A spatial analysis of the environmental correlates of COVID-19 incidence in the provinces in Spain

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Abstract

Spreading with astonishing speed, the novel SARS-CoV2 has swept the globe, causing enormous stress to health systems and prompting social distance guidelines and mandates to arrest its progress. While there is encouraging evidence that early public health interventions have slowed the spread of the virus, this has come at a high cost as the global economy is brought to its knees. How and when to ease restrictions to movement hinges in part on the question whether SARS-CoV2 will display seasonality associated with variations in temperature and humidity. In this research, we address this question by means of a spatial analysis of the incidence of COVID-19 in the provinces in Spain. Use of a spatial SUR approach allows us to model the incidence of reported cases of the disease per 100,000 population, as a function of temperature and humidity, while controlling for GDP per capita, population density, percentage of older adults in the population, and presence of mass transit systems. Our results indicate that incidence of the disease is lower at higher temperatures. The evidence with respect to humidity is more mixed, with coefficients for this variable that are significant in only some equations. Our control variables also yield interesting insights, as population density and percentage of older adults display negative associations with incidence of COVID-19, whereas the presence of mass transit systems in the province is associated with a greater incidence of the disease.

Introduction

From a small outbreak linked to a live animal market at the end of 2019 to a global pandemic in a matter of weeks, the SARS-CoV2 virus has threatened to overrun health systems the world over. In efforts to contain the spread, numerous governments in many nations and regions have either recommended or mandated social distancing measures, and as of this writing, millions of people in five continents shelter in place. There are encouraging signs that these measures have arrested the spread of the virus where they have been implemented, and

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have thus helped to keep a bad situation from becoming even worse (e.g., 2020). However, this has come at a high cost, and the consequences for all spheres of the economy, social, and cultural life have been dire (e.g., Fernandes, 2020; Luo and Tsang, 2020). As a result, there is a sense of urgency to anticipate the progression of the pandemic, in order to plan for progressive lifting of restrictions to movement and social contact (e.g., Kissler et al., 2020). Needless to say, this has become a delicate, and politically charged, balancing act between public health and the economy (Gong et al., 2020).

A salient question in the debate on how and when to ease social distancing measures is whether the virus will display seasonal variations. Earlier, diverse studies have shown the effect of temperature and humidity on the incidence of influenza (e.g., Mäkainen et al., 2009; Jaakkola et al., 2014; Kudo et al., 2019). Jaakkola et al. (2014), for example, found that a decrease of temperature and absolute humidity precedes the onset of symptoms of influenza A and B viruses by 3 days in places where the temperature is low. After the 2002-2004 outbreak of SARS, researchers also began to investigate the relationship between these factors and SARS-CoV. In this way, Casanova et al. (2010) used two surrogates, namely the gastroenteritis (TGEV) and mouse hepatitis viruses (MHV), to find that virus inactivation was more rapid at temperatures of 20C than 4C, and at 40C than 20C; in terms of humidity, these researchers reported that survival of the virus was lower at moderate relative humidity levels. In a similar vein, but working directly with SARS-CoV, Chan et al. (2011) found that viability of the virus was lost at temperatures higher than 38C and relative humidity superior to 95%.

While existing research on similar pathogens suggests that SARS-CoV is more stable and potentially easier to transmit in conditions of low temperature and low humidity, it is far from certain that this will also be the case with the novel SARS-CoV2. If such is the case, there is the possibility of easing restrictions to social contact as the weather warms; however, weeks or possibly months of costly measures could become undone if not, and the restrictions are lifted prematurely. Not surprisingly, this issue has triggered a lively debate.

In this paper, we report results from a spatial analysis of incidence of COVID-19 in fifty provinces in Spain. Spain is one of the countries hardest hit by the virus, and enacted lockdown measures on March 16, 2020, in response to a rapidly growing outbreak of COVID-19. We combine data on reported cases of the disease with metereological information, to create a spatio-temporal dataset covering a period of 30 days. We then join this dataset with provincial-level economic and demographic information to act as controls to our key environmental variables. These data are analyzed using a spatial SUR approach, which allows us to account for residual spatial autocorrelation. The results provide persuasive evidence of the effect of temperature on the incidence of COVID-19, as **NOTE ABOUT THE MAGNITUDE OF THE EFFECT**. The evidence concerning humidity is more mixed: while the direction of the effect is negative, as anticipated, the coefficients for this variable are only significant in some of equations in the system. Our control variables also provide some intriguing insights. The results of this analysis provide support to the hypothesis of seasonality of the novel SARS-CoV2, and should be of interest to public health officials and policy makers wrestling with the question of the trajectory of the pandemic.

