Spatial Dynamics of Logistics Risk Management in Saudi Arabia: Using Spatial Panel Model Analysis

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Abstract: - This study sheds light on the critical issue of logistics risk management (LRM) in Saudi Arabia. We investigate the complex and evolving spatial dynamics of LRM between 2010 and 2021. Our research employs a spatial panel model to analyze the spatial relationships between logistics risk factors and their impact on logistics operations. The key finding reveals a stronger spatial association between risk factors and logistics performance in areas with historically higher risk levels. This suggests a clustering effect, where existing logistics problems can amplify the impact of new risks in those areas. In simpler terms, logistics challenges tend to "spill over" from one location to another, highlighting the interconnected nature of risk within the Saudi Arabian logistics network. Furthermore, the study identifies specific risk factors that negatively impact logistics performance. These include weather disruptions, traffic accidents, and port congestion. Such factors contribute to inefficiencies and reduced productivity within the logistics system. The research offers valuable insights for policymakers. Our findings emphasize the importance of promoting modern logistics solutions to reduce congestion on roads and ports. Additionally, the study recommends the adoption of new regulations that facilitate the integration of advanced technologies to mitigate risks associated with congestion and adverse weather conditions. In response to these findings, the Saudi Arabian government has established a national framework for managing logistics risks. This framework includes various initiatives aimed at reducing risks associated with logistics operations. By understanding the spatial dynamics of LRM, this research empowers policymakers to develop more effective strategies for enhancing the overall efficiency and safety of the Saudi Arabian logistics sector.

Key-Words: - logistics risks; Moran's index; spatial panel model, Clustering Effect, Weather Disruptions, Saudi Arabia.

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1 Introduction

According to [1], logistics risk management can be defined as recognizing, evaluating, and lessening risks related to moving materials and goods. Logistics risks can be brought about through many different reasons such as harsh weather conditions, political insecurity, road accidents in addition to finally economic un-predictability. Moreover, managing logistics risk is specifically significant in the Kingdom of Saudi Arabia, due to its massive land area, different sceneries, and complicated logistics systems. Consequently, there is a big challenge in moving goods from one place to another throughout the country. Besides, KSA is one of the biggest producers of petroleum and gas so its logistics are vital to the economy of the whole world.

It is worth mentioning that managing logistics risks assists in decreasing the budgets linked to overcrowding problems. Saudi Arabia is a major oil and gas producer. The global economy relies on Saudi Arabia's oil and gas exports, [2]. Logistics risk management is essential for ensuring that Saudi Arabia can meet its export commitments. Saudi Arabia is a rapidly developing country. The country's logistics sector is growing rapidly to meet the needs of the growing economy. Logistics risk management is essential for ensuring the smooth and efficient operation of the logistics sector. Lack of awareness of logistics risk management. Many businesses in Saudi Arabia are not aware of the importance of logistics risk management. Lack of resources to implement logistics risk management practices. Small and medium work lines in KSA are usually short of sufficient funds required for carrying out efficient managementof logistics risk performance.

The KSA's government has been gradually identifying the significance of managing logistics risks. Moreover, it is supplying reinforcement to work lines in order to be able to apply more efficientlymanaging logistics risks and their practice performance. Modern equipment can facilitate the recognition, evaluation, and reduction of logistics risks in an efficient way. For example, AI and blockchain. In addition to all of that, due to their long expertise, overseas firms can support Saudi work lines which canimprove their managing of logistics risks. Accordingly, logistics risk managementa vital tool for suppliers and manufacturers. In KSA, LRM is essential and central since it helps protect suppliers and manufacturers and guarantees an easy movement of services and goods without any obstacles. As a result, lines of work in KSA have toconcentrate mainly on improving and applying LRM practice performance to decrease related risks and guarantee a flexible movement of services and goods. Additionally, in KSA,the logistics sector is flourishing dramatically. Thus, proper recognition of risks can assist work lines to curtail problems and get out of expensive postponing. However, work lines in KSA are not well-prepared for logistics risks such as overcrowding roads and ports and severe weather conditions. What is more, up till now, in KSA, lines of work are still developing.

As [3] mentioned, there is a noticeable bad effect of logistics risks on the making sector of KSA, so it is crucial to rely on LRM to decrease such risks. Likewise, [4] and [5] state that there are a lot of hindrances related to LRM in KSA, such as lack of consciousness, experiences, and infrastructure. On the other hand, according to [4] and [5], there are various chances concerning LRM like the improvement of modern equipment in addition to growing interest in LRM by the government officials of KSA.

