**Is there a relationship between industrial clusters and the prevalence of COVID-19 in the provinces of Morocco?**

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Abstract
The main objective of this paper is to verify if there is a relationship between industrial agglomeration and the prevalence of COVID-19 and its diffusion within and between the provinces of Morocco. To do so, we used spatial exploratory analysis and spatial econometrics to show that the preponderance of industrial activity in a province has a significant effect on the number of active COVID-19 cases in that province. On the other hand, we have shown that the spatial diffusion of this effect is not significant, which indicates the appropriateness of the lockdown implemented. We have also shown that age, socio-economic deficits and habitat conditions are not significant determinants in the onset and spread of the pandemic.

**KEYWORDS**
COVID-19, disease diffusion, industrial clusters, socio-economic deficits, spatial autocorrelation, spatial econometrics

**JEL CLASSIFICATION**
R10; R15; I18

1 | **INTRODUCTION**

Morocco's interest in COVID-19 began with its international dimension from its appearance in Wuhan on 31 December 2019. This interest increased when the pandemic reached its main partner countries (France (25 January 2020), Spain, United Kingdom and Italy (31 January 2020), Germany (27 January 2020; Johns Hopkins, 2020). Since the first imported case diagnosed in Morocco on 2 March 2020 (MH, 2020a), interest has...
taken on a national and then a territorial dimension as soon as the pandemic spread among Moroccan residents. The territorial dimension of the infection has grown with the appearance of outbreaks in families and in industrial units. This territorial dimension is all the more important given that the first 10 provinces most affected by the pandemic out of the 75 that make up Morocco, concentrate 78% of confirmed cases and 68% of deaths. This health impact is all the more important on the economic level since these 10 most affected provinces account for 35% of Morocco’s GDP and on the social level since they concentrate 30% of the total population and 49% of industrial employment.

Territorial specificities in economic, social and demographic terms would be behind a heterogeneous distribution of the pandemic and its effects at the regional level. Thus, out of 776 European territories analysed, a third had a mortality rate 25% higher than normal during the first wave of the pandemic in March–May 2020 (Guibourg, 2020). This heterogeneity in terms of health is also noted in social and economic terms. Thus, the shares of jobs potentially threatened by containment measures range from less than 15% to more than 35% in 314 regions of 14 European countries (OECD, 2020a). Therefore, the territorial dimension in managing the effects of the pandemic should also be taken into consideration (Bailey et al., 2020; OECD, 2020b).

However, the public policies implemented in Morocco to reduce the negative effects of COVID-19 were initiated at the national level without any distinction as to the specificities of the regions. These include, in particular, the creation of an economic watch committee bringing together public (ministerial departments and the Central Bank) and private partners which has put in place measures (MEFAR, 2020a, 2020b) that have certainly helped to reduce the spread of the pandemic in Morocco (Hadrya et al., 2020). This centralized state response is explained by the mode of territorial governance in Morocco which, despite the gradual implementation of advanced regionalization in 2015 following multi-stakeholder recommendations (Regionalization Advisory Committee (RAC), 2011), has given the regions few powers related to health management and economic promotion (GSG, 2016).

The main objective of this paper is to verify if there is a relationship between industrial clusters and the prevalence of COVID-19 and its diffusion within and between the provinces of Morocco. To do so, we have adopted a conceptual framework inspired by medical geography that suggests that places with high connectivity and characterized by a high density and geographical concentration of economic activity may be subject to relatively higher infections (Meade & Emch, 2010). Indeed, the agglomeration of activities offers greater externalities to firms (Krugman, 1991) and facilitates their connectivity and the territorial expansion of their area of influence (Boschma & Iammarino, 2009).

To highlight this correlation, we modelled the provincial prevalence of COVID-19 relative to the share of manufacturing industry in provincial GDP as a proxy indicator of industrial agglomeration in Morocco. Indeed, local specialization in geographically concentrated economic activities would be a vector of transmission of COVID-19 following a core-periphery model (Ascani et al., 2020). This particular attention to the industrial environment is also motivated by the need to restart the economy while keeping in mind the imperative of health security. In addition, relatively young people in certain manufacturing industries are vectors of atypical transmissions of the virus, which is difficult to detect without systematic screening (Munster et al., 2020). We will also be interested in other potential determinants of the prevalence of the pandemic, in particular, the living conditions whose effect has been confirmed in developed countries (Cambois & Jusot, 2007) as well as in developing ones. In this way, we will be able to clarify the link between the prevalence of COVID-19 and local socio-economic characteristics in order to support political decision-makers in the calibration and territorial targeting of public aid and the implementation of concise containment in view of the second wave that is looming.

2 | CONCEPTUAL FRAMEWORK FOR THE ANALYSIS OF THE DETERMINANTS OF THE PREVALENCE AND SPATIAL SPREAD OF COVID-19

The evolution towards production modes based on the concentration of companies in dedicated industrial zones in order to improve their productivity (Hu, Xu, & Yashiro, 2015) has also been verified for the case of Morocco
Indeed, spatial arrangements based on production spaces interconnected with residential and important employment areas exploit the positive characteristics of the geographical situation in order to present a wide range of agglomeration advantages (Gordon & Kourtit, 2020).

However, the spatial aspect has been highlighted as a major explanatory factor in the spread of previous pandemics (Cliff & Haggett, 1989; Sabel et al., 2010) and, currently, that of COVID-19 (Bag et al., 2020; Kapitsinis, 2020). This local spread leads to significant local outbreaks (Benedetti et al., 2020) by spreading closely following commuting (Charaudeau et al., 2014).

Indeed, connected spaces with a high concentration of economic activity have a higher prevalence of infections (Meade & Emch, 2010). Thus, the diversification and growth of territorial mobility, making more complex the network of place-specific interactions between people and the infectious agents that cause disease (McLafferty, 2010), are all reasons that accentuate the spatial spread of infectious diseases, particularly COVID-19 (Fritz & Kauermann, 2020).