Context and Data

Covid-19 in Spain

Background information go here.

Sources of data and data preparation

Explain the sources of data and data preprocessing.

Methods: Spatial SUR

The econometric model

The baseline model propouse in this paper is a classical SUR model without spatial effects (from here, SUR-SIM). Following the classical expresion for thios model in stacked form

$$\begin{bmatrix} y_1 \\ y_2 \\ ... \\ y_T \end{bmatrix} = \begin{bmatrix} X_1 & 0 & ... & 0 \\ 0 & X_2 & ... & 0 \\ ... & ... & ... & ... \\ 0 & 0 & ... & X_T \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_1 \\ ... \\ \beta_T \end{bmatrix} + \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ ... \\ \epsilon_T \end{bmatrix} \tag{1}$$

where $y_t = (y_{1t}, ..., y_{Nt})$ is the incidence ratio in the province s ($s = 1, ..., N$) the day t ($t = 1, ..., T$); X_t is a $N \times k_t$ matrix of the k_t independen variables; $\beta_t = (\beta_{1t}, ..., \beta_{Nt})$ is a vector of coefficients and ϵ is the error vector. Like is characteristic in SUR model, we consider dependence among error vector $E[\epsilon_t \epsilon'_{t'}] = \sigma_{tt'}]$. Note that this especification is flexible allowing changes in the coefficients β_{it} in order to modulate the effect of $X_i t$ on y_t. This flexibility is not always diserable and is posible impose restrinctions and consider time constant some β coefficients. In this case we can reformulate the coefficients expression of $\beta_t = (\beta_1, ..., \beta_r, \beta_{r+1}, ..., \beta_{Nt})$ if we want to consider the first r coefficients contanst. The equation (**???**){eq:sur-sim} can be write in compact form,

$$y = X\beta + \epsilon \tag{2}$$

where. . . .

Like in case of cross-section, it is possible identify spatial autocorrelation in the residuals of (**???**){eq:sur-sim} and several tests has been develop to test the null of spatial independence (López Mur Herrera). In case of reject the null alternative specifications has been propose to include spatial effects ((**???**), see also (**???**)). The taxonomy of spatial mod- els that we present in this paper is well known (see Elhorst 2014) and we extend in the SUR framework.

The spatial lag SUR model (SUR-SLM) incorporates a spatial lag of the dependent variable as an explanatory factor.

In this paper we consider the spatial lag model

$$\mathbf{Ay} = \mathbf{X}\beta + \epsilon\epsilon = \mathbf{N}(\mathbf{0}, \mathbf{\Omega}) \tag{3}$$

where A $=I_{TN} - \mathbf{\Lambda} \otimes \mathbf{W}$ with $\mathbf{\Lambda} = \mathbf{diag}(\lambda_\mathbf{1}, ..., \lambda_\mathbf{T})$.

This model can be estimated by maximum likelihood (ref) or instrumental variables (ref). We considerer this methodology to estimate the model. This specification assumes that inceidencein a province ($y_s t$) is partially determined by the weighted average (Wy_st) of incidence in neighbouring provinces. Parameter λ_t identifies the intensity and the sign of the impacts. The strategies of selection and comparison between these models are present in López et al. (2014)

where $y_t = (y_{1t}, ..., y_{Nt})$ is the incidence ratio in the province s ($s = 1, ..., N$) in day t ($t = 1, ..., T$), $X_{st} = (X^1_{st}, ..., X^k_{st})$ is a vector of k independent variables observed in (s,t). The model consider $\beta_t = (\beta^1_t, ..., \beta^k_t)$ coefficients constant in s. The panel model enables correlation between residuals of explanatory models of each time period t, such that $E[\epsilon_t \epsilon'_{t'}] = \sigma_{tt'}$] Analysis and Results ===================

The literature about COVID-19 suggested that population density is the one of the most important proliferate cause of these viscous, however this ill spread with different intensity at big cities of the world. Controlling for socioeconomic characteristics the objective of this paper is observe the effect of clime on COVID-19 proliferation.

Discussion

Possibly do some simulations with the model.

Concluding Remarks

More words go here.

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