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Analysis of the effect of the COVID-19 pandemic on regional socio-economic variables in Morocco using spatial econometric modeling.

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Abstract

The objective of this study is to assess the spatial influence of socioeconomic determinants of regional death rates related to the COVID-19 pandemic in Morocco. We start from a territorial approach to these issues through data published by the Ministry of Health at the level of each Moroccan region. We then use exploratory spatial econometrics techniques to detect autocorrelation and spatial heterogeneity phenomena, in order to highlight the influence of population density, social inequalities in terms of income, employed population and hospital services on the rate of deaths related to the pandemic and to highlight spillover effects between regions located in close proximity to each other. The results of the fixed-effects model with the SEM spatial specification show the direct positive effect of the COVID-19 pandemic on socioeconomic factors in the Moroccan regions. Its indirect effects are insignificant and are generally explained by the central characteristic of the Moroccan Center-Periphery model.

Keywords : Pandemic COVID-19, Regional socioeconomic factors, Spatial exploratory analysis, spatial econometrics.

Introduction

The COVID-19 crisis is prompting governments around the world to take various health measures to contain the spread of the pandemic, a virus whose damage and speed of spread are raising unprecedented questions about healthcare systems, political strategies, working patterns, consumer habits and the resilience of communities everywhere, so unprepared to see their daily lives turned upside down so quickly.

The term "regional health capital" refers to all regional investments designed to strengthen health services, human resources and regional hospital services as a whole, with the aim of improving quality of life and worker productivity, and thus fostering economic development not only in central areas but also in peripheral and remote areas. It also refers to all spending designed to improve the quality of health services in peripheral regions, in order to attract other activities and increase the level of economic growth. Theoretical and empirical literature affirms the close link between socio-economic factors and the COVID-19 crisis in a territory.

The aim of this article is to analyze the effect of the COVID-19 pandemic on regional socio-economic variables in Morocco, using spatial econometric modeling. The aim of the analysis is to describe the spatial distribution of the number of deaths linked to this pandemic in the Moroccan regions. The data used come from the Ministry of Health. For each region, an indicator of the intensity of the pandemic was taken into consideration: the number of deaths linked to COVID-19 at the latest available date. Thus, to capture the socio-economic determinants of the pandemic's diffusion effects. Initial analyses on this subject have highlighted strong spatial heterogeneity in the distribution of the number of individuals who died linked to COVID-19 between the different Moroccan regions (according to reports published by the Ministry of Health, 2020). For this reason, we propose to econometrically test the influence of regional socio-economic factors likely to explain pandemic-related mortality, and to analyze the respective weight of demographic characteristics, income levels and distribution, and living conditions. Insofar as the epidemic has spread over part of the country, and its spread has received considerable attention from the public authorities. We also seek to highlight the geographical structure of the data. To do this, we use exploratory analysis techniques and spatial econometrics to detect autocorrelation and spatial heterogeneity phenomena, in order to highlight the influence of population density, social inequalities in terms of income, the employed workforce and hospital services on the rate of deaths linked to the pandemic, and to highlight spillover effects between regions located in close proximity to each other.

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The article is structured as follows: In the first part, we present the state of the art and review the empirical literature on the link between socio-economic factors and the COVID-19 crisis. The second part presents the model and the exploratory spatial analysis of the variables. Finally, the third part explains the results or effects of simulations of the fixed-effects model with the specification, to draw lessons and recommendations for conclusion.

1. State of the art and review of empirical literature

1.1. State of the art

In Morocco, as in many other countries around the world, the existence of major economic and social inequalities and imbalances in terms of health has been widely recognized by researchers. Even if a large proportion of studies focus on analyzing the causes of these inequalities. Measuring them remains an important public health issue, particularly when it comes to assessing the policies implemented to reduce them, as in the case of the COVID-19 pandemic, which affected an unprecedented number of countries, with far-reaching consequences (Aiach, 2000).

A number of disciplines have emerged since the 1990s, under the influence of numerous and varied research projects in the fields of epidemiology, environmental sciences, social sciences, public health and service management, with the aim of accounting for spatial disparities in access to care, exposure to disease and morbidity. Health geography is a discipline that seeks to analyze the multidimensional determinants impacting health inequalities, especially in times of health crisis. Taking context into account in the analysis of health-related issues is necessary on several levels.

Firstly, Geronimus et al (1999) and Bayer and Kuhn (2020) point out that local differences in health and illness are increasingly taken into account in the literature, and that their omission would lead to a limited understanding of the phenomena studied. Demographic determinants act as factors of spatial differentiation. Demographics differ from one region to another, and can therefore explain geographical differences in terms of access to healthcare systems.