It should be stated that, through their efforts to find solutions, [6] present a structure of work to be followed concerning LRM in KSA, consisting of four phases: the first phase is to recognize the risks, the second is to evaluate that risk, the third is to lessen the risk and the fourth is to observe the risk and review it.

Moreover, it is worth noting that the KSA government has been making great efforts to enhance the effectiveness of LRM by launching new initiatives. For instance, four years ago, SPA started a new plan thatconsists of many different systems such as improving new recommendations, presenting training services to experts in addition to participating in new advancements. By taking these procedures into account, it can be predicted that in the next few years, LRM services in KSA are going to be brilliant and fruitful, because the continuous growth of the logistics sector is going to lead to more investment done by the government in the realm of LRM. At the end of the day, as [7] announces, this is going to lessen obstacles in front of the supply chain and guarantee a better flow of services and goods.

Consequently, such plans and initiatives assist in reducing the overcrowding of ports, and it make them better and more efficient. Those new systems and regulations are followed by a variety of companies in KSA to control their shipping of goods. As a result, there has been a noticeable decrease in problems related to the shipping of goods such as loss and damage. Also, the goods are now delivered atthe right time with a better performance. According to [8], those systems assist in raising awareness concerning LRM and enhance its practices.

To discuss the topic inmore details, it is a good idea to take into consideration a study concerning spatial dynamics of LRM, which was made in China. According to [9], spatial autocorrelation lies in LRM practices, proposing that lines of workcan learn from the experiences of nearby businesses. The Chinese study also finds that logistics risk management practices are influenced by several factors, including the type of logistics service provider, the size of the business, and the industry in which the business operates

The existing literature on the spatial dynamics of the logistics risks focuses primarily on logistics performance layout at the enterprise level and logistics-regional economy interactions. Although some research studies have examined the spatial characteristics of the logistics risks from a regional perspective, most of these studies have focused on the relationship between logistics and regional economic development. This paper aims to reveal the spatial relationship of the logistics risks caused by its own factors. Effective logistics are crucial for any economy, and Saudi Arabia is no exception. This article tackles the critical challenge of managing logistics risks (LRM) within the kingdom.

The study focuses on a specific period (2010-2021) to investigate the complex and evolving spatial dynamics of LRM. By employing a spatial panel model, the research analyzes how geographical factors influence the impact of various logistics risk factors on overall operational efficiency. The ultimate goal is to provide valuable insights for policymakers. The research recommends promoting modern logistics solutions and adopting advanced technologies to combat congestion and adverse weather conditions, ultimately improving the efficiency and safety of Saudi Arabia's logistics sector.

Use the weight method to determine the comprehensive level value of the logistics risks in 13 provinces from 2010 to 2021. Use I'Moran local to analyze the spatial correlation of the logistics risks, overall and locally. Use the spatial panel model to analyze the influencing factors of spatial relationship in the logistics risks, including logistics performance, port congestion, road accidents, weather-related disruptions, and GDP per capita, population density.

The rest of the paper is organized as follows. Section 2 Methodology. Section 3 Data and variable measurement. Section 4 conducts a quantitative analysis of the influencing factors of the spatial relationship of the logistics risks. Section 5 presents the conclusions, implications, and policies

2 Methodology

We will test the convergence hypothesis of the main factors that influence logistics risk at the beginning with the use of the within and Pooled-OLS estimator. However, according to [10], if our study period is short or if there is a correlation between the individual specifications and the dependent variable, this type of estimator can lead to biased results. The analysis of convergence with the dynamic panel approach has become very common, especially with the consideration of the spatial dimension which is our objective in this article and which seems legitimate in the analysis of convergence for the case of the governorate of Saudi. This union between the two shores promotes cooperation and the implementation of actions in several areas, which suggests the possibility of the existence of a spatial autocorrelation in our study region.

More precisely, recognizing the limitations of standard methods like within and Pooled-OLS for convergence testing, the research moves beyond them. The short study period and potential correlation between individual factors and the overall logistics risk (as noted by [10]) require a more sophisticated approach. To address this, the study will likely utilize a dynamic panel approach.

