RESEARCH ARTICLE

SPREAD OF COVID-19 IN EUROPEAN COUNTRIES: ARE STRINGENCIES EFFECTIVE?

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ABSTRACT

Although European countries occasionally impose national border restrictions, Europe was one of the regions that is most affected by the pandemic, owing to the free movement of citizens across national borders since the beginning of the COVID-19 pandemic. In this study, the spread of COVID-19 cases among countries and the effects of the stringencies imposed against COVID-19 within and between countries were investigated with consideration to five European countries with a large amount of COVID-19 cases, namely, France, Germany, Italy, Spain, and the United Kingdom (UK) by using Vector Error Correction Model. The data period covers the weekly data from March 27, 2020, to June 4, 2021. According to the results, the increase in the stringency index significantly reduced the number of COVID-19 cases per week after two weeks for France and Italy, and after three weeks for Spain. In other words, it takes about 2–3 weeks to observe the impact of a certain policy against COVID-19 on the number of recorded cases. In terms of the spread of COVID-19, cases in Germany and Italy were the most affected when there was a shock to cases in France. When there was a shock in cases in Germany, cases in Italy were the most affected. When there was a shock in cases in Italy, cases in Germany were the most affected. When there was a shock in cases in Spain, cases in Germany were the most affected. Finally, when there was a shock in cases in the United Kingdom, cases in Germany were the most affected. In summary, Germany and Italy appear to be the most negatively affected countries in Europe when COVID-19 cases increase. International travel, the health infrastructures of the country, and people's habit of using masks may cause this difference in countries.

Keywords: *COVID-19, vector error correction, impulse response analysis.*

ARTICLE INFO

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Received: 09.02.2023
Accepted: 03.07.2023

Cite This Paper:

Kaya, G., Aydın, U., Ülengin, B., Karadayı, M. A., & Ülengin, F. (2023). Spread of COVID-19 in European Countries: Are Stringencies Effective. Hacettepe Sağlık İdaresi Dergisi, 26(3), 707-722

ARAŞTIRMA MAKALESİ

AVRUPA ÜLKELERİNDE COVID-19'UN YAYILMASI: DEVLET POLİTİKALARI ETKİLİ Mİ?

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ÖZ

Avrupa ülkeleri zaman zaman ulusal sınır kısıtlamaları uygulasa da COVID-19 pandemisinin başlangıcından bu yana vatandaşların ulusal sınırlar arasında serbest dolaşımı nedeniyle Avrupa pandemiden en çok etkilenen bölgelerden biri olmuştur. Bu çalışmada, COVID-19 vakalarının ülkeler arasındaki yayılımı ve COVID-19'a karşı ülke içinde ve ülkeler arasında uygulanan kısıtlamaların etkileri, vektör hata düzeltme modeli kullanılarak, COVID-19 vakalarının yoğun olarak görüldüğü beş Avrupa ülkesi olan Fransa, Almanya, İtalya, İspanya ve Birleşik Krallık (İngiltere) göz önünde bulundurularak incelenmiştir. Veri dönemi 27 Mart 2020 ile 4 Haziran 2021 tarihleri arasındaki haftalık verileri kapsamaktadır. Sonuçlara göre, sıkılık endeksindeki artış, Fransa ve İtalya için iki hafta sonra, İspanya için ise üç hafta sonra haftalık COVID-19 vaka sayısını önemli ölçüde azaltmıştır. Başka bir deyişle, COVID-19'a karşı belirli bir politikanın kaydedilen vaka sayısı üzerindeki etkisini gözlemlemek yaklaşık 2-3 hafta sürmektedir. COVID-19'un yayılması açısından, Fransa'daki vakalarda bir şok olduğunda Almanya ve İtalya'daki vakaların en çok etkilendiği tespit edilmiştir. Almanya'daki vakalarda bir şok olduğunda en çok İtalya'daki vakalar etkilenmiştir. İtalya'daki vakalarda bir şok olduğunda en çok Almanya'daki vakalar etkilenmiştir. İspanya'daki vakalarda bir şok olduğunda en çok Almanya'daki vakalar etkilenmiştir. Son olarak, Birleşik Krallık'taki vakalarda bir şok olduğunda en çok Almanya'daki vakalar etkilenmiştir. Özetle, COVID-19 vakaları arttığında Avrupa ülkelerinde en olumsuz etkilenen ülkeler Almanya ve İtalya olarak görünmektedir. Uluslararası seyahat, ülkenin sağlık altyapısı ve insanların maske kullanma alışkanlığı ülkeler arasındaki bu farklılığa neden olabilmektedir.

Anahtar Kelimeler: *COVID-19, vektör hata düzeltme, etki tepki analizi.*

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Gönderim Tarihi: 09.02.2023
Kabul Tarihi: 03.07.2023

Atıfta Bulunmak İçin:

Kaya, G., Aydın, U., Ülengin, B., Karadayı, M.A., & Ülengin, F. (2023). Spread of COVID-19 in European Countries: Are Stringencies Effective. Hacettepe Sağlık İdaresi Dergisi, 26(3), 707-722

I. INTRODUCTION

Various pandemics have occurred around the world and have severely affected national economies and human lives. The current COVID-19 pandemic resulted from the spread of a viral infectious disease that was first reported in Wuhan, China, in December 2020 (World Health Organization [WHO], 2021). By March of 2020, COVID-19 had spread to almost every country in the world, and a pandemic was declared (WHO, 2021). Owing to lockdowns, which lasted 2–3 months, this pandemic has had a great impact on human lives and the economy. France, Germany, Russia, Spain, Italy, and the United Kingdom (UK) reported the largest number of cases in Europe, according to Worldometer's COVID-19 statistics (Worldometer, 2021). As of June 2021, France was first, Russia was second, the UK was third, Italy was fourth, Spain was fifth, and Italy was sixth in the number of reported COVID-19 cases. In May 2023, WHO declared that COVID-19 no longer constitutes a "global emergency" in terms of health. Despite this statement, lessons need to be learned from this pandemic in order to prevent a similar situation in the world once again.