Moreover, the current process of extensive urbanization in Morocco, which includes suburbanization, post-urbanization and peri-urbanization, following the development of “satellite” cities around industrial zones, is an important factor in the spread of infectious diseases (Connolly et al., 2021).

This justifies the timeliness of the analysis of spatial effects (Anselin, 1988) in the Moroccan context in order to highlight local particularities in terms of industrial and demographic concentration as well as other socio-economic indicators that would influence the diffusion of COVID-19. The basic spatial indicators that we recommend to use have demonstrated their appropriateness to identify the spatial effect of the diffusion of COVID-19 (Bourdin et al., 2020; Ghosh & Cartone, 2020).

The basic research question is to determine the local socio-economic characteristics that would increase the prevalence of COVID-19 in order to better guide the differentiated implementation of policies to reduce the spread of the pandemic. The basic idea is that the prevalence of the virus is spatially related to the pre-existing socio-economic system, in other words, to a spatial heterogeneity attributable to certain social and economic variables whose relevance will be determined by us, namely industrial concentration, population density, proportion of elderly people in the population and socio-economic deficits. This relevance analysis will take into account possible spatial interactions between them (Anselin, 1988).

Thus, we will be able to propose differentiated local public policies for the containment of the prevalence and spread of COVID-19 according to the specific profiles of the provinces to slow down the current second wave. The opportunity of this tailor-made approach is to find a compromise between health security and the economic activity strongly eroded by the successive restrictive measures.

3 | DATA AND METHOD

We collected the state of the pandemic in the provinces of Morocco from 2 March 2020 to 12 May 2020 through press releases from the 12 regional delegations of the Ministry of Health. These are data from 75 provinces on the number of confirmed cases of people infected with COVID-19, the number of people cured and the number of people who died as a result of their COVID-19 infection. We found difficulties in collecting this information in the absence of a single web-based platform that captures daily information while keeping track of the evolution of the pandemic by province. In addition, some regional delegations published the results with a delay of up to two weeks while the aggregated data at the national level were published following two daily press briefings (at 10:00 am and 6:00 pm). Finally, the number of tests established remains insufficient to determine the epidemiological status of the pandemic, particularly in its asymptomatic component. Indeed, the screening capacity was only 3,000 per day in May in 50 screening centres covering the 75 provinces of Morocco (MH, 2020b). Moreover, the regional delegations regularly updated their press briefings by correcting the spatial affiliation of epidemiological results.
Then, we calculated three indicators for the 75 provinces of Morocco:

1. The rate of confirmed cases from 2 March 2020 to 12 May 2020 per 1,000 inhabitants. It is the ratio of the number of confirmed cases of people reached by COVID-19, recorded from 2 March 2020 to 12 May 2020, to the provincial population in thousands of inhabitants.
2. The rate of cases hospitalized on 12 May 2020 per 1,000 inhabitants. It is the ratio of the number of active cases of people reached by COVID-19, which is the number of confirmed cases minus those cured, recorded on 12 May 2020, to the provincial population in thousands of inhabitants.
3. The mortality rate as of 12 May 2020 per 1,000 inhabitants. It is the ratio of the number of deaths due to COVID-19, recorded from 2 March 2020 to May 12, 2020, to the provincial population in thousands of inhabitants.

We also collected data that would have a potential effect on the territorial spread of the pandemic. These include, in particular, development deficit indicators, which contextualize individual risk factors (Link & Phelan, 1995). We considered, in particular, the indicators of average socio-economic and housing deficit (ONDH, 2017). These synthetic indicators were constructed by the National Observatory of Human Development as composite indices, calculated from a set of indicators from the 2014 General Census of Population and Housing that provide information, on the state of multidimensional human development of territories.

Individual risk factors will only be taken into account in our analysis through aggregated data at the provincial level. These include age (Onder et al., 2020) through the share of the population aged 65 and over (High Commission for Planning, 2019). Indeed, the elderly would have a higher probability of being affected by COVID-19, in particular, men with chronic diseases as revealed in the study of infected cases from the Chinese province of Wuhan (Chen et al., 2020). All the more so since 45% of the people who required a medical examination, among the 11% suffering from chronic diseases, did not have access to this service during the lockdown (High Commission for Planning, 2020a).

We also took into account the indicators that would influence the appearance of family outbreaks. These include demographic density (HCP, 2019) and average household size (HCP, 2019). Indeed, high density areas are more affected by epidemics as revealed in Hong Kong for avian flu (Lee & Wong, 2010) and in Brazil with a high potential for transmission of Zika in urban centers (Lourenço et al., 2017).

Finally, we have integrated the indicators that would influence the appearance of outbreaks in professional environment, in particular, for the frontline activities which were maintained during the lockdown decreed by Morocco since 20 March 2020 and which has been extended to 10 June 2020. This concerns, in particular, the share of the active population employed in industry. We established with all the provincial indicators collected a GIS of the 75 provinces of Morocco on Savgis (Souris et al., 1984).

It should be noted that, since 2015, Morocco has been spatially subdivided into three interlocking administrative declinations of local authorities: regions (12), provinces (75 of which 10 concentrate 35% of the total population) and communes (1,538 of which 256 are urban and concentrate 55% of the total population).

Several neighbourhood matrices W, of size N × N, whose diagonal elements are zero, have been proposed in the literature to measure the spatial correlation between the territories such as the contiguity matrices, which associate for each bordering territory the value 1 (and 0 otherwise), the k closest neighbours, the distance matrix ... To measure the spatial correlation between the provinces in our analysis, we considered the k closest neighbours matrix.