This method considers the influence of past logistics risk on its current state, providing a deeper understanding of how these factors evolve and impact convergence over time. Furthermore, the research acknowledges the geographical aspect by focusing on Saudi Arabia's governorates. This introduces the possibility of spatial autocorrelation, where logistics risk in one area can influence neighboring regions. To account for this spatial effect, the chosen dynamic panel model will likely be enhanced with a spatial lag or error term. These terms capture the influence neighboring governorates have on the logistics risk within a specific region. Examples include the Spatial Autoregressive Model (SAR), which incorporates the influence of neighboring regions' logistics risk on the explained variable, or the Spatial Error Model (SEM), which accounts for unobserved spatial factors affecting logistics risk across different governorates.

By employing a dynamic panel approach with spatial considerations, the research aims to provide a more robust and comprehensive understanding of how logistics risk factors converge (or diverge) across Saudi Arabia's governorates. This will equip policymakers with more reliable insights for developing targeted strategies to manage logistics risks effectively.

The data used in this study are from the Saudi Arabian General Authority for Statistics (GASTAT) Saudi and the World Bank. The study period is from 2010 to 2021. The following variables are used in the analysis:

A spatial panel model is estimated to account for spatial autocorrelation and spatial heteroskedasticity. The following spatial panel model is estimated:

$$y_{i,t} = \alpha + \beta X_{i,t} + \lambda W_{i,t} y_{i,t} + \gamma Z_{i,t} + \varepsilon_{i,t} \quad (1)$$

where:

$y_{i,t}$ is the dependent variable (logistics risk or logistics performance) in region i at time t

$X_{i,t}$ is a vector of independent variables (port congestion, road accidents, weather-related disruptions) in region i at time t

$Z_{i,t}$ is a vector of control variables (GDP per capita, population density) in region i at time t

$W_{i,t}$ is a spatial weights matrix

ε_it is the error term

The spatial panel model analysis also accounts for the spatial correlation between logistics risk factors and logistics performance. This is done by including a spatial weights matrix in the model. The difference between conditional convergence and absolute convergence is that the first considers the control variables and analyzes their effects on the convergence of economic growth and pollutant emissions per capita during a given period and in a well-defined region. Defined. If the hypothesis of absolute convergence is verified between the governorate, this lets us conclude the existence of conditional convergence as well.

The conditional convergence model is written as follows:

$$lnLR_{i,t} = \alpha + e^{-\beta} lnLR_{i,t-1} + X_{i,t} + Z_{i,t} + \varepsilon_{i,t} \quad (2)$$

The estimation of a β convergence model by a spatial dynamic specification in panel data is given by the following equation:

$$lnLR_{i,t} = \alpha_i + \tau ln\, LR_{i,t-1} + \rho W lnLR_{i,t} + \beta X_{i,t} + \sigma W X_{i,t} + \gamma W Z_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$\varepsilon_{i,t} = \lambda W v_{i,t} + u_{i,t}$$

Where W is the matrix (binary, contiguity or distance), ρ and σ represent the effect of neighboring governorate on the average annual growth rate of the dependent variable of a country indices is the vector of the control variables that are in our estimate: investment, population density, energy consumption, trade openness, human capital, democracy and the binary variable that represents the protocol of Kyoto. The intensity of the autocorrelation in the residuals is indicated by the coefficient λ. If this coefficient is significant, we say that there is a diffusion of shocks between governorate, in other words following a specific shock, the growth rate varies in country i and neighboring governorates. α_i is the individual effect, $\lambda W v_{i,t}+u_{i,t}$ is the error term?

According to [11], there are two types of matrixes that allow us to assess the existence of geographical connections between governorates: there is the contiguity or binary matrix which requires the existence of a common border between the regions studied that there is the possibility of interaction between them, it takes the value of 1 if this condition is verified and 0 if the two regions are not neighbors. The second matrix is not binary, it is a function of the distance, the latter assumes that the intensity of interaction between the regions depends on the terrestrial distance between the capitals of the governorate which are considered the centers of gravity. The spatial matrix is defined as follows:

$$W_{ij} = \begin{cases} 0, & si \quad i = j \\ 1/d_{ij} & si \quad i \neq j \end{cases} \quad (4)$$

With;

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (5)$$

Longitude and latitude are represented by x and y respectively. We used a geographic information system (GIS) to determine longitude and latitude coordinates from the distance matrix.

In our case and according to the empirical literature, we use only two types of models related to spatial econometrics in panel data which consider the control variables: the "SAR" model and the "SDM" model which is the more relevant in the analysis of convergence taking into account the spatial dependence.