The spread of COVID-19 is dangerous because the virus is contagious, poses a risk of serious illness and death, and overloads health systems, making it potentially dangerous to spread for many reasons. COVID-19 can be a mild illness with mild symptoms for most people. However, for some people, it can cause complications such as severe breathing problems, acute respiratory distress syndrome (ARDS), organ failure and death. Older adults and people with underlying health conditions are particularly vulnerable to COVID-19. Therefore, the spread of the virus endangers the most vulnerable segments of society. The large number of people falling ill and being admitted to hospitals during the COVID-19 pandemic can overload health systems. Resources such as bed capacity, respiratory equipment and medical staff may be limited. Overloaded health systems can lead to reduced resources for treating other diseases and make access to health services more difficult. This can negatively affect overall health and prevent patients from accessing better healthcare.

Time series models (TSMs) are typically used to assess the impact of pandemics and forecast future disease patterns. The TSMs require less information and account for seasonal trends and fast disease-related fluctuations. In the current COVID-19 pandemic, studies have employed multiple time series models to identify the data-generating process and represent anticipated circumstances regarding COVID-19, as found through a literature review. In addition, spatial panel data models also investigated COVID-19 case spillovers in the literature. However, in these studies, the coefficient indicating spatiality shows an average spatial effect considering all countries in panel data. This study, from a different perspective, investigates how cases in countries specifically affect each other (*e.g. country A => country B, country B => country C*). Therefore, the VECM method is preferred. Methodologically, it differs from other studies due to its approach.

International travel, policies against the spread of COVID-19 between countries, and people's habit of wearing masks can affect the spread of COVID-19 cases. With this motivation, this study mainly aims to investigate the spread of COVID-19 cases among countries with the highest cases using vector error correction models (VECM) and described the impulse responses among them. Estimating the spread of COVID-19 cases using the proposed approach can be useful for developing appropriate strategies related to trade and transportation to address the consequences of the pandemic. This is particularly important for European countries; whose borders are generally open except for temporary restrictions imposed by governments. This study also investigated the amount of time required for the effect of imposed restrictions or stringencies on COVID-19 cases to become noticeable in each country. This may help to make decisions for policymakers to prevent the spread of COVID-19. With the help of this modeling approach, a country can take precautions by testing case spillovers using a dataset of neighboring countries thereby reducing its spread. Section 2 presents a literature review of the impact of COVID-19 in different areas. Section 3 underlines the data and methodology used in this study. Section 4 presents the empirical findings and provides policy suggestions for the considered countries. The conclusions drawn from this study and suggestions for future work are provided in the last section.

II. LITERATURE REVIEW

Since the first quarter of 2020, studies investigating the impact of COVID-19 in many different areas have been published. For example, some studies have investigated the impact of COVID-19 on the stock market (Mazur et al. 2021), and the socio-economic and environmental impact of COVID-19 (Bashir et al., 2020; Martin, 2020; Jain et al., 2021, DuPre et al., 2021). Mazur et al. (2021) reported the positive and negative effects of COVID-19 on various stock markets sectors, such as the natural gas, food, healthcare, petroleum, entertainment, and hospitality sectors. Bashir et al. (2020) reported that COVID-19 has caused the generation of a large amount of medical waste, severe demographic changes, unemployment, and adversely affected the transport and travel industries. Martin et al. (2020) investigated the impact of COVID-19 on household consumption and poverty. They reported that the severity of the economic impact is spatially heterogeneous, and certain communities are affected more than the average and may take more than a year to recover. Additionally, Jain et al. (2021) found that air pressure, temperature, and humidity have a significant effect on the number of confirmed COVID-19 cases and air pollution has had a significant effect on COVID-19-related deaths in six South Asian countries. Moreover, Mogi and Spijker (2021) have reported that social and economic factors are strongly and positively associated with COVID-19 in 23 European countries. Lastly, DuPre et al. (2021) found that younger counties, counties with a higher proportion of females, Hispanic and Black populations, and counties with more private sector employment have a higher likelihood of having worse cases and death.

In addition to studies on the effects of COVID-19, many studies have also investigated the spread of COVID-19 based on spatial analysis. For instance, Amdaoud et al. (2021) focused on the spatial heterogeneity of the spread of COVID-19 in 125 regions of 12 European countries and conducted investigations using spatial regression models. They found that the proportion of elderly individuals in the population, GDP per capita, distance from achieving European Union objectives, and unemployment rate are associated with high COVID-19 death rates. Similarly, Sannigrahi et al. (2020) investigated the global and local spatial relationships between the socio-demographic composition and COVID-19 deaths in 31 European countries using spatial regression models. They reported that the considered demographic and socio-economic components, including the total population, poverty, and income, are key factors in regulating the overall casualties resulting from COVID-19 in Europe. Based on data from the United States of America (USA), Devarakonda et al. (2021) proposed a spatial diffusion model by adapting the Newtonian gravity model and predicted the highest risk patterns for COVID-19 in New York City neighborhoods characterized by clustered socioeconomic inequalities and racial and ethnic heterogeneity. For China, Huang et al. (2020) used Moran's index to the spatial panel data models and found that COVID-19 has spread mainly from Hubei Province in central China to neighboring regions. Additionally, Xie et al. (2020) investigated the spatial and temporal patterns of COVID-19 and its effect on human development. Their results revealed that COVID-19 exhibits a dispersed spatial pattern, which increases the difficulty of controlling the spread of the disease. They also mentioned the negative impact of COVID-19 on human development and reported that approximately 80% of students' online learning is ineffective because access to reliable and uninterrupted Internet services is lacking in the rural areas of China. Krisztin et al. (2020) used Bayesian spatial econometric models to analyze the daily infection rates of COVID-19 in different countries by specifically focusing on the temporal importance of alternative spatial links structures, such as the number of flight links, international trade relationships, and common borders. Their results revealed that, in the early stages of the virus, significant spatial spread occurred through international flight links. In the later stages, a sharp decrease in the spatial spread of density was observed owing to national travel restrictions. This indicates that travel restrictions lead to a reduction in cross-country spillovers. Although these studies considered the spatial interaction of COVID-19 with the help of socio-economic variables, they did not clarify the extent to which an increase in the number of cases in a certain country leads to an increase in the number of cases in neighboring countries.

