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Do Infrastructural Facilities Reduce the Vulnerability to External Shocks? Evidence from Odisha, India

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Abstract Economies are vulnerable to multiple socio-economic factors since they are frequently exposed to several kinds of external shocks. Exogenous shocks such as heat waves, cold waves, cyclones, floods, droughts and inundations have increased recently. Infrastructure plays an important role in reducing the economy's vulnerability to external shocks. Odisha, being one of the of the coastal states of India, is vulnerable to various kinds of exogenous shocks. Therefore, this study attempts to assess the level of vulnerability of districts of Odisha to external shocks and identify the role of infrastructure in influencing the vulnerabilities. By using secondary data, a vulnerability standardized index is formulated from eighteen indicators and four major infrastructure indices have been constructed. Then, thirty districts are ranked accordingly. A linear regression model has been used to study the relationship between the development of infrastructure and the degree of vulnerability to exogenous shocks. Results indicate that both financial and physical infrastructure have statistically significant effects on reducing the economy's vulnerability to external shocks. To address these vulnerability issues, an appropriate policy prescription is prescribed.

Keywords: vulnerability, external shocks, infrastructure, Odisha, India

1. INTRODUCTION

Economies are consistently exposed to different types of shocks, making them vulnerable to different socio-economic aspects. Shocks of different types may impede the economy's ability to progress by making it vulnerable to a particular dimension. Shocks can be classified as endogenous or exogenous. In recent times, the most important exogenous shock is climate

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change and its associated rising events like flash floods, drought, cyclones, heat waves, cold waves, snowfall, and inundation. These climate extremes or shocks make the local economy, especially the rural economy, vulnerable by affecting it directly or indirectly. The Intergovernmental Panel on Climate Change (IPCC), in its 2012 report, shows that the frequency and intensity of climate extremes have increased, and the occurrence of such events is likely to increase in the future. The increasing climate extremes produce undesired results of health hazards, crop yield loss (Dash et al., 2024), loss of properties, loss of animals, and loss of human capital due to the to the low adaptive capacity of the economy. Vulnerability has been considered a "structure" that stems from enduring characteristics and features of a dynamic system rather than recent or current policy. Given the nature of vulnerability, appropriate long-term policy intervention is required to build a robust economic structure that can sustain the strain of exogenous shocks. Therefore, identifying and understanding the vulnerability of the national and local economies to various shocks is important to frame appropriate policy measures to withstand the negative effects of any shocks.

In recent decades, disaster-induced vulnerabilities have increased and as per the United Nations Office for Disaster Risk Reduction (UNDRR), "disasters can create new vulnerabilities or exacerbate existing ones, leading to increased risk and vulnerability" (UNDRR, 2017). Studies have found that climate shocks or disasters can aggravate vulnerability through various mechanisms, including physical damage to infrastructure and housing (Kreibich et al., 2017), casuing economic losses and livelihood disruption (Birkmann et al., 2013), and leading to social and psychological impacts like trauma and displacement (Adger et al., 2005). Climate shocks or disasters exposure can also exacerbate existing vulnerabilities, such as poverty, inequality, and lack of access to resources and services (Mascarenhas &Wisner, 2012).

Vulnerability to climate shocks can be influenced by a number of factors, such as socioeconomic factors that include poverty, inequality, and lack of access to resources and services (Adger et al., 2005); physical factors, such as location, infrastructure, and environmental conditions (Kreibich et al., 2017); demographic factors, such as age, gender, and disability (Birkmann et al., 2013); institutional factors, such as governance, policies, and emergency preparedness (UNDRR, 2017).

1.1 Background of the Study

Despite being an agriculturally dependent economy, Odisha is gradually performing well in terms of macroeconomic indicators; however, the district or sub-regional-level economic conditions are found to be very scattered with different levels of physical, social, and financial infrastructure availability. The uneven economic conditions, along with varied infrastructural facilities, make each district distinctive in terms of capacity and vulnerability to exogenous shocks (World Risk Report, 2016). Some districts have better rural