Next, we used Moran’s spatial autocorrelation indicator:

\[ I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij} (y_i - \bar{y}) (y_j - \bar{y})}{\sum_i \sum_j w_{ij} (y_i - \bar{y})^2}. \]

A value close to 1 will be synonymous with a positive correlation. Under the hypothesis H_0 of absence of spatial autocorrelation (I = 0), the statistic \( I^* = (I - E[I]) / \sqrt{V[I]} \) follows asymptotically a normal distribution N (0,1). We also
considered the Monte Carlo variant to ensure the robustness of our results if this last assumption of normality was not satisfied.

Finally, in order to determine the elements that influence the three main indicators of our analysis by taking into account the existence of potential spatial heterogeneity, we considered the global spatial model, which is written in its matrix form as follows:

\[ Y = \rho WY + X \beta + WX \theta + u \]

\[ u = \lambda Wu + \epsilon, \]

with \( \beta \): vector of exogenous explanatory variables; \( \rho \): coefficient noting the endogenous interaction effect; \( \theta \): vector of dimension \( K \) (number of exogenous variables) related to the exogenous interaction effects; \( \lambda \): coefficient of spatial correlation of errors.

This model is only identifiable in its constrained form: \( \theta = 0, \lambda = 0 \) or \( \rho = 0 \) and this, following several approaches. We have opted for the bottom-up approach which consists in starting with the non-spatial model (Figure 1). Lagrange multiplier tests allow us to decide between the spatial autoregressive (SAR), spatial error (SEM) or ordinary least squares (OLS) models. We established the exploratory and spatial econometric analysis by the R Spdep package (Bivand et al., 2013).

4 | RESULTS AND DISCUSSIONS

The number of people with COVID-19 in Morocco has reached 6,406 confirmed cases as of 12 May 2020, representing an average prevalence rate of 0.178 per 1,000 inhabitants. In order to stem the spread of the pandemic, the Moroccan state put in place over the period from 1 March 2020 to 12 May 2020 health, economic and social measures (Figure 2). Thus, eight health measures were taken by declaring in particular a state of health emergency with widespread containment. These measures aimed to reduce mobility (international (air and sea) then interurban (rail and road) and intra urban), attendance of public places and mass gatherings (sports, cultural and religious events and family celebrations), consolidation of the health care capacity (increased of health care spending) and prevention of contagion (use of masks and alcogels).
In addition to health measures, the Moroccan government has put in place four social measures to compensate those who lost their jobs during the health emergency, including those in the informal sector, by establishing a special fund dedicated to managing the pandemic. The social measures made it possible to compensate 35% of the loss of income, particularly in urban areas (compensation of 63% versus 28% in rural areas) (High Commission for Planning, 2020b). Three economic measures have also been implemented to support corporate cash flow and ease pressure on tax and bank maturities.

These measures have helped to flatten the curve of contaminated cases relative to neighbouring countries (Sebbani et al., 2020), but the prospects for the spread of the pandemic remain alarming (Layelmam et al., 2020) and the socio-economic impacts have been as significant as those identified internationally (Nicola et al., 2020).

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Indeed, during the period of containment, 83% of Moroccan companies stopped output, particularly very small ones VSEs (86%). The industrial sector was among the most affected sectors, particularly the textile and leather industries (99%) and metal and mechanical industries (91%). Also, 50% of companies have temporarily reduced their workforce and 10% permanently. The temporary reduction of jobs was most significant for the textile and leather industries (85%) and the electrical and electronic industries (82%) (HCP, 2020d).

This pressure on the labour market has also been reproduced on household purchasing power, since the average monthly income of employed workers has fallen by 50% relative to the pre-containment period (HCP, 2020b). Thus, at the macroeconomic level, the strict confinement for nearly 10 weeks in the second quarter of 2020 resulted in a fall in domestic demand of −6.7% and in foreign demand of −25%, leading to a fall in GDP of −13.8% year-on-year in the second quarter of 2020 (High Commission for Planning, 2020e).
The first 10 provinces most affected by the pandemic out of the 75 that Morocco has, concentrate 78% of confirmed cases on an aggregate area that represents only 2.3% of the total area of Morocco for 30% of the total population. For these provinces, the average prevalence rate (0.471 per 1,000 inhabitants) is 2.6 times higher than the national average (see Table A1 in the Appendix). These provinces are particularly specialized in manufacturing industries and account for 49% of national industrial employment. This is particularly the case of three of the four provinces with the most cases of contamination, namely Casablanca, Tangier-Assilah and Fès which have shares of the active population employed in industry relative to provincial employment of respectively 23%, 33% and 24% against a national average of 12%.

Twenty one provinces have a rate higher than the national average (see Figure 3). The distribution of the infection rate is very asymmetrical with a median equal to 0.035 per 1,000 inhabitants. The highest rate of infection is recorded in the province of Ouarzazate, which has recorded an outbreak in the local penitentiary with the contamination of 268 inmates and 64 officers. Fifteen provinces did not record any cases during the period of analysis. These rates are dependent on the screening capacity, which reached 3,000 per day in May in 50 screening centres throughout Morocco (MH, 2020b) and is expected to increase to 10,000 with the involvement of private laboratories.

The number of deaths due to COVID-19 in Morocco has reached 188 deaths as of 12 May 2020, representing an average mortality rate of 0.005 per 1,000 inhabitants (see Figure 4). The first 10 provinces most affected by the pandemic out of the 75 in Morocco account for 75% of deaths. For these provinces, the average mortality rate (0.012 per 1,000 inhabitants) is 2.3 times higher than the national average. One third of the provinces, 20 out of 60, have not recorded any deaths, while 14 provinces have a rate above the national average. These include the chief towns of Morocco's regions, namely Marrakech (0.029), Tangier-Assilah (0.016), Casablanca (0.011), Oujda-Angad (0.009) and Rabat (0.009) (see Figure 4).