Various studies have attempted to predict the effects of COVID-19 on the financial markets of different countries, and some studies have attempted to forecast cases or deaths using time series models (such as ARIMA, VAR, VECM, and so on). Singh et al. (2020) used the autoregressive integrated moving average (ARIMA) model to predict confirmed cases, deaths, and recoveries for the top 15 countries from April 24 to July 7, 2020. Using the ARIMA and vector autoregression models, Monllor et al. (2020) predicted that the transmission rate for Spain would decline earlier compared with Italy in the month of April. This forecast also indicated a significant increase in the intensive care unit (ICU) needs of Spain. For Italy, however, the ICU needs were forecasted to decrease in the same period. Similarly, Alzahrani (2022) predicts the new confirmed cases of COVID-19 by using the log-linear Poisson Autoregressive model for Saudi Arabia. Khan et al. (2020) used vector autoregressive time series models to forecast new daily confirmed cases, deaths, and recoveries over ten days in Pakistan. Roy et al. (2021) also forecasted the epidemiologic pattern in the prevalence and incidence of COVID-19 with the Autoregressive Integrated Moving Average (ARIMA) for India. Finally, Wang et al. (2021) proposed a vector autoregression (VAR) time series model to predict positive COVID-19 cases in the USA. Some studies have used other methods to make predictions. For example, Chan et al. (2021) predicted the short-term number of new COVID-19 cases per day in 18 countries based on count regression models. Hafner (2020) investigated the spread of COVID-19 using VAR, spatial models, and connectedness measures. However, in contrast to our study, Hafner did not consider the long-term and short-term effects. Similarly, our study, Britt et al. (2023), analyzed weekly COVID cases, hospitalizations, and deaths in 2020 and 2021 by using data of Minnesota, Wisconsin, Colorado, and Georgia. They used vector autoregression (VAR) and found that the efficiency of short-term forecasts is illustrated by observing the effect of vaccination on COVID development in the state of Minnesota in 2021. This study did not use the stringency index used in our study and again does not show long-term effects. Our study differs from these studies in general as it considers both long-run and short-run effects of COVID-19 cases, examines countries specifically, and observes the effect of the stringency index on COVID-19 cases.

This study investigated the spread of COVID-19 among countries in the short- and long-term using a vector error correction model (VECM) that can obtain results for each considered country and represent the impulse responses among them. Estimating the spread of COVID-19 using this approach can be helpful as a guideline for implementing policies in different sectors, such as trade and transportation, particularly in European countries where national borders are generally open unless restrictions are imposed by governments. Additionally, this study also investigated the amount of time required to observe the effect of restrictions or stringencies on the number of COVID-19 cases in each country.