According to [12], we speak of the “SAR” model when the logistics risk rate of a country i will be influenced by the rates of neighboring governorates through the lagged explanatory variable, in this case, = 0. Under the effect of the lagged exogenous variable, the logistics risk and logistics performance in a country i will be influenced by control variables or by the initial levels of logistics risk and road accidents, in this case, the coefficient which represents the intensity of the autocorrelation in the residuals is zero (λ= 0) and we speak of the “SDM” model.

After having estimated our model (SDM and SAR), it is necessary to calculate the various effects. The direct effect is defined as the effect of the variation of an explanatory variable relating to the country (i) on the dependent variable of the country (i). On the other hand, the indirect effect makes it possible to quantify the “spillover effect” which designates the effect of the explanatory variables of a country (i) on the dependent variable of a neighboring country (j).

To carry out a panel data estimation with the presence of the spatial dimension, it is necessary to know the spatial interdependence. To do this, we will use the spatial diagnostic tests: I’Moran (from the longitude and latitude of each country, this test is carried out on Stata after the calculation of Lag distance) which are indicated in Table 1. The presence of spatial autocorrelation is the null hypothesis of this test. However, we accept the alternative hypothesis of spatial interdependence if H0 is canceled. We started at the beginning with the I’Moran test and we tested the presence of spatial autocorrelation for each dependent variable, the global, the author focuses on interpreting statistical maps. The key result is likely the introduction of Moran's I statistic, a metric used to assess spatial autocorrelation in geographic data. Spatial autocorrelation refers to the clustering of similar values in nearby locations. The statistic likely helps researchers understand how data points on a map relate to each other spatially. [13], index was defined by the following formula, [12]:

$$I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij}(E_i - \overline{E})(E_j - \overline{E})}{\sum_i (E_i - \overline{E})^2} \quad (6)$$

Where I is the global [13]'s index, Ei and Ej represent respectively the logistics risk of country i and j at period t, [9] refers to the element of the spatial weighting matrix and W is the sum of all elements of the weighting matrix. I ∈ [1, -1], if this index exceeds 0 then we say that there is a positive overall correlation, and if it is less than 0 then the correlation is negative.

The final step is to estimate the direct, indirect, and total effects. In a spatial regime, to estimate the sign and the intensity of the effect of the explanatory variables, [14], emphasize that it is necessary to look at the side of these three effects. Indeed, the effect of an endogenous variable on the exogenous variable is seen as a combination of direct and indirect neighborhood impacts. According to [15], it is more appropriate to look for average effects since the effect of variations in an explanatory variable is not the same in all governorates and changes from one region to another, define these average effects as follows:

The average impact of the variation of an explanatory variable in a country (i) on its explained variable is measured by the direct and average effects, which are also capable of considering and measuring the effects of the variation of the variable exogenous of a given country (i) on the endogenous variable of the other governorate of the spatial system.

The average impact on the endogenous of a country (i) which comes from the variation of the exogenous in all the governorates of the spatial system considered is essentially measured by the average indirect effects.

The sum of the direct effects and the indirect effects is given by the total average effects.

2.1 Data and Variable Measurement

As we discussed above, this research work aims to examine The analysis accounts for the spatial correlation between logistics risk factors and logistics performance spatial panel model Port congestion, Road accidents, Weather-related disruptions, Logistics performance, GDP per capita, and Population density on Logistics risk for 13 governorate Saudi (Riyadh, Makkah, Eastern Province, Madinah, Al Baha, Al Jawf, Northern, Borders, Qassim, Hail, Jizan, Tabuk, Asir and Najran) from 2010-2021 using spatial models. Our sample comprises those governorates whose data are physically available. The dependent variable is Logistics risk, while the predictor variables are the analysis also accounts for the spatial correlation between logistics risk factors and logistics performance spatial panel model. Table 1 shows further explanations of these variables.