From another point of view, the quality of the healthcare system can also explain differences between regions Scott and Coote, (2007), as is the case for diabetes Scott et al.(2009) or tuberculosis Olson et al.(2012). Thus, poverty in the prevalence of serious diseases is a factor that explains regional differences in terms of health.

1.2. Empirical review

This section will discuss empirical work that has examined the issue of spatial analysis of the influence of socio-economic factors on the prevalence and consequences of the COVID-19

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epidemic, in order to have an efficient method to adopt in our empirical evaluation. The first use of a global economic model to examine the consequences of a serious disease dates back to the studies of Barlow (1967). He used a long-run macroeconomic simulation model to measure the impact of malaria eradication on real per capita income in Sri Lanka. The results confirm the positive link between the ability of the health system to counteract the impact of malaria on economic activity.

Another study by Piatecki and Ulmann (1997), using a model integrating “health capital” as a production factor in the Solow model, establishes a link between health and growth, explaining the evolution of health expenditure and its consequences on economic performance. The estimation results confirm that health plays a role in the economic growth process, through employment in the health sector. The results obtained, although questionable, seem to support this hypothesis for most OECD countries. What's more, in the context of the balanced growth path, estimates have shown that the rate of improvement in healthcare has been roughly twice as fast as the rate of production accumulation, over the past thirty years in France.

Nevertheless, health plays a major role in growth. On the one hand, the health sector can compete with the education sector for scarce resources, and thus have an influence on the growth process, particularly in an endogenous approach that gives education a central role in the accumulation of skills. On the other hand, good health is a prerequisite for economic growth, given its influence on labor productivity, for example. As a result, it is possible to envisage the existence of opposing processes that may eventually offset each other.

A study by A.POCAS and E.SOUKIAZIS (2011) on the empirical evidence between the health factor and economic growth and convergence in Portuguese districts. Using panel modelling for the period 1996/2006 and the GMM estimation method, the authors show that differences in economic growth are generally explained by the health factor. The geographical location of Portuguese districts is also a factor that affects regional health and the convergence process of these localities.

Another work by Carla Blázquez-Fernández , D.C.Prieto, P.P.Gonzalez and J.L.Diaz (2014), analyzes the role of health capital on economic growth in Spanish regions over the period 1980-2007 using an econometric approach based on health survey data (Lorentzen, McMillan and Wacziarg (2008)). The results show a positive link between health and economic growth. Health governance and investments to improve the quality of regional health systems help to improve the health of citizens, and thus boost their returns.

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Furthermore, based on spatial panel modeling, Xiaofei Li, Fen Chen and Songbo Hu (2021), examine the spatial effects of public health spending on economic growth in Chinese provinces. Their findings suggest that public health spending positively influences people's fitness to guide them towards high-quality education, and consequently helps boost human capital productivity. Health spending policies can improve the medical and health environment, municipal facilities and other physical conditions. In addition, cities can attract more high-level, high-quality talent and improve the technology of local regions, which can strengthen technological innovation capabilities and global competitiveness to promote rapid economic growth and counteract the effects of COVID-19.

2. Model presentation and exploratory spatial analysis of variables

2.1. Sample of regional data

The model used to account for the spatial heterogeneity of the COVID-19 pandemic and the associated number of deaths. It is based on regional data recently updated by the various data sources (Ministry of Health; Directorate of Financial Studies and Forecasts/ MEFRA; Haut commissariat au plan (HCP)). Our analysis covers the 12 Moroccan regions according to the Kingdom's new administrative and territorial division in 2015. For each region, an indicator of pandemic intensity was taken into consideration, namely : the number of deaths linked to COVID-19 at the latest available date. Thus, to capture the socio-economic determinants of the pandemic's diffusion effects, we chose the following regional indicators, based on empirical literature and the availability of localized data :

- **COVID-19 regional death rate (2020) :** Number of COVID-19 deaths out of the number of infected cases ;

- **Regional real GDP growth rate (2015/2020) :** Economic indicator reflecting the performance of economic activity in each Moroccan region;

- **Regional unemployment rate (2020) :** socio-economic indicator that represents the mass of unemployment for each region;

- **Regional population density per Km2 (2020) :** demographic indicator that reflects the population density of each region. It is used to spatially capture the spread of death rates linked to the COVID-19 pandemic;

- **Number of hospital services (2020) :** social indicator reflecting regional capacity in terms of hospital coverage.