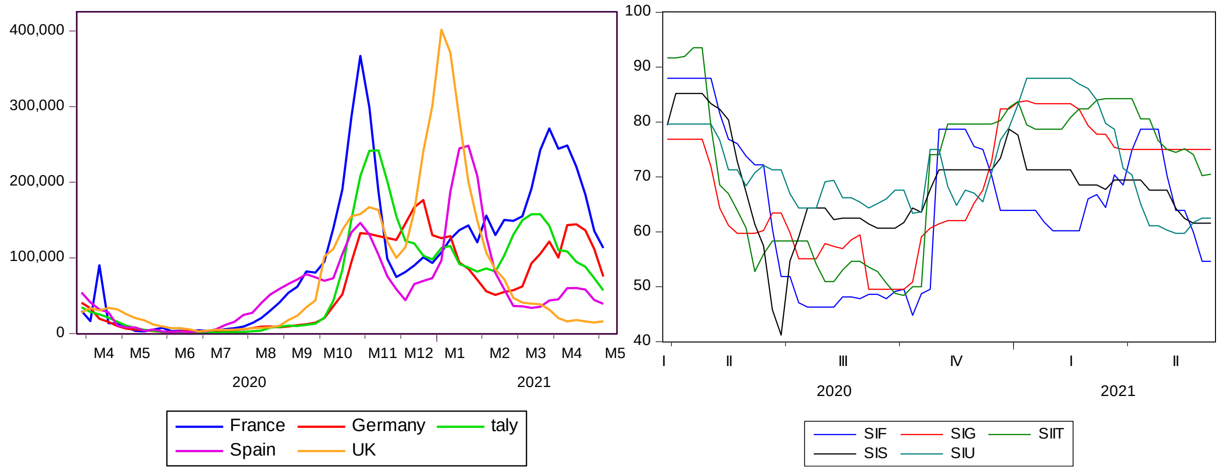
III. DATA AND METHODOLOGY

This study considered five countries: France, Germany, Spain, Italy, and the UK, which reported the highest COVID-19 case numbers in Europe. These countries have also been investigated by other COVID-19-related studies (Sannigrahi et al., 2020; Hafner, 2020; Bontempi, 2021). The dataset was obtained from the “Our World in Data” database (https://ourworldindata.org/coronavirus-source-data). Our World in Data (Ourworldindata.org) is a world data site. Data is used extensively to describe social changes in the world in health, economy, media, and technology. The site offers worldwide trends that individuals can compare and provides digital service of the comprehensive and appropriate amount of data published cheerfully. This database uses the Johns Hopkins University dashboard and provides information such as the daily total COVID-19 cases, number of deaths, and number of tests in all countries. Additionally, the database presents the stringency index proposed by Hale et al. (2021), which is an indicator of the measures taken by governments against COVID-19. This is a composite metric based on nine reaction indicators, such as school closures, workplace closures, and travel restrictions, rescaled to a number between 0 and 100 (100 being the most stringent). If policies differ at the subnational level, the index can be calculated using the level of the tightest sub-response region. Hence, it is necessary to investigate the temporal effects of the Stringency Index on the number of COVID-19 cases. For instance, according to Bontempi (2021), the imposed restrictions and the willingness to accept them are important factors to consider when assessing the spread of the virus. Therefore, the stringency index has been used by several studies to investigate COVID-19 cases (Oliveira et al., 2021; Zhu et al., 2021).

Owing to the high volatility and noise in the number of daily cases, the daily dataset was converted to a weekly dataset, and the natural logarithmic weekly total number of new cases was considered as an endogenous variable. Owing to the differences among the dates of the first recorded cases of different countries (for example, in Germany, the first case was recorded on January 27, 2020), the dataset period was considered from March 27, 2020, to June 4, 2021. Although there are lots of COVID-19 cases in 2022, due to the vaccine and being confused with the flu epidemic, the number of cases in 2022 was not included in the study because it was not as reliable as the data in the early days of COVID-19. Moreover, when the "Our World in Data" database is examined, it can be seen that there are deficiencies in the disclosure of data from many countries after May 2022. Therefore, the data set of this study covers the period when the data is relatively more reliable.

The weekly average values of the stringency index, which was considered an exogenous variable, were also included in the analysis. The weekly number of new COVID-19 cases and the weekly stringency index values for each country are shown in Figure 1. Here, "Sif" is the stringency index of France, while "Sig" refers to Germany, "Siit" refers to Italy, "Sis" refers to Spain, and "Siu" refers to the UK. There are two peaks in the cases, albeit at different times for each country. The magnitude of the stringency indices varies from country to country, but the temporal distributions are similar among the considered countries.

Figure 1. Graphs of Weekly New COVID-19 Cases and Stringency Indices for Each Country



The Vector Error Correction Model (VECM) is a model used in econometrics, time series analysis, and causality analysis. Models the relationship between long-run equilibrium relations and short-run dynamics. VECM is based on a vector autoregressive (VAR) model. The VAR model is used to model the relationship between multiple variables. However, the VAR model captures the short-run dynamics between time series variables, not the long-run equilibrium relationships. Therefore, VECM is used to correct errors that occur as a result of the VAR model. VECM is based on the concept of cointegration. Cointegration means that there is a long-run equilibrium relationship between time series variables. That is, it means that these variables act together and are influenced by each other in the long run. VECM includes cointegration relationships and error correction mechanism. Cointegration relationships represent long-run equilibrium relationships between variables. Error correction mechanism, on the other hand, states that the short-term divergence between the variables returns to equilibrium in the long term. VECM is often used to model the relationship between two or more cointegrated variables. The model starts with cointegration analysis such as unit root tests. When cointegration is detected, the VAR model is converted to VECM. While VECM relies on the existence of unit roots and cointegration relationships, it corrects error terms and is used to predict long-run relationships between variables. It can also be used for causality analysis and predictions. For these reasons, VECM is a widely used econometric model in economic and financial time series analysis (Levendis, 2018).

Vector error correction models (VECM) are used to assess the possible long- and short-term dynamic relationships within and across countries. The vector autoregressive (VAR) models, proposed by Sims (1980), are multivariate time-series models and indicate the dynamic behavior of economic time series by identifying the dependence among the variables. Additionally, these models can predict the potential paths that a selected variable will follow in the future (forecasting). In a VAR model, all variables are treated depending on their lag and the lags of all other exogenous variables. The VAR model can be represented in matrix form, as follows:

$$\begin{bmatrix} Y_{1t} \\ Y_{2t} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} Y_{1t-1} \\ Y_{2t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \tag{1}$$

Here, Y_{1t} and Y_{2t} denote the endogenous and stationary variables, respectively; b denotes the slope coefficients, α denotes a constant, and e denotes the error terms, which must be independent and identically distributed (IID). The lag length is determined by criteria such as Akaike and Schwarz.

The VAR models are used when the variables are stationary or if there is no cointegration among the non-stationary variables. If the non-stationary variables are co-integrated, the error correction model (VECM) can be estimated. The existence of cointegration indicates that there is a long-term relationship among the variables. The cointegration was tested using Johansen's (1992) cointegration test. The VECM may represent more than one cointegration relationship, and tests based on the constraints of long-term parameters are possible. The VECM is the outcome of adding error correction features to a VAR model. To estimate a VECM, a VAR with non-stationary variables must first be calculated, followed by the Johansen test to check for cointegration. Finally, the VECM can be estimated and interpreted.

Table 1. Descriptive Statistics

Weekly New Cases	**FRANCE**	**GERMANY**	**ITALY**	**SPAIN**	**UK**
Mean	99,214.3	59,065.2	66,566.5	59,618.9	71,773.9
Maximum	367,221	176,587	242,127	248,326	401,821
Minimum	2762	2219	1255	2047	2773
Standard Deviations	88,723.74	53,935.37	65,928.15	55,440.21	91,781.66
Stringency Index					
Mean	64.8	68.3	71.2	68.1	72.0
Maximum	88.0	83.9	93.5	85.2	88.0
Minimum	44.8	49.5	48.4	41.2	59.7
Standard Deviations	13.4	10.9	13.6	8.6	8.6
Number of Observations	63	63	63	63	63

Table 1 presents the number of weekly new cases and the stringency indices of the five considered countries in the period from March 27, 2020, to June 4, 2021. As can be seen, the average number of weekly cases was relatively high in France and the UK. Among these five countries, Germany had relatively few average weekly cases. Regarding the stringency index, high averages were observed for Italy and the UK. These two countries, on average, have implemented more stringent measures to prevent the spread of COVID-19 than other countries. However, the variability of the index for Italy is relatively high.