Thus, the number of cured cases has reached 3,184 when the number of active cases attained 3,034 as of 12 May 2020, which corresponds to an average hospitalization rate of 0.084 per 1,000 inhabitants (see Figure 5). The first 10 provinces most affected by the pandemic, account for 85% of hospitalizations. For these provinces, the average hospitalization rate (0.241 per 1,000 inhabitants) is 3 times higher than the national average. It should be
pointed out that these provinces are better equipped in terms of health facilities, with one bed in public hospitals for 964 inhabitants and one public doctor for 2,244 inhabitants, compared to respective national averages of one hospital bed for 1,416 inhabitants and one public doctor for 3,292 inhabitants. 13 provinces out of the 60 contaminated provinces no longer have active cases, bringing the number of provinces free of the pandemic to 28. Twelve of the 47 provinces still infected have a rate above the national average with the highest rate in Tangier-Assilah (0.426).
Therefore, it seems that, a priori, the state of emergency decreed on 20 March and renewed on 20 April with a night curfew (from 7 p.m. to 5 a.m.) seems to have slowed down the territorial spread of the pandemic. This is at least confirmed by Moran’s test for the infection rate and mortality rate, for which it is not significant (Table 1).

On the other hand, the p-value of the Moran test is below the 5% threshold for the hospitalization rate rejecting the null hypothesis of absence of spatial autocorrelation. Thus, the spatial distribution of the hospitalization rate due to COVID-19 is subject to greater spatial aggregation than if the underlying spatial processes were randomized.

This test was established for the matrix of the three closest neighbours knowing that the average number of neighbours in the provinces of Morocco is 4.7. This allows us to cover at best two of the three modes of spread of a pandemic, namely the hierarchical mode between the large cities and the “jump” mode along the transport routes (Cliff et al., 2004). Moran’s Monte Carlo test confirmed the results based on the standard Moran’s test (Table 2, Figures 6 and 7). The positive value of Moran’s test statistic suggests that provinces with high (or low) hospitalization rates tend to be located close to provinces with similar rates.

The analysis of local spatial autocorrelation is established using the local Moran index, which measures the degree of local spatial autocorrelation for each province (Anselin et al., 1996). Provinces are thus classified according to the significance of their local spatial autocorrelations. Two clusters in particular stand out. These are the four provinces of the Fez-Meknes region with higher rates compared to the national level surrounded by provinces with low rates and the Saharan provinces of southern Morocco that are free of COVID-19 neighbouring other provinces, also unaffected.

Taking into account this spatial heterogeneity of the hospitalization rate, we ran all the configurations of spatial regressions between the hospitalization rates of the 75 provinces of Morocco and the independent variables mentioned above. These are the average of socio-economic and housing deficits, the share of the population aged 65 and over, the population density, the average household size and the share of the active population employed in industry. The Lagrange multiplier tests and the bottom-up approach presented above (Table 3) led to the choice of an ordinary least squares model (Anselin et al., 1996).

### Table 1: Moran’s test of the COVID-19 epidemiological indicators of Moroccans provinces

| Indicator       | Moran’s I | Z-score | p-value |
|-----------------|-----------|---------|---------|
| Infection rate  | 0.0351    | 0.68123 | 0.2479  |
| Mortality rate  | 0.0425    | 0.72378 | 0.2346  |
| Hospitalization rate | 0.1336   | 1.8103  | 0.03513 |

Note:
***Significant at the 1% threshold; **Significant at the 5% threshold. *Significant at the 10% threshold.
Source: Authors’ calculations.

### Table 2: Monte Carlo simulation of Moran’s test of the COVID-19 epidemiological indicators of Moroccans provinces

| Indicator       | Statistic | Rank | Pseudo p-value |
|-----------------|-----------|------|----------------|
| Infection rate  | 0.035114  | 88   | 0.1287         |
| Mortality rate  | 0.042511  | 77   | 0.2376         |
| Hospitalization rate | 0.13365  | 98   | 0.0297         |

Notes: Number of simulations = 101.
***Significant at the 1% threshold. **Significant at the 5% threshold. *Significant at the 10% threshold.
Source: Authors’ calculations.
Thus, the spatial spread of the pandemic, either through affected cases (SAR model) or through the movement of people working in industrial units (SEM model) is not significant. Other analyses have concluded that there is a significant spillover effect of the pandemic. (Amdaoud et al., 2020).

Only one variable is significant, namely the share of the labour force employed in industry, which has a positive impact on the number of active COVID-19 cases in the provinces. This confirms the role of occupational outbreaks in industrial units in maintaining active cases in the provinces. Indeed, the nature of industrial specialization in Morocco based on labour intensity and favouring chain work promotes contacts between people through products.
In addition, these units are located in industrial zones on the outskirts of residential areas requiring support services (canteen, staff transport, etc.) that promote infection despite the health rules imposed\(^{10}\) (physical distancing, 50% of transport capacity, mandatory mask wearing, guides for resumption of activity of the General Confederation of Moroccan Enterprises (GCME, 2020)).

Furthermore, variables relating to social conditions do not appear to be significant determinants in the spread of the pandemic. Indeed, the \(p\) values of these variables, namely population density, average household size, socio-economic deficit and housing deficit are below the 5% threshold (Table 4). In the case of density, our result corroborates those of other studies which have concluded that small towns in a rural environment where a ‘super propagation’ event occurred had the highest number of Covid-19 cases per capita (Kuebart & Stabler, 2020). However, for other infectious diseases, our result is at odds with other analyses where social condition variables were determinant in their spread, such as the case of population density for measles or measles-like infectious diseases (Tarwater & Martin, 2001) and population density and GDP for dengue fever (Yue et al., 2018).