2.2. Spatial models mobilized

The econometric specification considered in this research takes as its starting point the ordinary least squares (OLS) linear regression model :

$Y = X\beta + \epsilon$, with $\epsilon > N(0,1)$

Y represents the endogenous variable (Number of deaths linked to COVID-19). X represents the vector of exogenous variables used, β is the parameter vector to be estimated and ϵ is the residual or error term, normally distributed. When a spatial autocorrelation phenomenon is ignored in the model specification, but present in the data-generating process, ordinary least squares estimators are biased and non-convergent.

The spatial autoregressive model (SAR) consists in correcting for this bias by integrating a “lagged endogenous variable” WY into the model, and taking into account the spatial autocorrelation relative to the variable Y. The model is written as follows :

$Y = \rho.WY + X\beta + \epsilon$

Where WY is the lagged endogenous variable for the 2-neighbor matrix, ρ is the autoregressive parameter that captures the effect of the interaction between observations of the endogenous variable Y. In this spatial model, the observation of the number of deaths linked to COVID-19 is partly explained by the values taken of the same variable in neighboring regions.

A second way of incorporating spatial autocorrelation into econometric models is the Spatial Durbin Model (SDM). This type of spatial model takes into account spatial autocorrelation through the reaction of the endogenous variable Y and the exogenous variables X. The model is written in the form :

$Y = \rho.WY + X\beta + \theta.WX + \epsilon$

With W X the vector of spatially lagged exogenous variables for the 2-nearest-neighbor matrix, θ is the parameter that measures the interaction impacts between explanatory variable observations on the number of COVID-19-related deaths.

A final way of incorporating spatial autocorrelation into econometric models is the Spatial Error Model (SEM), which involves specifying a process of spatial dependence of residuals in a regression model. The SEM model is defined as follows :

$Y = X\beta + \epsilon$, with $\epsilon = \lambda.W\epsilon + \mu$

The parameter λ reflects the intensity of the interdependence between the regression residuals, and μ is the error term. Omitting a spatial autocorrelation of errors produces unbiased but inefficient estimators, so OLS-based statistical inference will be biased.

According to ElHorst (2010), different approaches can be used to select the right spatial model. We have chosen the so-called Mixed approach, starting with a non-spatial model (MCO). Lagrange multiplier tests (Anselin et al. 1996) are then used to decide between the SAR, SDM or SEM model, or the non-spatial model (MCO) that minimizes the value of the AIC criterion.

2.3. Spatial exploratory analysis: Moran and Geary spatial autocorrelation test

The spatial polarization of the indicators analyzed may result from a contagion effect, spreading the disease from one locality to another. In the presence of this type of spatial grouping of data, the use of standard analysis methods (recourse to OLS modeling) is accompanied by a risk of bias. Indeed, if the phenomenon observed in region i is influenced by what happens in region j, the normality condition of the residuals is no longer respected. To test for the existence of spatial clustering in the data, we apply the ESDA (Exploratory Spatial Data Analysis) method, recommended for analyzing local data (Baumont et al. 2006; Gillain and Le Gallo, 2010).

Determining the multiple interactions between the Kingdom's twelve regions, relies on the definition of a spatial weight matrix (Florax and Nijkamp, 2014). The spatial matrix W used here is the so-called " **Inverse distance matrix** ". We tried two types of spatial autocorrelation tests, summarized in Table 1, namely: Moran and Geary tests. The aim is to check the consistency of the results of the ACS test, in order to detect the nature of Morocco's territorial configuration (positively or negatively concentrated and random).

Table 1 : Moran and Geary ACS Global Tests

	Weight matrix : Inverse distance matrix			
	MORAN'S TEST		**GEARY'S TEST**	
	INDICE ACS	**P-VALUE**	**INDICE ACS**	**P-VALUE**
Number of deaths COVID 2020	0.30	0.0601*	0.64	0.06926*
Regional GDP 2020	0.23	0.05701*	0.69	0.09282*
Regional unemployment rate 2020	0.54	0.006069**	0.37	0.00395***
Number of Hospital Services 2020	0.62	0.00193***	0.35	0.00327***

Significance: *p<0.10; **p<0.05 and ***p<0.01

Source : prepared by the authors

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3. Estimates and discussion of results

3.1. Spatial model Estimates

Spatial model estimates : the detection of individual spatial effects requires consideration of the nature of the interactions linked to all model variables. As proposed in the empirical literature, the choice of the optimal model depends on the weakest traditional choice criteria (Akaike and Baynesian). The estimation procedure enabled us to select the SEM specification (lowest AIC criterion -103.22), which tends to explain spatial interactions via the endogenous variable (regional real GDP) and the explanatory variables.