IV. EMPIRICAL FINDINGS

Before establishing the VAR model, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were carried out to assess whether the variables contain a unit root or not, given in Table 2. According to the results obtained from both tests, all variables were considered to be first-order integrated, which is denoted as I(1). To carry out the Johansen cointegration test, the lag length for the VAR model was set to two weeks based on the Akaike, Schwarz, and Hannan-Quinn criteria which are given in Table 3. According to the Johansen cointegration test results which are given in Table 4, three cointegration equations were found to be significant at the 0.10 significance level. Therefore, the model was estimated using VECM. The optimal lag length of VECM and the lag of each exogenous variable were determined using the Schwarz criteria.

Table 2. Results of Unit Root Tests[1]

Augmented Dickey-Fuller					
Logarithmic Weekly New Cases	**France**	**Germany**	**Italy**	**Spain**	**UK**
Level	0.80	-0.62	-0.79	0.04	-0.22
First Difference	-9.29***	-4.40***	-3.15***	-5.53***	-5.10***
Stringency Index					
Level	-1.20	-0.45	-0.92	-0.64	-0.88
First Difference	-7.95***	-11.61***	-6.60***	-5.02***	-13.26***
Phillips-Perron					
Logarithmic Weekly New Cases	**France**	**Germany**	**Italy**	**Spain**	**UK**
Level	0.13	-0.21	-0.39	-0.26	-0.004
First Difference	-9.16***	-4.54***	-3.23***	-6.09***	-5.11***
Stringency Index					
Level	-1.11	-0.13	-0.85	-0.53	-0.32
First Difference	-7.88***	-10.62***	-6.64***	-4.95***	-13.26***

*significant at 0.10, ** significant at 0.05, ***significant at 0.01

[1]Since the constant and trend coefficients at the 0.05 level are insignificant, the "none" model is obtained as the most appropriate in the test equation of all variables.

Table 3. VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
1	0.07	-	1.52E-06	0.79	1.64	1.13
2	54.98	92.40	5.95e-07*	-0.16*	1.54*	0.51*
3	75.44	31.17	7.11E-07	-0.01	2.54	0.99
4	93.39	24.51	9.51E-07	0.21	3.61	1.55
5	127.56	41.22*	7.99E-07	-0.08	4.17	1.59

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table 4. Results of Johansen Cointegration Test

Sample: 3/27/2020 6/04/2021				
Included observations: 63				
Unrestricted Cointegration Rank Test (Trace)				
Number of Cointegrating Equations	Eigenvalue	Trace Statistic	Critical Value	P value
None *	0.63	122.39	69.82	0.01
At most 1*	0.39	60.27	47.86	0.01
At most 2*	0.26	29.06	29.80	0.06
At most 3	0.10	9.84	15.49	0.29

The cointegrating equations of the VECM indicate the long-term impact of the spread of COVID-19 among different countries (see Table 5). Because the coefficients for the UK in two long-run equations were found to be insignificant, constraints were established on the long-term equations such that the coefficients of the UK are zero, and these constraints were not rejected (Chi-square (2) = 2.38, prob: 0.30). Variables with coefficients of 1 in the long-run equation indicate the dependent variable and these equations are interpreted by setting them equal to zero. Therefore, when interpreting the signs, they are interpreted as the opposite of the sign that appears in the equation. That's why, it can be said that the number of COVID-19 cases in France, Germany, and Italy is positively correlated to the number of COVID-19 cases in Spain. An increase of 1% in the number of COVID-19 cases in Spain caused the number of COVID-19 cases to increase by 2.05% in France, 1.49% in Germany, and 1.62% in Italy, ceteris paribus. For each error correction equation their own error correction coefficients (CointEq coefficients) are negative and statistically significant for France, Germany, and Italy at a 10 % significance level. When there is a deviation in the long-term relationships, the COVID-19 cases correct themselves and short-term adjustments are made in these countries, while the UK makes no effort to approach long-term equilibrium. This correction takes about 3.5 weeks (1/0.29) in France, about 6 weeks (1/0.17) in Germany, and about 3 weeks (1/0.33) in Italy.