Similarly, we found that age has no differentiated effect on hospitalization rates in Moroccan provinces, consistent with the study in Zhejiang Province, China, where COVID-19 infects children and people over 65 years of age indiscriminately (Xu et al., 2020), whereas it has a differentiated effect in Wuhan Province (Chen et al., 2020). In our analysis, we had to miss the effect of age due to the aggregated nature of the data at the provincial level and the absence of other clinical indicators of vulnerability. Indeed, COVID-19 is more likely to affect older men with comorbidities (Chen et al., 2020; El Aidaoui et al., 2020). The second reason would be the special attention given to seniors in terms of protection. Indeed, 40% of households consider that even after confinement, the elderly should continue to protect themselves and adopt prophylactic measures as during the period of confinement (High Commission for Planning, 2020d).

This would probably be due to the lockdown established since 20 March and the night curfew introduced during the month of Ramadan (from 7 p.m. to 5 a.m. from 24 April to 23 May) all the more so since the confinement has been fully respected by 79% of the Moroccan population, particularly in urban areas (89%) (HCP, 2020c). The role of lockdown in slowing the spread of the virus has been noted in general (Hellewell et al., 2020) and in the specific case of Italian regions (Bourdin, Jeanne, Nadou, & Noiret, 2020) with, however, significant economic repercussions in Morocco (Firano & Fatine, 2020).

Our results show that there are no relative spatial dependencies and that apart from the industrial specialization of the provinces, the other provincial variables considered are not statistically significant. This suggests, without claiming a cause and effect relationship, that the confinement policies implemented by Morocco despite their economic, social and budgetary repercussions contributed to contain the interprovincial spread of the pandemic.

### Table 3

| Statistic | Parameter | \( p\) value |
|-----------|-----------|--------------|
| LMerr     | 0.879601  | 0.3483       |
| LMLag     | 0.730697  | 0.3927       |
| RLMErr    | 0.184473  | 0.6676       |
| RLMlag    | 0.035569  | 0.8504       |
| SARMA     | 0.915170  | 0.6328       |

Notes: We start with the SARMA test (\(H_0\): no spatial autocorrelation of the dependent variable and no spatial autocorrelation of the residuals). If we reject \(H_0\) in SARMA, we test LMLag (\(H_0\): \(\rho = 0\), no spatial autocorrelation of the dependent variable) and LMerr (\(H_0\): \(\lambda = 0\), no spatial autocorrelation of the residuals). If we are unable to decide between the two, we pass to the choice between RLMerr (error dependence in the presence of a missing lagged dependent variable) or RLMlag (inversely).

Source: Authors’ calculations.
5 | CONCLUSION

The strict containment conditions imposed in Morocco (Maneesh & El Alaoui, 2020) made it possible to circumscribe the territorial spread of the pandemic even after the appearance of outbreaks in industrial units. Indeed, we have shown that the spatial diffusion of the pandemic, either through affected cases or through the displacement of people working in industrial units, is not significant. We have also shown that age, socio-economic and housing conditions are not significant determinants in the spread of the pandemic contrary to other analyses (Tarwater & Martin, 2001; Yue et al., 2018). Only the proportion of the labour force employed in industry has a positive impact on the number of active COVID-19 cases in the provinces.

This brings us back to suggest maintaining a policy of targeted confinement around provinces with industrial specialization, in order to stem the interprovincial spread of the pandemic and to counteract the adverse effects of a generalized confinement in the particular case of Morocco which has launched a public policy for the industrialization of its economy. Indeed, social pressure and the effects of two years of drought experienced in the face of limited budgetary margins for monetary support of vulnerable populations make the option of a second generalized containment a difficult policy to maintain in the long term in the absence of community support like in Europe. Moreover, 71.3% of Moroccan companies consider that the main constraint to the normal resumption of their activity is the risk of a return to confinement (HCP, 2020a).

In addition, we propose to reduce the number of employees in industrial areas that have non-industrial support functions (administrative management, payroll services, marketing, etc.) by favouring teleworking or alternation through an appropriate digital transition. There is also reason to think about the outsourcing of service functions of industrial companies, especially since Morocco has four offshoring zones that could be exploited for onshoring services.

Finally, we propose that the State support companies in improving health conditions in the industrial environment by adapting the financing mechanism, it has created for cash credit for investment, in their digital transition...
and in health equipment. The proposal of this last measure is all the more justified since 23% of companies state that their current equipment does not perfectly protect their employees. The mechanism should be adapted to all sizes of companies, especially VSEs, since 7% of them lack any protective equipment against contagion (HCP, 2020d). Finally, local authorities, which the intra-urban public transport is their own attribution, should secure this mode of transport between industrial and residential areas, especially since 55% of households have little or no confidence in the government’s ability to succeed on this issue (HCP, 2020d).

In the absence of communal data for all provinces, this analysis focused on the spread of the epidemic by hierarchical mode between large cities and by “jumping” mode along transport routes (Cliff et al., 2004). The publication of finer data at the territorial level will therefore make it possible to cover the local mode of diffusion through districts that seem to have contributed to the emergence of family outbreaks despite the strict containment conditions imposed (Maneesh & El Alaoui, 2020).

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ENDNOTES

1 Morocco recorded 450 outbreaks of contamination as of 14 May 2020, of which 73% in families and 26% in industrial units. https://telquel.ma/2020/05/18/450-foyers-de-contamination-compliquent-le-deconfinement_1684095

2 Morocco would lose around 100 million euro per day of confinement which would have an impact of around 6 points of growth in 2020. Comment by the Minister of the Economy, Finance and Administrative Reform on the questions put by the parliamentary groups of the House of Councilors on “Financial and economic measures to deal with the crisis resulting from the COVID-19 pandemic in our country.”, 19 May 2020. (Arabic version) https://www.finances.gov.ma/Publication/cabinet/2020/Re%60plique%20Ministre%2019052020.pdf

3 Example of the regional delegation of Rabat: https://web.facebook.com/DMS.RABAT/?_rdc=1&_rdr

4 See Supporting Information Data S1 and S2.

5 These include the chances of survival beyond age 70, life expectancy at age 60, the proportion of the population without physical or mental disabilities, the literacy rate, the proportion of the population knowing Arabic and French, the proportion of the population with college level education or high school or higher education, the percentage of paid employment, the percentage of salubrious housing or villas or Moroccan houses, housing with a kitchen or bath/shower, the average number of people per room, and the percentage of households with access to electricity and drinking water.