Table 2 : Estimation results for SAR, SDM and SEM fixed-effects models

	MCO	**SAR**	**SDM**	**SEM***
Regional real GDP 2020	-2.354e-05 (1.226 e-04)	-1.6773e-05 (9.258 e-05)	6.2295e-05 (1.5946 e-04)	8.2169e-05 (6.916 e-05)
Regional unemployment rate 2020	-2.428 (1.529)	-2.9152 (1.2185)	-1.5759 (1.1665)	-2.6265** (8.839 e– 01)
Number of Hospital Services 2020	1.532 (1.321)	1.7799 (1.0161)	5.2432 e -01 (1.9063)	5.6842 e -01 (6.204 e– 01)
P	-	-0.3254	-	-
Λ	-	-	-	-0.6766
θPIB	-	-	2.0665e-04* (1.208 e-04)	-
θUnemployment rate	-	-	-3.1190 (2.5435)	-
θNumber of hospital services Constant	3.555 (2.516 e + 01)	4.6278e + 01 (2.0855e + 01)	7.3257e + 01* (4.1301)	4.1097 e + 01** (1.447e + 01)
Comments	12	12	12	12

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AIC	104.41	105.02	107.39	103.22
R^2 ajusté	0.5156	-	-	-
Moran's Test	-0.4101 (0.6591)	-	-	-
LM-Error Test	1.4190 (0.2336)	-	-	-
LM-Lag Test	1.1400 (2856)	-	-	-
Robust LM-Error Test	0.2888 (0.9210)	-	-	-
Robust LM-Lag Test	1.4289 (0.4895)	-	-	-
Common factor test	-	-	1.8234 (0.6098)	-
Test LM residual auto	-	1.3982 (0.2370)	3.4365* (0.0637)	-
Huasman Test	-	-	-	1.6948 (0.7919)

Significance : p<0.10*; p<0.05** and p<0.01***, values in brackets represent standard errors of coefficients.

Source : prepared by the authors

The model indicates that the regional unemployment rate has a significant negative impact on the COVID-19 mortality rate. Specifically, the coefficient for this variable is -2.6265, suggesting that an increase in the unemployment rate is associated with a decrease in the mortality rate. While this might seem counter intuitive at first, a potential explanation could be related to specific economic and social dynamics. For example, a higher unemployment rate

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may result in fewer social interactions and population movements, which could indirectly limit the spread of the virus in certain regions. This interpretation might also reflect regional disparities where areas with higher economic activity (and thus lower unemployment) experienced more population movements, increasing exposure to the virus.

Regarding the impact of regional GDP, although the coefficient does not appear to be significant, its positive value (+8.2169e-05) suggests that an increase in regional GDP is weakly correlated with a rise in mortality. This could reflect the fact that economically developed regions, with more services and activities, were more exposed to higher transmission rates. In these regions, the intensity of economic exchanges and higher population densities may have exacerbated the spread of COVID-19, leading to higher mortality rates.

As for the number of hospital services, the coefficient is not significant in your SEM model. This suggests that the availability of hospital services in 2020 did not have a measurable direct impact on COVID-19-related mortality. This could be interpreted in several ways. On the one hand, it is possible that hospital capacity in Morocco, particularly during the early phase of the pandemic, was quickly overwhelmed in certain regions, nullifying the effect of better hospital infrastructure. On the other hand, it may also reflect disparities in the quality of services provided or the unequal distribution of these resources.

In summary, your model's results seem to highlight regional disparities and complex interactions between economic factors and COVID-19 mortality in Morocco. Unemployment and regional economic activity played key roles in the pandemic's dynamics, with more economically dynamic regions showing increased vulnerabilities to virus transmission. However, access to healthcare services appears to have had a less direct impact, possibly due to structural constraints in managing the pandemic.

This analysis raises important considerations for how public policies in Morocco could address not only healthcare infrastructure but also regional economic dynamics, to strengthen resilience in the face of future health crises.

3.2. Discussion of results

The results of the SEM model, where the COVID-19 mortality rate is the dependent variable and the independent variables include regional GDP, the unemployment rate, and the number of hospital services, provide important insights into the economic and spatial determinants of mortality during the pandemic in Morocco.

First, the negative and significant relationship between the regional unemployment rate and the COVID-19 mortality rate (-2.6265) is a key finding. Although it might appear counterintuitive

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at first, this relationship can be explained by the dynamics of social interaction and mobility. Higher unemployment rates are likely associated with lower levels of economic activity and reduced mobility, which could have led to fewer opportunities for the virus to spread. This effect is particularly relevant in regions where economic downturns resulted in more people staying at home or experiencing reduced interaction with others, thus lowering the transmission of COVID-19. In contrast, regions with lower unemployment might have experienced higher population movement and economic activity, potentially increasing the spread of the virus and, subsequently, the mortality rate.