Table 5. Estimation Result of VECM

Sample: 3/27/2020 6/04/2021					
Included observations: 63					
Cointegrating Equations	**CointEq1**	**CointEq2**	**CointEq3**		
$Ln(France)_{t-1}$	1.00	0.00	0.00		
$Ln(Germany)_{t-1}$	0.00	1.00	0.00		
$Ln(Italy)_{t-1}$	0.00	0.00	1.00		
$Ln(Spain)_{t-1}$	-2.05	-1.49	-1.62		
	(0.19)	(0.16)	(0.17)		
	[-11.09]	[-9.40]	[-9.40]		
$Ln(UK)_{t-1}$	0.60	0.00	0.00		
	(0.08)				
	[7.35]				
Constant	4.47	5.34	6.75		
Error Correction:	**D(Ln(France))**	**D(Ln(Germany))**	**D(Ln(Italy))**	**D(Ln(Spain))**	**D(Ln(UK))**
CointEq1	-0.29	0.16	0.19	0.08	-0.09
	(0.10)	(0.07)	(0.05)	(0.10)	(0.09)
	[-2.91]	[2.29]	[3.58]	[0.77]	[-0.96]
CointEq2	-0.14	-0.17	0.13	0.29	0.15
	(0.13)	(0.09)	(0.07)	(0.12)	(0.12)
	[-1.08]	[-1.87]	[1.90]	[2.34]	[1.31]
CointEq3	0.36	0.01	-0.33	-0.21	-0.10
	(0.14)	(0.10)	(0.08)	(0.14)	(0.13)
	[2.57]	[0.06]	[-4.46]	[-1.54]	[-0.79]
$D(Ln(France))_{t-1}$	-0.06	-0.04	-0.03	0.13	0.16
	(0.13)	(0.09)	(0.07)	(0.13)	(0.12)
	[-0.45]	[-0.47]	[-0.46]	[1.02]	[1.37]
$D(Ln(France))_{t-2}$	0.01	-0.04	0.04	-0.06	0.13
	(0.10)	(0.07)	(0.05)	(0.10)	(0.09)
	[0.06]	[-0.55]	[0.81]	[-0.60]	[1.42]
$D(Ln(Germany))_{t-1}$	0.54	0.30	0.11	0.07	-0.06
	(0.24)	(0.17)	(0.13)	(0.24)	(0.22)
	[2.20]	[1.72]	[0.82]	[0.28]	[-0.25]
$D(Ln(Germany))_{t-2}$	0.15	0.20	0.16	-0.25	0.13
	(0.22)	(0.16)	(0.12)	(0.21)	(0.20)
	[0.67]	[1.30]	[1.38]	[-1.19]	[0.64]
$D(Ln(Italy))_{t-1}$	0.14	0.21	0.40	0.25	-0.14
	(0.27)	(0.19)	(0.14)	(0.26)	(0.25)
	[0.53]	[1.12]	[2.83]	[0.95]	[-0.57]
$D(Ln(Italy))_{t-2}$	0.12	0.04	0.34	0.30	0.11
	(0.26)	(0.18)	(0.14)	(0.25)	(0.24)
	[0.45]	[0.23]	[2.45]	[1.18]	[0.46]
$D(Ln(Spain))_{t-1}$	0.22	0.18	-0.13	0.15	-0.09
	(0.15)	(0.11)	(0.08)	(0.14)	(0.14)
	[1.48]	[1.67]	[-1.61]	[1.04]	[-0.65]
$D(Ln(Spain))_{t-2}$	0.09	-0.04	-0.13	0.28	-0.25
	(0.14)	(0.10)	(0.08)	(0.14)	(0.13)

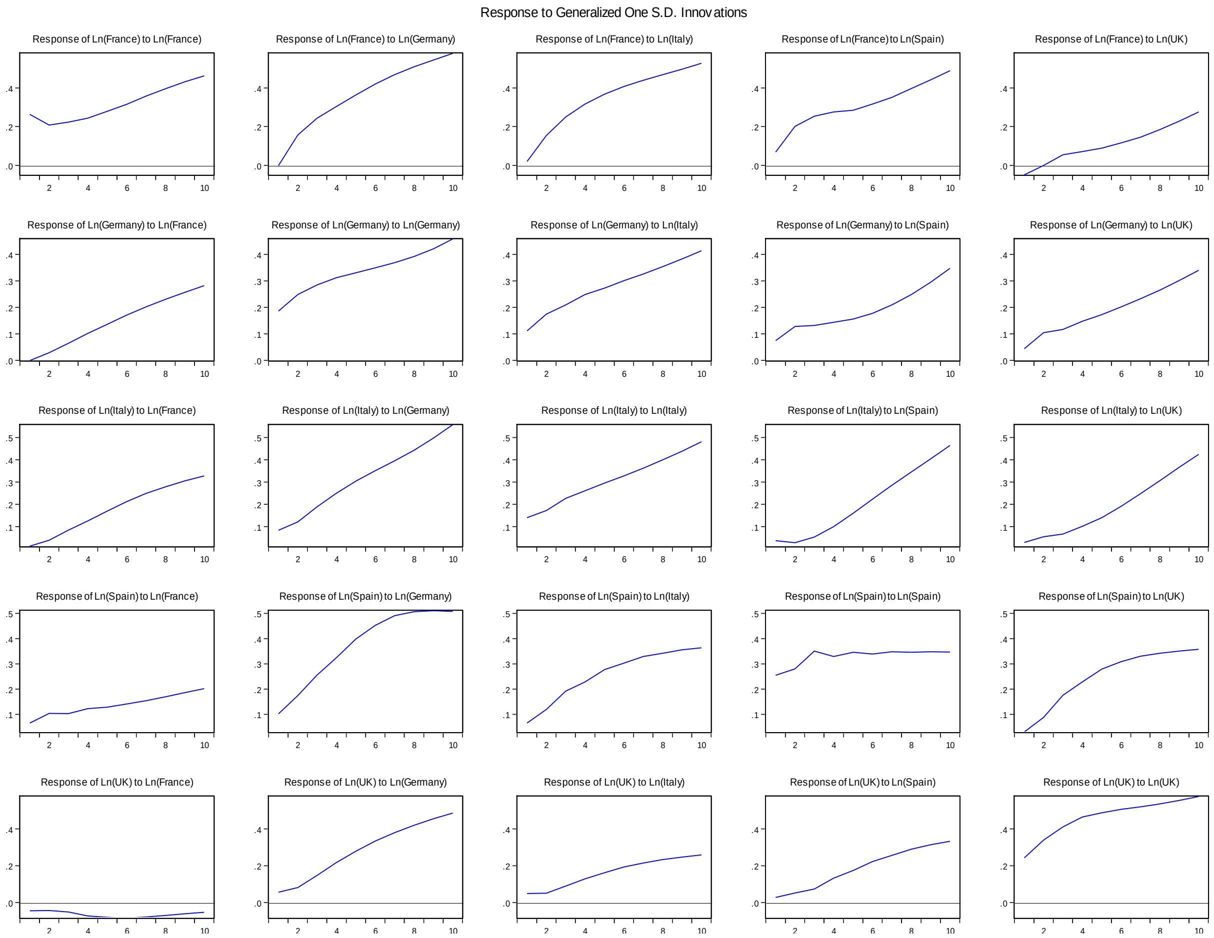
	[0.60]	[-0.37]	[-1.71]	[2.04]	[-1.91]
$D(Ln(UK))_{t-1}$	0.12	0.12	-0.01	0.18	0.47
	(0.16)	(0.11)	(0.08)	(0.15)	(0.15)
	[0.73]	[1.08]	[-0.10]	[1.17]	[3.27]
$D(Ln(UK))_{t-2}$	0.09	-0.20	-0.15	0.10	0.13
	(0.19)	(0.13)	(0.10)	(0.18)	(0.18)
	[0.45]	[-1.52]	[-1.46]	[0.52]	[0.75]
Constant	0.02	-0.01	-0.02	-0.01	0.00
	(0.04)	(0.03)	(0.02)	(0.03)	(0.03)
	[0.59]	[-0.39]	[-1.26]	[-0.26]	[-0.04]
$D(Sif)_{t-2}$	-0.03	-0.01	-0.01	-0.01	0.00
	(0.01)	(0.006)	(0.004)	(0.008)	(0.007)
	[-3.34]	[-0.99]	[-1.80]	[-0.76]	[-0.48]
$D(Sig)_{t-4}$	-0.04	-0.01	-0.01	0.00	0.00
	(0.01)	(0.007)	(0.005)	(0.009)	(0.009)
	[-4.12]	[-0.85]	[-1.23]	[0.001]	[-0.23]
$D(Siit)_{t-2}$	-0.02	-0.01	-0.01	0.00	0.00
	(0.01)	(0.006)	(0.005)	(0.009)	(0.008)
	[-1.91]	[-1.81]	[-2.16]	[-0.08]	[-0.08]
$D(Sis)_{t-3}$	-0.02	0.01	0.01	-0.02	-0.01
	(0.01)	(0.007)	(0.005)	(0.009)	(0.009)
	[-2.52]	[1.01]	[1.48]	[-1.71]	[-0.72]
$D(Siu)_{t-3}$	0.04	0.00	0.01	0.01	-0.01
	(0.01)	(0.005)	(0.004)	(0.007)	(0.006)
	[5.92]	[-0.20]	[2.13]	[0.79]	[-1.08]
R-squared	0.75	0.64	0.81	0.57	0.48
Adj. R-squared	0.65	0.50	0.74	0.39	0.26
F-statistic	7.46	4.42	10.66	3.20	2.23