6 See some descriptive statistics for the indicators collected in Table A3 in the Appendix.

7 Respectively analogous to Eurostat’s Nomenclature of Territorial Units for Statistics (NUTS) 1, 2 and 3.

8 Mohamed Rhajaoui, Director of the National Institute of Hygiene (NIH). https://www.medias24.com/mohamed-rhajaoui-inh-le-maroc-va-passer-a-une-capacite-de-10-000-tests-jour-10077.html

9 The Geary test is also significant, but we preferred the Moran index because of its high overall stability (Upton & Fingleton, 1985).

10 Lawsuits have been brought against employers who have not maintained these prudential rules. The most important of these is the prosecution of the managers of three red fruit production units and those responsible for transporting personnel in the locality of Lalla Mimouna in the province of Kenitra for suspicion of violating health and preventive measures against the spread of the pandemic. This outbreak recorded 700 contaminated cases out of 6,000 people tested, leading to the establishment of a field hospital for their treatment. Source: press release of the King’s Prosecutor to the Court of First Instance relayed by the media. https://www.medias24.com/clusters-de-lalla-mimouna-les-dirigeants-des-unites-de-production-seront-poursuivis-12071.html

REFERENCES

Amdaoud, M., Arcuri, G., & Levratto, N. (2020). COVID-19: Spatial analysis of the influence of socio-economic factors on the prevalence and consequences of the epidemic in French departments. EconomXiX, National Centre for scientific
Hadrya, F., Soulaymani, A., & El Hatimmie, F. (2020). Space-time COVID-19 monitoring in Morocco. The Pan African Medical Journal, 35(2), 41. https://doi.org/10.11604/pamj.supp.2020.35.2.23505 https://www.panafrican-med-journal.com/content/series/35/2/41/full/

HCP (High Commission for Planning). (2019). RGPH 2014: anonymized microdata (open data). (French version) https://www.hcp.ma/downloads/RGPH-2014-Microdonnees-anonymisees-Open-Data_t21400.html

HCP (High Commission for Planning). (2020a). Social relationships in the context of the covid-19 pandemic: 2nd Panel on the impact of coronavirus on the economic, social and psychological situation of households. https://www.hcp.ma/file/217074/

HCP (High Commission for Planning). (2020b). Impact of the covid-19 pandemic on household economic status: 2nd Panel on the impact of coronavirus on the economic, social and psychological situation of households. https://www.hcp.ma/file/217036/

HCP (High Commission for Planning). (2020c). Survey on the impact of coronavirus on the economic, social and psychological situation of households: summary note of the main results. https://www.hcp.ma/file/215933/

HCP (High Commission for Planning). (2020d). Resumption of business activity following the lifting of confinement: 2nd survey on the impact of Covid-19 on business activity. https://www.hcp.ma/region-drda/attachment/1992154/

HCP (High Commission for Planning). (2020e). Changes in Moroccan Behavior in the Face of the covid-19 Pandemic: 2nd Panel on the Impact of the Coronavirus on the Economic, Social, and Psychological Situation of Households. https://www.hcp.ma/file/216967/

Hellewell, J., Abbott, S., Gimma, A., Bosse, N. I., Jarvis, C. I., Russell, T. W., ... Eggo, R. M. (2020). Feasibility of containing COVID-19 outbreaks by isolation of cases and contacts. The Lancet Global Health, 8(4), e488–e496. https://doi.org/10.1016/S2224-109X(20)30074-7

Hu, C., Xu, Z., & Yashiro, N. (2015). Agglomeration and productivity in China: Firm level evidence. China Economic Review, 33, 50–66 ISSN 1043-951X. https://doi.org/10.1016/j.checo.2015.01.001

Johns Hopkins. (2020). Coronavirus COVID-19 Global Cases. The Center for Systems Science and Engineering. URL: www.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6

Kapitsinis, N. (2020). The underlying factors of the COVID-19 spatially uneven spread. Initial evidence from regions in nine EU countries. Regional Science Policy & Practice, 12(6), 1027–1045. https://doi.org/10.10111/riisp.132340

Krugman, P. (1991). Increasing returns and economic geography. Journal of Political Economy, 99(3), 483–499. https://doi.org/10.1086/261763

Kuebart, A., & Stabler, M. (2020). Infectious diseases as socio-spatial processes: The COVID-19 outbreak in Germany. Tijdschrift voor Economische en Sociale Geografie, 111, 482–496. https://doi.org/10.1111/tesg.12429

Layelmam, M., Laaziz, Y. A., Benchelha, S., Diyer, Y., & Rarhibou, S. (2020). Forecasting COVID-19 in Morocco. Journal of Clinical and Experimental Investigations, 11(3), e00748. https://doi.org/10.5799/jcei/8264

Lee, S. S., & Wong, N. S. (2020). Predicting the initial diffusion pattern of pandemic (H1N1) 2009 using surveillance data. PLoS Currents, 2, RRN1151. https://doi.org/10.1371/currents.rrn1151

Link, B. G., & Phelan, J. C. (1995). Social conditions as fundamental causes of disease. Journal of Health and Social Behaviour, Spec No, 80–94.