In terms of regional economic activity, the positive coefficient for regional GDP (although not statistically significant) suggests a weak positive correlation between economic development and COVID-19 mortality. Regions with higher GDP are typically more densely populated, with greater mobility and higher levels of interaction, which could lead to a faster spread of the virus. Additionally, more developed regions may have been more exposed to external contacts (through business or tourism), which could have further exacerbated the transmission of the virus. However, the lack of statistical significance implies that the effect of regional GDP on mortality is not as robust as that of unemployment.

Interestingly, the number of hospital services does not show a significant direct effect on COVID-19 mortality in this model. This result can be interpreted in several ways. One possibility is that the healthcare system in Morocco, while potentially adequate in terms of the number of services available, faced capacity constraints during the pandemic. Even in regions with a higher number of hospital services, the rapid influx of COVID-19 cases may have overwhelmed healthcare facilities, limiting their ability to significantly reduce mortality. Furthermore, there could be regional disparities in the quality or accessibility of healthcare services, with some regions being better equipped to handle severe cases of COVID-19 than others. This finding underscores the importance of not only expanding healthcare infrastructure but also ensuring its resilience and quality during times of crisis.

The spatial error dependence (Λ = -0.6766) captured in the SEM model also highlights the presence of spatial autocorrelation in the mortality data. This indicates that COVID-19 mortality rates in one region are influenced by the rates in neighboring regions. Such spatial spillover effects could be explained by the movement of people across regional borders, the spread of the virus through economic or social networks, or the shared use of healthcare resources across regions. The existence of this spatial dependence suggests that local policies

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alone may not be sufficient to contain the pandemic and that regional cooperation and coordinated responses are crucial.

Finally, the goodness-of-fit indicators, such as the Akaike Information Criterion (AIC), suggest that the SEM model performs well in explaining the variation in COVID-19 mortality across regions, with an AIC of 103.22, which is lower than that of other models tested. This supports the choice of the SEM model as the best-fitting approach to capture the spatial and economic dynamics of COVID-19 mortality.

In conclusion, the results of this analysis provide valuable insights into the regional and economic factors that influenced COVID-19 mortality in Morocco. The significant impact of unemployment suggests that economic disruptions during the pandemic may have had protective effects in some regions, while the complex relationship between GDP and mortality underscores the need for careful consideration of how economic development influences health outcomes during crises. Additionally, the findings highlight the limitations of healthcare infrastructure and the importance of addressing regional disparities and spatial spillovers in public health policy. Overall, this analysis suggests that addressing the socioeconomic determinants of health and fostering regional cooperation will be key to enhancing resilience against future pandemics in Morocco.

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Conclusion

In this study, our main objective is to assess the spatial influence of socioeconomic determinants of regional death rates related to the COVID-19 pandemic in Morocco. We take a territorial approach to these issues, using data published by the Ministry of Health for each Moroccan region. We have estimated an endogenous economic growth model based on panel-spatial models that better control and capture the specific differences between the 12 regions. In this sense, a spatially augmented neoclassical Cobb-Douglas production function in the Solow sense is used to explain the spatial diffusion effects of health on regional economic growth.

Despite the data restrictions which conditioned our empirical analysis and which, in part, may weaken our results, we were nonetheless able to draw some interesting conclusions. In addition to the positive and significant impact of physical capital on regional growth, we found that health capital exerts a positive effect on regional economic activity over the entire period studied, leading to confirmation of the increasing returns of the health sector. Our results also show that the spatial structure of Moroccan regions in terms of economic growth depends on interactions between growth levels and investment in physical capital. Inter-regional migration, rural exodus and the attractiveness of the healthcare system in the central regions explain the positive impact of healthcare. Public decision-makers therefore need to pay particular attention to the issue of regional health. High ratios between the number of inhabitants and the number of doctors, as well as satisfactory quality and availability of health facilities, are advantages for improving access to health services, a problem common to most rural and isolated regions, but also to more dynamic urban areas. This underscores the need to develop inclusive local policies to ensure that health capital is available to those who need it most. However, to boost Morocco's regional economy POSTCOVID, the Kingdom's authorities must now turn their attention to enhancing intangible capital, through increased investment in human capital (education and health), social capital, public capital, but above all digitalization and digitization practices, which are the pillars of an inclusive and sustainable development model. The key to success is consensus in the territorialization of public policies and the participation of all stakeholders, who represent the conditions for the development of the Moroccan territories of the future.

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