Standard errors in ( ) & t-statistics in [ ]

The short-run effect of the restrictions against COVID-19 on the number of weekly cases was identified from the coefficients of the stringency indices in the VECM. According to the results, the increase of the stringency index of the related country led to a significant decrease in the number of weekly COVID-19 cases after two weeks for France and Italy, and after three weeks for Spain at a 10 % significance level. In summary, it takes approximately 2–3 weeks to observe the effect of a certain policy against COVID-19 on the number of cases. However, for Germany and the UK, the effect of stringency on the number of COVID-19 cases was found to be insignificant. The stringencies in Germany, Italy, and Spain effectively reduced the number of cases in France at a 10 % significance level. The decrease in the number of cases in Germany is affected by the stringencies imposed by Italy. Similarly, the cases in Italy are affected by the stringencies imposed by France.

After this step, the generalized impulse response functions of the VECM were calculated as presented in Figure 2. The impulse-response functions (IRFs) in Vector Error Correction Models (VECM) are used to analyze the dynamic relationships between variables in a vector autoregressive (VAR) system with cointegration. The impulse-response functions in a VECM show the response of each variable in the system to a one standard deviation shock to one of the variables while holding the other variables constant. It provides insights into the dynamic interactions and the speed of adjustment towards equilibrium. According to Figure 2, one standard deviation shock in France most effects to the cases in Germany and Italy; one standard deviation shock in Germany most effects to the cases in Italy; one standard deviation shock in Italy most effects to the cases in Germany; one standard deviation shock in Spain most effects to the cases in Germany; one standard deviation shock in the UK most effects to the cases in Germany. Germany and Italy appear to be the countries that are most negatively affected by the other considered European countries when COVID-19 cases are rapidly rising.

Figure 2. Impulse-Response Graph



V. CONCLUSION AND FURTHER SUGGESTIONS

During the COVID-19 pandemic, almost every country-imposed restrictions on people's movements, which severely disrupted international mobility. The imposed controls include visa restrictions, quarantine regulations, border closures, and airline suspensions. The index of travel restrictions indicated the scope and evolution of these measures locally and globally in 2020, with the scope of restrictions increasing throughout the year.

In March 2020, the European Commission issued recommendations, including health transmission, to ensure that European Union workers in essential occupations could continue working (EU Commission, 2020). Particularly, the Commission recommended that member states develop appropriate, burden-free, and quick border crossing actions to enable smooth movement of frontier and posted personnel. However, in different countries, health protocols are governed by different rules and regulations. Quarantine standards have not been developed in a consistent manner among countries, which results in increased information costs and the slowdown, if not complete disruption, of some travel operations. This topic came up regularly during Organisation for Economic Co-operation and Development (OECD) discussions with business alliances and individual enterprises and has received considerable attention. Moreover, this topic has come up several times during OECD meetings with business federations and individual enterprises and has been emphasized by Businesses at OECD (BIAC, 2020). Except for a few countries, such as Sweden, most OECD countries enforced a 14-day quarantine period for anyone authorized to enter by the end of May 2020 (OECD, 2020). Slovenia imposed a seven-day quarantine, while Norway and Switzerland imposed a ten-day quarantine.