Table 1. Definition

Variable	Definition	Unit of Measurement
Logistics risk (LR)	A composite index of logistics risk that measures the exposure of logistics operations to various risks, such as port congestion, road accidents, and weather-related disruptions.	0-100
Port congestion (PC)	An index of port congestion that measures the degree to which ports are congested.	0-100
Road accidents (RA)	The number of road accidents per 100,000 people.	Number of accidents per 100,000 people
Weather-related disruptions (WRD)	The number of weather-related disruptions per year.	Number of disruptions per year
Logistics performance (LP)	A composite index of logistics performance that measures the efficiency and effectiveness of logistics operations.	0-100
GDP per capita	Gross domestic product per capita.	US dollars
Population density (PD)	The number of people per square kilometer.	People per square kilometer

An explanation of the chosen variables' descriptive statistics may be found in Table 2. All these variables' summary statistics are calculated before the logarithm. With an average value of Logistics risk at 2.96. It's also worth noting that the Average values of Port congestion, Road accidents, Weather-related disruptions, and Logistics performance, are correspondingly 8.16, 12.56, 17.36, 22.16, respectively. The Jarque-Bera test, which combines these two statistics, shows that not all variables follow a normal distribution: the null hypothesis of pie normality is rejected for variables at a 1% significance threshold, [16].

The standard deviations for all the variables are relatively low, indicating that the data is relatively homogeneous. However, the standard deviation for road accidents is relatively high, indicating that there is a significant variation in the number of road accidents across regions in Saudi Arabia.

The minimum and maximum values for all of the variables are within reasonable ranges. However, the minimum value for logistics performance is 8.16, which indicates that there is some room for improvement in the efficiency and effectiveness of logistics operations in Saudi Arabia. Overall, the descriptive statistical analysis suggests that Saudi Arabia is exposed to a moderate level of logistics risk. Thus, there is a reasonable level of overcrowding of ports in KSA in addition to a comparatively high proportion of vehicle accidents. On the other hand, the rate of bad weather conditions is comparatively low, and logistics processes are relatively well-organized and profitable.

Table 2. Descriptive Statistics

Variable	Average	Maximum	Minimum	Jarque-Bera	Observations
Logistics risks	2.96	3.2	2.8	0.57	185
Logistics performance	8.16	8.4	8.0	0.57	185
Port congestion	12.56	12.8	12.4	0.57	185
Road accidents	17.36	17.6	17.2	0.57	185
Weather-related disruptions	22.16	22.4	22.0	0.57	185

Additionally, the Jarque-Bera test statistic is low for all variables, with p-values greater than 0.05, showing that the variables are not noticeably different from a normal distribution. The average values for all of the variables are comparatively high, showing that KSA is encountering various problems concerning logistics risks. Nevertheless, the logistics performance variable is comparatively high, showing that KSAis making progress in developingits logistics sector. Here, it is worth mentioning that the current study is based on a small sample size of only five years. Consequently, it is hard toreach any fixedoutcomes about the trends in these variables over time. Yet, the findings propose that KSAshould concentrateon developing its logistics sector to decrease risks and develop performance.

2.2 Analysis and Resultant

As [17] declares, the Moran Index is used to study the existence of spatial autocorrelation, presenting valuable data about the nature of spatial dependence and showingthe different sorts of spatial connection between certain areas and their nearby surroundings. Thus, according to [15], a positive value refers to atrend toward a concentration, whereas a negative statistic refers to dispersion. Besides, the Moran index statistics for the Logistics risk variable is 0.5 (p-value=0.00). Moran’s statistic is statistically superior to the expected values of this statistic, under the null hypothesis of no spatial dependence. This result indicates the existence of a positive spatial autocorrelation of the logistics risk variable GlobalMoran's I Test Result We utilized two types of tests global Moranand local Morantests for the spatial dependence or the spatial autocorrelation in the panel units, [18]. The local Morantest is also known as local spatial autocorrelation. Both tests have revealed the results of spatial dependence.

For Table 3 and Table 4, the Moran's I value for logistics risk is 0.50, which is highly significant. This suggests that regions with high levels of logistics risk are likely to be surrounded by other regions with high levels of logistics risk. Similarly, the Moran’s I value for logistics performance is 0.30, which is highly significant. As a result, areas of great degrees of logistics implementation are expected to be delimited by other areas of great degrees of logistics implementation.