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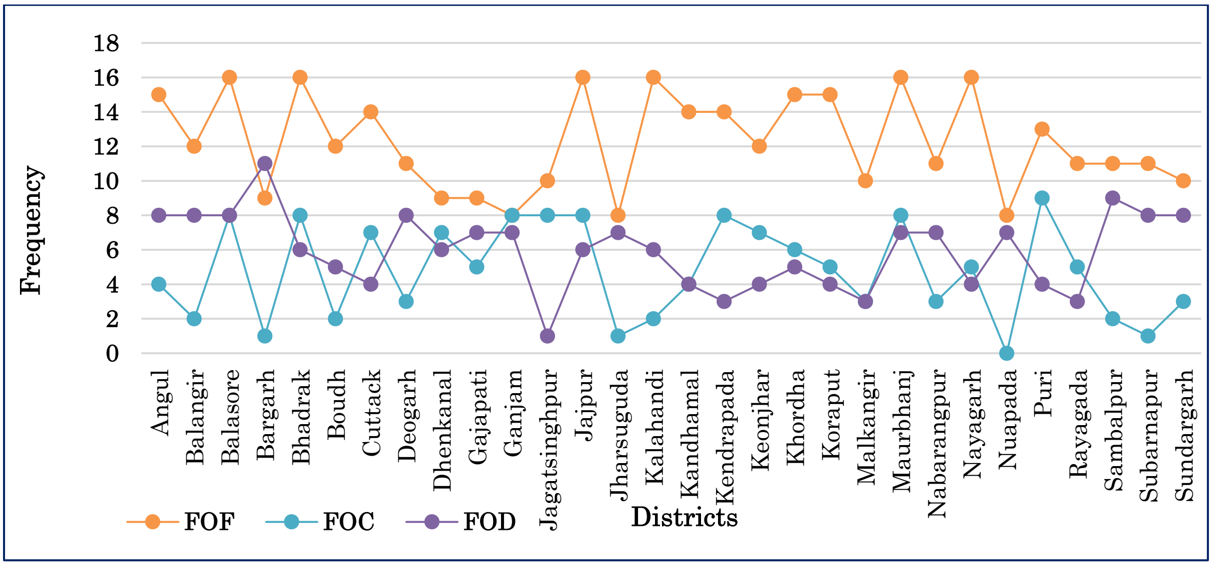
infrastructure, whereas others have very poor infrastructure, affecting different levels of agricultural activities like crop diversification in Odisha (Nayak & Kumar, 2015) and in turn decides potential capacity to face external events. During the period from 1891 to 2021, Odisha has faced more than 100 tropical cyclones. In the last two decades alone, it has confronted 10 major cyclones, making the state highly exposed from various aspects (Economic Survey of Odisha, 2021). Exogenous shocks like natural calamities are regular events in Odisha and each year one or more external shocks has encountered the state, since 1994 (Annual Report on Natural Calamities, 2021-22).

Vulnerability and exposure to extreme climatic events are intrinsically linked. Historically, Odisha is prone to floods, cyclones and droughts that encounter each district in different ways (Bahinipati, 2014; Das & Das, 2024). Figure 1 depicts frequency of flood (FOF), cyclone (FOC) and drought (FOD) over a period of 21 years (2000-2021). It is observed that the highest number of floods happen in the Balasore district, followed by Bhadrak and Jajpur. Cyclone is another extreme event that is occurring regularly, with the highest frequency of cyclones occurring in the Puri district, followed by Balasore, Bhadrak, Ganjam, Jagatsinghpur, Jajpur and Kendrapada. The western part of the state is historically vulnerable to drought (Saha et al., 2021; Naik & Murari, 2022) and Figure 1 indicates Bargarh district faced the highest number of droughts in the last two decades, followed by Sambalpur, Angul and Bolangir.



Source: Authors interpretation from Govt. of Odisha Reports 2000-21.

Figure 1. Disproportionate exposure of districts of Odisha to external shocks (2000-21)

Along with three extreme climatic events, there are other principal indicators that decide the exposure of a state to external events i.e. variability in minimum temperature, variability in maximum temperature and variability of rainfall of the same 21 years (Table 1). It is evident from Table 1 that the districts like Kalahandi, followed by Nuapada, Koraput, Malkangiri and Nabarangpur, are confronted with the highest minimum temperature variability. Similarly, Koraput, followed by Malkangiri and Nabarangpur, records the highest maximum temperature variability. Districts like Ganjam, Kalahandi and Nuapada are exposed to the highest variability in rainfall distribution.

Table 1. Disproportionate exposure of districts of Odisha to Climatic Variation (2000-21)

Districts	Minimum temperature variability	Maximum temperature variability	Variability in rainfall	Districts	Minimum temperature variability	Maximum temperature variability	Variability in rainfall
Angul	1.07	0.90	246.49	Kandhamal	2.00	1.98	340.52
Blangir	1.31	1.28	273.66	Kendrapada	0.39	0.35	244.05
Balasore	0.49	0.43	304.12	Keonjhar	0.66	0.37	290.19
Bargarh	0.87	0.74	246.92	Khordha	0.37	0.69	273.84
Bhadrak	0.70	0.92	270.80	Koraput	2.02	2.43	316.76
Boudh	2.00	1.98	232.09	Malkangir	2.02	2.43	327.48
Cuttack	1.22	0.62	275.48	Maurbhanj	1.70	1.07	353.43
Deogarh	0.87	0.74	251.94	Nabarangpur	2.02	2.43	286.81
Dhenkanal	1.07	0.90	227.61	Nayagarh	0.38	0.35	308.31
Gajapati	0.47	0.39	253.78	Nuapada	2.03	1.31	366.05
Ganjam	0.47	0.39	1805.22	Puri	0.38	0.35	289.16
Jagatsinghpur	0.39	0.35	232.81	Rayagada	2.02	2.43	228.86
Jajpur	1.22	0.62	295.47	Sambalpur	0.87	0.74	283.15
Jharsuguda	0.30	0.54	250.47	Sonepur	1.31	1.28	305.90
Kalahandi	2.03	1.31	378.71	Sundargarh	1.37	1.17	204.58