However, reduced mobility has led to a drop in commercial services in the first quarter of 2020, owing to the reduction of travel and transportation services. These activities were affected by further measures intended to manage the COVID-19 pandemic, in addition to the direct restrictions imposed on international travel and behavioral modifications. Quarantine procedures briefly halted maritime traffic, while the increase in border restrictions hindered land traffic (World Trade Organization, 2020). Travel prohibitions that restrict people's movement may increase delivery costs in all service sectors. As a result, restoring safe international travel is critical to reducing the economic and social consequences of COVID-19 and ensuring a resilient recovery.

In October 2020, the member states of the European Union accepted a council recommendation for a coordinated approach to restrict free movement in response to the COVID-19 pandemic. This recommendation called for collaborative efforts to offer better transparency on testing and self-quarantine procedures imposed on travelers arriving from high-risk areas. The international coordination of protocols and health standards (for example, reciprocal recognition of antigen test results obtained in accordance with specified norms) will stimulate international mobility and commercial services, and accelerate economic recovery.

According to last news, the WHO announced that Covid-19 no longer constitutes a "global emergency" in terms of health. Therefore, it has been declared that the global emergency of Covid-19 is over. WHO President Dr. Tedros Adhanom Ghebreyesus stated that according to official figures, at least seven million people died in the epidemic. However, he stated that the real number is about three times that, close to 20 million, and warned that the virus continues to be a significant threat (BBC, 2023). International Monetary Fund [IMF] (2020) evaluated the global economic impacts of the COVID-19 pandemic. The report showed that the pandemic had a negative impact on global economic growth as businesses shut down, job losses, and economic uncertainty. For this reason, it is important to measure the effectiveness of the restriction policies in order to avoid similar situations when there is a pandemic and to measure the rate of spread of the pandemic across borders. This study aims to measure the long and short-term spread of COVID-19 cases between countries during the pandemic and the impact of policies to prevent the spread of the virus. Thus, it also provides an idea about the modeling approach to be examined in similar pandemic situations.

This study highlights the fact that COVID-19 has an interaction in transmission between countries in the both short and long term. According to the results, France, Germany, and Italy have a long-term equilibrium relationship with the COVID-19 cases in Spain. When there is a shock in the cases, these countries' relationships with Spain comes into balance. While this period is about 6 weeks in Germany, it is 3 and 3.5 weeks in Italy and France, respectively. Government policy implementation on the spread of COVID-19 increases the stringency index. Although the increase in the stringency index is not significant for the UK and Germany in the short term, it takes effect after two weeks in France and Italy and after 3 weeks in Spain. In fact, the policies implemented by countries affect cases in other countries (for example, policies in Italy affect cases in Germany). For this reason, the policies implemented are important both because they reduce the cases within the countries themselves and because they have a cross-border effect. Impulse-Response functions, on the other hand, showed that when there was a shock in the cases in these 5 countries, Germany and Italy were most affected, and these shock effects continue for a long time.

There are several reasons why Germany and Italy are so affected by COVID-19. One of them is the early spread and dense population. For example, Italy was one of the countries where COVID-19 first appeared in Europe. In Italy, the virus spread rapidly, especially in the Lombardy region. This early spread made it difficult to contain the virus. These countries are also densely populated countries. Dense populations can contribute to the easy spread and transmission of the virus in areas where people live and work together. Also, during the COVID-19 pandemic, the healthcare system in Italy was under great pressure. High case numbers have caused hospitals and intensive care units to exceed their capacities. Insufficient health personnel and resources made it difficult to provide treatment and care services effectively (Çöl, 2021). Finally, Germany and Italy are countries with a high proportion of the elderly population. COVID-19 can lead to more serious consequences, especially for older adults and individuals with underlying health problems. The higher risk of illness and death in the elderly population may have contributed to the number of cases in these two countries being affected so much in other countries.

At the beginning of the pandemic, it is very important to take quick measures. Taking precautions late leads to the rapid spread of the virus and an increase in the number of cases. However, the situation in each country may be different and the level of impact depends on many factors. Rapid and effective measures, the capacity of health systems, and the level of adaptation of society are of great importance in the fight against the COVID-19 epidemic.

This study emphasizes the significance of international coordination among the considered European countries. Such cooperation can help restore safe cross-border mobility. The strength and speed of recovery will be largely determined by the recovery of the service sector, which emphasizes the necessity of integrated mutual recognition agreements and border health protocols. International travel restrictions must be eliminated as soon as the hygienic conditions are favorable, and international cooperation in doing so will help the economy recover even faster. This approach will only be viable if governments adopt a proactive approach and commit to implementing a large anti-epidemic strategy.

In terms of limitations, this study covers a small number of European countries. In future work, the scope of this study can be expanded to include the countries around the world that recorded the highest number of cases during the pandemic by using different methodologies such as spatial VECM. It can deal with a large number of countries' data based on spatial weights. Hence, it will be possible to identify the countries that are most affected by COVID-19 cases in other countries, and the governments of the involved countries will be able to establish integrated strategic collaborations. The vaccine effect is not included in this model, because of the worrying about loss of degrees of freedom. This is also one of the limitations of this study. Difference in differences models may be preferred in future studies to investigate whether vaccination is effective or not in cases. Furthermore, the spread of the pandemic among countries can be investigated using social network analysis and diffusion, in addition to temporal eigenvector methods, to identify countries that play a key role in the spread of COVID-19 and develop collaborative strategic policies to reduce the impact of any kind of pandemic on global trade and social mobility.

Ethics Committee Approval: Since this study does not involve any clinical or experimental research on humans or animals, it does not require an ethics committee approval document. The dataset used in the study is based on secondary data.

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