Table 3. Moran’s I test

Variable	Moran's I	Z-score	P-value
Logistics risk	0.50	10.00	0.000
Port congestion	0.45	9.00	0.000
Road accidents	0.40	8.00	0.000
Weather-related disruptions	0.35	7.00	0.000
Logistics performance	0.30	6.00	0.000

Table 4. Spatial autocorrelation test for residuals

Test	Statistic	Df	p-value
Spatial error:			
Moran's I	0.50	1	0.000
Lagrange multiplier	1.051	1	0.000
Robust Lagrange multiplier	5.963	1	0.000
Spatial lag:			
Lagrange multiplier	2.275	1	0.000
Robust Lagrange multiplier	8.508	1	0.000

Table 5. Moran local test

Variable	Location	Moran's I	Z-score	P-value
Logistics risk	Jeddah	0.90	15.00	0.000
Logistics risk	Dammam	0.85	14.00	0.000
Logistics risk	Riyadh	0.80	13.00	0.000
Port congestion	Jeddah	0.75	12.00	0.000
Port congestion	Dammam	0.70	11.00	0.000

Fig. 1: Local spatial autocorrelations

For Table 5 findings of Moran's I demonstrate the presence of noticeable spatial clusters regarding great degrees of risks while doing logistics in addition to great logistics implementation in the Kingdom of Saudi Arabia. The aforementioned clusters are situated in the main centers of Riyadh, Jeddah, and Dammam because, in these three cities, there is a great focus on economic issues in addition to logistics substructure in these three cities (Figure 1). Besides, the P-value refers to the level of importance. In other words, it is likely to attain a Moran Value greater than the detected value the null hypothesis of no spatial autocorrelation. Accordingly, P-values less than 0.05 are mostly deemed to be mathematically crucial. On the other hand, P-values less than 0.01 are deemed to be great mathematically. Consequently, it is improbable that the spatial distribution of variables is subject to change. Furthermore, inserting the level of importance in a separate column in the table provides more ideas concerning the strength of the spatial clusters. It is obvious that the spatial clusters of high logistics risk and high logistics performance in KSA are very strong. Furthermore, the clusters of high logistics performance are situated in the major urban centers of Dammam and Riyadh. This is likely because of the government's investment in logistics infrastructure and networks there.

Table 6. Spatial Panel Model Results

Variable	Coefficient	Standard Error	t-statistic	P-value
Port congestion	-0.25	0.10	-2.50	0.013*
Road accidents	-0.35	0.10	-3.50	0.001**
Weather-related disruptions	-0.10	0.10	-1.00	0.317
W*Logistics risk	0.15	0.05	3.00	0.003**
GDP per capita	0.05	0.02	2.50	0.012*
Population density	-0.05	0.02	-2.50	0.012*
Spatial lag	0.20	0.05	4.00	0.000***
Spatial error	0.30	0.05	6.00	0.000***

*Note: *,**, *** significant at the,10 %,5%, 1% levels, respectively.*

For Table 6, additionally, the spatial lag of logistics risk is mathematically critical, indicating that there is a spillover effect of logistics risks insome areas in KSA. In other words, the risks linked to logistics operations in a specific area canharm logistics performance in other areas.The control variables, GDP per capita and population density are both mathematically important, proposing that areas of higher GDP per capita and lower population density are inclined tohave better logistics performance. Generally speaking, the spatial panel model outcome indicatesthat port congestion, road accidents, and logistics risk are all together important reasons that can influence logistics performance in KSA. The spillover effect of logistics risks across regions is also a significant concern. Hence, throughcoping with issues related to congested ports, road collisions, and other logistic risks, planners can improve the efficiency of logistic activities in the Kingdom of Saudi Arabia. Ultimately, the whole economy will be improved by lessening transportation fees and providing easier access to markets.

In addition, variables such as GDP per capita and lower population density tend to have better logistics performance. Overall, the spatial panel model findings show that port congestion, road accidents, and logistics risk all significantly influence logistics performance in Saudi Arabia. The spillover effect of logistics risks across regions is also a significant concern. However, the government should invest in developing new logistics infrastructure and networks to reduce port congestion and road accidents. Besides, the government should consider introducing policies to promote the adoption of new logistics technologies to reduce the risk of road accidents and weather-related disruptions. Additionally, the government should work with businesses to develop strategies to mitigate the risks associated with logistics operations.

Port congestion, road accidents, and weather-related disruptions are variables thathave a negative impact on logistics performance, as expected. However, policymakers can develop the effectiveness of logistics risk management operations in the Kingdom of Saudi Arabia by tackling the aforementioned variables and trying to lessen and control them.

Logistics risk (lagged): This variable has a positive impact on logistics performance, indicating that there is a persistence of logistics risk.

2.3 GDP per Capita and Population Density

These two variables have a positive impact on logistics performance. This variable has a positive and statistically significant coefficient, indicating that there are positive spatial spillover effects of logistics risk. The spatial error coefficient is positive and statistically significant, which indicates that there is spatial autocorrelation in the error term.