Source: Authors calculation from India Meteorological Department (IMD) data

Above historical events are witness that districts of Odisha are disproportionately exposed to different kinds of climatic events; accordingly, it is crucial to understand the level of vulnerability and the adaptive capacity of different regions of Odisha to such exogenous shocks. Because the risk is associated with both exposure and vulnerability of a region to climate (World Risk Report, 2024). Therefore, this paper attempts to assess the level of vulnerability of different districts of Odisha to such exogenous factors and will identify the role of different infrastructures in influencing the degree of such vulnerabilities.

2. BRIEF REVIEW OF LITERATURE

Vulnerability is a multidimensional concept (Thornton et al., 2006) that varies across the system depending upon economic, social, geographic, demographic, cultural, institutional, and environmental factors. There are various definitions of vulnerability that can be measured in different dimensions (Reed et al., 2013; Thornton et al., 2006). Among all those definitions, the IPCC defined it comprehensively (IPCC, 2001): “The degree to which a system is susceptible to or unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.” The IPCC (2000) also proposed an in-depth analysis regarding the importance of vulnerability and its association with existing systems and networks. Vulnerability is not only influenced by a series of extreme events and demographic characteristics; it also depends on the history of the development of infrastructure, the distribution of resources, and the functioning of civil institutions (Adger et al., 2007). External shocks and their vulnerability can be reduced through better coping capacity, which is associated with the availability of better infrastructural facilities (Jamshidi et al., 2019; Ahmed et al., 2020). The absence of better infrastructural facilities in different forms increases social vulnerability in multiple ways (Roncancio et al., 2020). Climate extremes and their related degree of impact can be measured through the advancement of infrastructural facilities and network systems in that region (Lu, 2019; Farahmand et al., 2021). Hence, it should be given utmost importance in identifying the existing infrastructural facilities and vulnerable infrastructure that needs to be developed.

According to Economic Survey of Odisha (2022), "As an agrarian State, majority of the rural workforce in Odisha (about 55 per cent) are engaged in agricultural activities. Agriculture sector continues to be the main source of livelihood for a large section of the population in the State. Every year the state is affected by a number of external shocks which creates a more comprehensive and authentic scenario of havoc. Among those the climatic shocks have been felt significantly. According to Odisha State Disaster Management authority (OSDMA), "Drought, flood and cyclone are the recurrent external shocks that have bedeviled the economy of the state over decades and centuries". During the last fifty years Odisha has been affected by natural calamities for 41 years. External shocks and its degree of impact varies from region to region, due to different geographical existence and availability of various kinds of infrastructural facilities. Therefore, for better understanding clearer picture should be drawn, regarding shocks related vulnerability relation with infrastructural facilities in different districts of Odisha.

Das (2021b) observed that the farmers' households in a locality are exposed to different types of external shocks that lead to the vulnerability of different types of farmers of various socio-economic backgrounds (Naik et al.,2024). The vulnerability of such farmer households and localities is attributed to the low level of adaptive capacity and lack of basic facilities and services (Das, 2021a; Tofu et al., 2022).

Infrastructure plays very important role in reducing vulnerability to various shocks, including natural disasters, economic crises, and health pandemics. Different types of infrastructure, including physical, social, financial, and health infrastructure, contribute to vulnerability reduction in different ways. Studies revealed that investment on climate-resilient infrastructure can reduce the economic impacts of natural disasters by up to 50% (World Bank, 2019) and it can be helpful in mitigating the impacts of extreme weather events, such as floods, heatwaves, and storms (IPCC, 2014). It is observed that physical infrastructure, such as roads, bridges, and buildings, can reduce vulnerability to natural disasters by providing safe evacuation routes and shelters (Kunreuther et al., 2013; Rodriguez et al., 2018). While studying the importance of infrastructure in mitigating the hazardous impact of natural hazards, it was observed that power sector infrastructure is critical in resilience strategies that provide essential services to sustain the lives and activities of human beings (Dahlberg et. al., 2015; Mohanty et al., 2020; OECD, 2019). Wilbanks and Fernandez (2013) identified some better strategies that will enhance both traditional and innovative infrastructure to cope with external shocks like climate change. Institutional well-being and the role of physical infrastructure also matter in the case of adaptation to various shocks (Musyoka et. al., 2020; Zio, 2016b). Similarly, social infrastructure, including schools, hospitals, and community centers, can foster social cohesion and provide essential services during crises (Aldrich, 2012; Dynes, 2005). Research has shown that social infrastructure can help to reduce the impacts of disasters on vulnerable populations, such as children and the elderly (Peek & Fothergill, 2009). On the other hand, financial infrastructure, such as banks and insurance companies, can provide financial protection and support during shocks & thereby reduce vulnerability (Laeven & Valencia, 2013; Merton & Bodie, 2005). Further, health infrastructure, including hospitals, medicals, and healthcare systems, can reduce vulnerability by providing timely and effective medical care (WHO, 2019; Kieny et al., 2017). It is evident that strong infrastructure in health and water aspects leads to minimal losses due to climate change (Handmer et. al., 1999; Ebi et. al., 2018; Riegel, 2008). Dash and Das (2019) have studied the nexus between infrastructure and economic outcome and observed that physical infrastructure contributes positively to economic outcome, and a lack of health infrastructure leads to a high vulnerability of states.