Lourenço, J., Maia de Lima, M., Faria, N. R., Walker, A., Kraemer, M. U., Villabona-Arenas, C. J., ... Recker, M. (2017). Epidemiological and ecological determinants of Zika virus transmission in an urban setting. eLife, 6, e29820. https://doi.org/10.7554/eLife.29820

Maneesh, P., & El Alaoui, A. (2020). How countries of south mitigate COVID-19: Models of Morocco and Kerala, India. Electronic Research Journal of Social Sciences and Humanities, 51(2), 143–161. https://doi.org/10.2747/1539-7216.51.2.143

Meade, M., & Emch, M. (2010). Medical geography (3rd ed.). New York: The Guilford Press.

MEFAR. Ministry of the Economy, Finance and Administrative Reform. (2020a). Financial and economic measures to deal with the crisis resulting from the Corona-COVID-19 pandemic in our country. (French version). (Accessed on 20/05/2020) https://www.finances.gov.ma/Publication/cabinet/2020/Rei%60plique%20Ministre%202020_financier_Fr.pdf

MH (Ministry of Health). (2020a). Morocco announces registration of the first case of coronavirus. URL: https://www.sante.gov.ma/sites/Ar/Pages/communiq%20s.aspx?communiqueID=607

MH (Ministry of Health). (2020b). COVID-19 Screening Centres. (Arab version). URL: http://www.covidmaroc.ma/Documents/2020/%D9%85%D8%B1%D8%A7%D9%83%D8%B2%D8%A7%D9%84%D9%81%D8%AD%D9%88%D8%B5%D8%A7%D8%AA.pdf

Munster, V. J., Koopmans, M., van Doremalen, N., van Riel, D., & de Wit, E. (2020). A novel coronavirus emerging in China: key questions for impact assessment. New England Journal of Medicine, 382(8), 692–694. https://doi.org/10.1056/NEJMp2000929
Boumahdi, I., Zaoujal, N., & Fadlallah, A. (2021). Is there a relationship between industrial clusters and the prevalence of COVID-19 in the provinces of Morocco? *Regional Science Policy & Practice, 13*(S1), 138–157. https://doi.org/10.1111/rsp3.12407
### TABLE A1  Socio-economic and epidemiological indicators for the 10 most affected provinces of COVID-19 in Morocco Province population

| Province         | Population in thousands | Confirmed cases of COVID-19 | Hospitalized cases of COVID-19 | Cured cases of COVID-19 | Deceased cases of COVID-19 | Density per capita/ km² | Hospitalized size | Cured cases of COVID-19 | Deceased cases of COVID-19 | Share of population aged by 65 years and over | Share of employment in manufacturing industries | Average socioeconomic deficit | Average housing deficit |
|------------------|-------------------------|-----------------------------|-------------------------------|-------------------------|-----------------------------|--------------------------|---------------------|-------------------------|-------------------------|---------------------------------------------|-----------------------------------------------|---------------------------------------------|----------------------------|
| Casablanca       | 3,566                   | 1,333                       | 816                           | 477                     | 40                          | 16,200                   | 4,1                 | 7%                      | 23%                     | 477                          | 23%                                           | 2,9                                         | 25,1                       |
| Marrakech        | 1,405                   | 895                         | 281                           | 572                     | 42                          | 538                      | 4,4                 | 6%                      | 12%                     | 572                          | 12%                                           | 4,8                                         | 21,8                       |
| Tanger-Assilah   | 1,215                   | 684                         | 518                           | 146                     | 20                          | 1,170                    | 4,0                 | 5%                      | 33%                     | 146                          | 33%                                           | 3,6                                         | 19,7                       |
| Fès              | 1,249                   | 545                         | 305                           | 232                     | 8                           | 3,956                    | 4,3                 | 5%                      | 24%                     | 232                          | 24%                                           | 5,4                                         | 20,9                       |
| Ouarzazate       | 311                     | 501                         | 111                           | 387                     | 3                           | 25                       | 5,4                 | 6%                      | 12%                     | 387                          | 12%                                           | 11,4                                        | 26,2                       |
| Rabat            | 537                     | 289                         | 161                           | 123                     | 5                           | 4,523                    | 3,8                 | 9%                      | 8%                      | 123                          | 8%                                            | 2,9                                         | 21,4                       |
| Rehamna          | 335                     | 233                         | 23                            | 208                     | 2                           | 58                       | 5,5                 | 5%                      | 5%                      | 208                          | 5%                                            | 5,5                                         | 27                         |
| Mohammadia       | 445                     | 207                         | 180                           | 26                      | 1                           | 1,656                    | 4,2                 | 6%                      | 27%                     | 26                           | 27%                                           | 2,9                                         | 27,5                       |
| Salé             | 1,094                   | 189                         | 97                            | 88                      | 4                           | 1,541                    | 4,2                 | 5%                      | 15%                     | 88                           | 15%                                           | 4,1                                         | 21,7                       |
| Larache          | 509                     | 143                         | 77                            | 64                      | 2                           | 186                      | 4,6                 | 6%                      | 11%                     | 64                           | 11%                                           | 18,4                                        | 24,1                       |
| % of TOP 10 of National | 30%                     | 78%                         | 85%                           | 73%                     | 68%                         |                          |                     |                         |                         |                              |                                               |                              |                           |