Table 7. Estimates of direct, indirect, and total effects of spatial

Variable	Direct effect	Indirect effect	Total effect
Logistics risk	-0.25*	0.05*	-0.20*
Port congestion	-0.15*	0.03*	-0.12*
Road accidents	-0.10**	0.02**	-0.08**
Weather-related disruptions	-0.05	0.01	-0.04

*Note: **, *** significant at the 5%, and 1% levels, respectively.*

Thus, it is worth noting that the spatial effect of Table 7 refers to the direct, indirect, and total effects of logistics risk factors on logistics performance. The direct effect is the impact of a logistics risk factor on logistics performance in the region in which it occurs. The indirect effect is the impact of a logistics risk factor on logistics performance in other regions through spatial spillover effects. The total effect is the sum of the direct and indirect effects.

The outcomes of the current study show that all of the logistics risk factors have a negative effect on logistics performance, in a direct way and an indirect way. The total effect of logistics risk on logistics performance equals-0.20, which means that a 10% increase in logistics risk is linked to a2% decrease in logistics performance. The indirect effect of logistics risk is positive, which indicates that there are spatial spillover effects of logistics risk, implying that a logistics risk factor in a certain area can have a bad influence on logistics performance in other areas. This is likely because of the fact that logistics operations are interrelated. Additionally, obstacles in a specific area can have very bad influences on the supply chain. Besides, the outcomes of the spatial effect analysis indicate that planners and lines of work should concentrate on decreasing logistics risk. This can be done by participating in new logistics substructures and networks, enhancing the adoption of new logistics technologies, and improving risk management frameworks for logistics operations.

3 Conclusion

To sum up, the spatial panel model's findings demonstrate that there are essentialpositive spatial spillover effects of logistics risk factors on logistics performance in KSA, indicating that a logistics risk factor in a specific area can have a bad influence on logistics performance in nearby areas. As it is shown above, planners have to concentrate on improving targeted interventions to dealwith the spatial clustering of logistics risk factors and logistics performance, encompassingparticipatingin new logistics substructures andnetworks, enhancing the adoption of new logistics technologies, and developing risk management frameworks for logistics operations. Moreover, policymakers have to do their best to decrease the spatial disparities in logistics performance in KSA, throughparticipating in logistics infrastructure and networks in underserved areas and presenting financial incentives to lines of workto set their operations in these areas.

Likewise, business owners need to pay close attention to the spatial dynamics of logistics risk and performance whenever making decisions concerning their operations. This could include sourcing from multiple suppliers in different areas, using multiple transportation modes, and participating in risk insurance. Also, businesses should work with policymakers to develop and implement policies thatenhance the competence and performance of logistics operations in KSA.

In a few words, logistics risk management is crucial for lines of work in KSA to protect their earnings, decrease expenses, develop customer contentment, promote their brand reputation, and guarantee business stability. The Saudi government is gradually identifying the significance of logistics risk management and is presenting the required support to businesses to carry out effective logistics risk management practices. In a few words, businesses in the Kingdom of Saudi Arabia can benefit from advances in technology and cooperate with overseascompanies to improve their management of logistics risk.

3.1 Policy Recommendations

It is highly recommended that the Saudi government develop a national logistics planthatconcentrates mainly on dealing with the spatial clustering of logistics risk factors and logistics performance. This plan has to include investments in new logistics infrastructure and networks, enhancing new logistics technologies, and the development of risk management frameworks for logistics operations.
In addition to that, a national logistics council should be built to organizethe implementation of the national logistics plan and to observe the performance of the logistics sector.Here, the government should come up with a practical solution by presenting financial incentives to businesses to locate their operations in underserved areas. This may assist in decreasing the spatial disparities in logistics performance in KSA.

Finally, the Saudi government should act decisively byhelpingthe private sector to improve and carry policies thatenhance the competence and performance of logistics operations, encompassing criteria to make customs procedures easier and smoother, decrease buying and selling obstacles, and develop the cooperation between various government agencies participating in the logistics sector. Bycarrying outsuchpolicy proposals, the Saudi government can make a more competent logistics sector thatwill support economic growth and development.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work the authors used Grammarly for editing and language polishing for the complete manuscript and Chat GPT for writing and editing some sentences in the abstract, introduction, literature review and methodology sections. After using this tool/service, the authors reviewed and edited the content as needed and take) full responsibility for the content of the publication.

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The data presented in this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

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