusch-Pagan test                       1         4.0914      0.04310

DIAGNOSTICS FOR SPATIAL DEPENDENCE
SPATIAL LAG DEPENDENCE FOR WEIGHT MATRIX : dis_250
TEST                                     DF      VALUE         PROB
Likelihood Ratio Test                    1         8.7228      0.00314
============================== END OF REPORT ================================
```
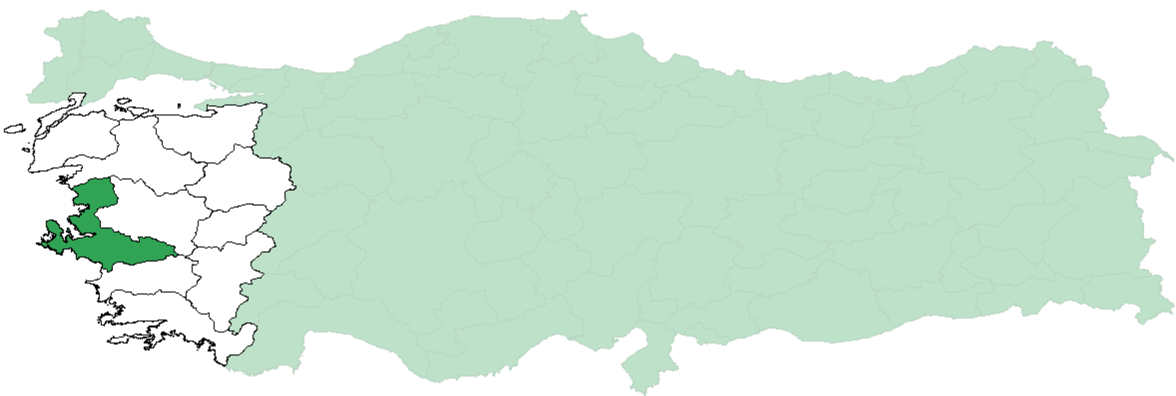

Table 8 gives that Lag coefficient (Rho)'s value is 0.461356 and it is highly significant (p=0.00745). This means that when İzmir's GDP and its purchases increase by one unit, the gross domestic product in the neighboring provinces increases by 0.46%. If we say the opposite, when the GDP and purchases of İzmir decrease by one unit, the gross domestic product in the neighboring provinces will decrease by 0.46%.

As was told above, in OLS regression without spatial weights, the average contribution of Istanbul's purchases to the gross domestic product in 81 provinces was only 0.09.

The neighboring provinces of İzmir (see the Connectivity Map 2) mostly consist of crowded industrial, agricultural, touristic cities (Manisa, Bursa, Aydın, Muğla, Balıkesir, Denizli, Uşak etc.). There is a strong interaction among its neighbors and İzmir. A lockdown to be implemented in İzmir will have huge negative economic impacts on the neighbors of this mega-city.

Connectivity Map 2: Neighbors of İzmir (250 km)



7. Conclusions

The Covid-19 epidemic both threatens people's lives and harms the economies of countries to an unprecedented degree. Many economists try to calculate the size of the negative economic effects and the burden of the measures taken. This study is intended to calculate what negative spatial spillover economic effects may take place in a mega-city lockdowns due to an epidemic or other reasons (for example, a large magnitude earthquake), unlike studies at the macroeconomic level.

Economic lockdown of a mega city with high production and consumption capacities will cause a great economic loss not only to itself but also to its neighbors. With the decrease of the gross domestic product of the cities, per capita income will decrease, unemployment will increase and other problems will come along.

But the problems are not just about mega-cities and their neighbors. The damage caused by the lockdown of a mega city will go beyond what we have calculated. Because, when supply chain is broken, the damage will spread to the whole country starting from the neighbors of Istanbul and Izmir. The speed of this spread in the country will also be very high.

When we consider Turkey's economic and regional conditions, the spillover economic costs of locking a mega city is very high. But whatever the price, when/if necessary, public authorities should not hesitate to lock a mega city or the whole country to protect human life since the price of a person's life cannot be measured with money.

In the short term, apart from the financial steps and regulations that will be taken to cover the costs of locking mega cities, another aspect of the issue comes up in the long term. In this point, another dimension of the issue is related to regional economic inequalities and imbalances which have been going on for many years in Turkey. Successful results have not been achieved in terms of reducing the migration from the Eastern cities to the cities in the West and the economic development of Eastern and South Eastern Anatolia.

Western Anatolian cities are more developed in terms of factors such as employment, production and consumption capacity, qualified employees, etc. These dynamics pose a big problem both for the rapid spread of the epidemic diseases and in the case of a potential lockdown. If regional inequalities are reduced, potential negative effects of a lockdown will be much less.

In this context, more efforts should be made to eliminate regional inequalities and imbalances in order to deal more effectively with similar potential threats that might arise in the coming years.

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Appendix: Map for Locations and Names of the Provinces (totally 81) in Turkey