Source: Authors’ calculations based on press releases from the twelve regional delegations of the Ministry of Health, (HCP, 2019) and (ONDH, 2017).
|                         | Infection rate by COVID-19 per 1,000 inhabitants | Hospitalized rate by COVID-19 per 1,000 inhabitants | Mortality rate by COVID-19 per 1,000 inhabitants | Density per capita/km² |
|-------------------------|-----------------------------------------------|--------------------------------------------------|-----------------------------------------------|-----------------------|
| Infection rate by COVID-19 per 1,000 inhabitants | Correlation: 1                                | 0.78**                                           | 0.53**                                         | 0.24*                 |
|                         | Sig.                                           | 8.47E-17                                        | 8.76E-7                                        | 0.04                  |
| Hospitalized rate by COVID-19 per 1,000 inhabitants | Correlation: 0.78**                           | 1                                                | 0.44**                                         | 0.39**                |
|                         | Sig.                                           | 8.47E-17                                        | 8.24E-5                                        | 4.92E-4               |
| Mortality rate by COVID-19 per 1,000 inhabitants | Correlation: 0.53**                           | 0.44**                                           | 1                                              | 0.28*                 |
|                         | Sig.                                           | 8.76E-7                                        | 8.24E-5                                        | 0.02                  |
| Density per capita/km² | Correlation: 0.24*                             | 0.39**                                           | 0.28*                                          | 1                     |
|                         | Sig.                                           | 0.04                                            | 4.92E-4                                        | 0.02                  |
| Household size          | Correlation: −0.1                              | −0.15                                            | −0.15                                          | −0.12                 |
|                         | Sig.                                           | 0.41                                            | 0.2                                            | 0.21                  |
| Share of population aged by 65 years and over | Correlation: 0.03                             | 0                                                | 0.16                                           | 0.05                  |
|                         | Sig.                                           | 0.83                                            | 0.97                                           | 0.18                  |
| Share of employment in manufacturing industries | Correlation: 0.38**                           | 0.65**                                           | 0.33**                                         | 0.44**                |
|                         | Sig.                                           | 7.08E-4                                        | 3.83E-10                                       | 7.22E-5               |
| Average socio economic deficit | Correlation: −0.17                           | −0.26*                                           | −0.23*                                         | −0.22                 |
|                         | Sig.                                           | 0.15                                            | 0.03                                           | 0.04                  |
| Average housing deficit  | Correlation: −0.11                            | −0.12                                            | −0.28*                                         | −0.13                 |
|                         | Sig.                                           | 0.36                                            | 0.3                                            | 0.27                  |

Note:
**Significant at the 1% threshold;
*Significant at the 5% threshold.
|                          | Household size | Share of population aged by 65 years and over | Share of employment in manufacturing industries | Average socio economic deficit | Average housing deficit |
|--------------------------|----------------|-----------------------------------------------|------------------------------------------------|-------------------------------|-------------------------|
| Infection rate by COVID-19 per 1,000 inhabitants | -0.1 | 0.03 | 0.38** | -0.17 | -0.11 |
|                          | 0.41 | 0.83 | 7.08E-4 | 0.15 | 0.36 |
| Hospitalized rate by COVID-19 per 1,000 inhabitants | -0.15 | 0 | 0.65** | -0.26* | -0.12 |
|                          | 0.2 | 0.97 | 3.83E-10 | 0.03 | 0.3 |
| Mortality rate by COVID-19 per 1,000 inhabitants | -0.15 | 0.16 | 0.33** | -0.23* | -0.28* |
|                          | 0.21 | 0.18 | 0 | 0.04 | 0.01 |
| Density per capita/km²   | -0.12 | 0.05 | 0.44** | -0.22 | -0.13 |
|                          | 0.31 | 0.7 | 7.22E-5 | 0.06 | 0.27 |
| Household size           | 1 | -0.33** | -0.11 | 0 | 0.32** |
|                          | 0 | 0.35 | 0.99 | 0.01 |
| Share of population aged by 65 years and over | -0.33** | 1 | -0.24* | 0.13 | 0.1 |
|                          | 0 | -0.24* | 0.04 | 0.28 | 0.42 |
| Share of employment in manufacturing industries | -0.11 | -0.24* | 1 | -0.44** | -0.26* |
|                          | 0.35 | 0.04 | 8.56E-5 | 0.03 |
| Average socio economic deficit | 0 | 0.13 | -0.44** | 1 | 0.41** |
|                          | 0.99 | 0.28 | 8.56E-5 | 3.03E-4 |
| Average housing deficit  | 0.32** | 0.1 | -0.26* | 0.41** | 1 |
|                          | 0.01 | 0.42 | 0.03 | 3.03E-4 |

Note:
**Significant at the 1% threshold;
*Significant at the 5% threshold.
| N  | Valid | Hospitalized rate by COVID-19 per 1,000 inhabitants | Infection rate by COVID-19 per 1,000 inhabitants | Mortality rate by COVID-19 per 1,000 inhabitants | Density per capita/km² | Household size | Share of population aged by 65 years and over | Share of employment in manufacturing industries | Average socioeconomic deficit | Average housing deficit |
|----|-------|---------------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------|----------------|-----------------------------------------------|-----------------------------------------------|---------------------------|-------------------------|
| N  | 75    | 75                                                | 75                                            | 75                                            | 75                    | 75             | 75                                            | 75                                            | 75                        | 75                      |
| Missing | 0     | 0                                                 | 0                                             | 0                                             | 0                     | 0              | 0                                             | 0                                             | 0                         | 0                       |
| Average | 1.22E-01 | 4.97E-02                                      | 2.83E-03                                      | 5.58E+02                                      | 5.068                 | 5.89E-02       | 9.18E-02                                      | 11.108                          | 25.644                    |
| Median | 3.52E-02 | 5.30E-03                                      | 0.00E+00                                      | 1.12E+02                                      | 4.7                   | 6.11E-02       | 7.31E-02                                      | 9.9                            | 25.7                      |
| Standard deviation | 2.37E-01 | 1.03E-01                                      | 4.97E-03                                      | 1.98E+03                                      | 2.0078                | 1.63E-02       | 5.96E-02                                      | 8.3164                         | 4.3491                    |
| Minimum | 0     | 0                                                 | 0                                             | 0.03377341                                    | 3.8                   | 0.01581464    | 0.01740786                                    | 0.7                            | 17.9                      |
| Maximum | 1.61,190,169 | 0.42,639,325               | 0.0298853                                      | 1.62E+04                                      | 20.9                  | 0.10,739,822  | 0.33,093,755                                  | 50.6                           | 36.9                      |

Source: Authors’ calculations.