There is a significant body of evidence from India and its regional level that highlights the importance of infrastructure in reducing vulnerability to various shocks. A study on the 2013 Uttarakhand floods found that communities with better road connectivity were less vulnerable to flood-related losses (Sharma et al., 2016). A study on the 2004 Indian Ocean tsunami found that communities with better coastal infrastructure, such as seawalls and jetties, were less vulnerable to tsunami-related losses (Birkmann et al., 2006). A study on the 2010 floods in the Indian state of Andhra Pradesh found that communities with stronger social networks and community-based organizations were more resilient to the floods (Rao et al., 2015). Further the study on the 2001 Gujarat earthquake found that communities with better social infrastructure, such as community centers and schools, were more resilient to the earthquake (Jigyasu, 2002) and during 2017 Gujarat floods it is found that communities with better health infrastructure, such as hospitals and healthcare services, were less vulnerable to flood-related health risks (Gupta et al., 2018). Similarly, study on the 2018 Kerala floods found that communities with better health infrastructure, such as emergency medical services and disease surveillance systems, were more resilient to the floods (Rajeev et al., 2019). Mohapatra et al. (2001) observed that during 1999 Odisha supercyclone, the communities with better road connectivity and infrastructure were less vulnerable to cyclone-related losses. It is also observed that during floods, the communities with better flood-control infrastructure, such as embankments and sluice gates, were less vulnerable to flood-related losses (Mishra et al., 2015). (Adger, 1999; Bahinipati, 2016) have explored various factors that determine social vulnerability and considered both individual and community-level vulnerability components in order to determine the level of vulnerability and, therefore, reduce the level of vulnerability. There is a necessity for the potential development of the economy through infrastructure, and identifying the role of infrastructure in this regard is vital. It is also seen that critical infrastructure is important not only for saving human lives but also for reducing

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vulnerability from physical and economic losses (Mohanty et al., 2020; Jeganathan et al., 2021; Zio, 2016a; Chou & Tseng, 2010). Therefore, the paper also attempts to examine the role of infrastructure development in reducing vulnerability.

3. DATA AND METHODOLOGY

For vulnerability ranking, eighteen indicators covering four major components, such as socio-demographic, occupational structure, agricultural indicators, and common resource base, are considered. After the selection of the indicators, data was collected for each indicator from various issues of Odisha Agriculture Statistics, the Social Economic Caste Census (SECC-2011), Five Decades of Agricultural Statistics, the Agricultural Census (2015-16), the Odisha Economic Survey 2021–22, and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). To analyze the advancement of infrastructure availability, this study constructed four important infrastructure indexes, such as the Physical, Social, Financial and Health Infrastructure Index. Data were collected from the RBI Handbook of Statistics, ICRISAT, Odisha Economic Survey, 2020 and Odisha Agricultural Statistics, State Level Bankers Committee (SLBC) issues, and the fifth round of National Family Health Survey (NFHS) data. The detailed list of variables considered under each category is shown in the subsequent sections.

3.1 Methods

First, we have constructed the vulnerability index for 30 districts of Odisha, considering 18 indicators as shown in Table 2, with the expected sign of relationships with vulnerability.

Table 2. Indicators under major indicators and their functional relationship with vulnerability

Major Components	Indicators	Functional Relationship	Description of the Indicators
Socio-Demographic	Number of household size	+	Larger the household member, the more dependent people are, which leads to increased vulnerability.
	Density of population (persons per sq. km)	+	High density of population in a region faces more loss and damage from climate shock and can create increased global warming and increased demand for resources.
	Percentage of female population	+	Low access to resources, opportunities, social customs and rules makes this group vulnerable.
	Percentage of Scheduled Castes (SC) population	+	These groups are regarded as a vulnerable section of society with low exposure to facilities and opportunities and face inequality in terms of societal norms.
	Percentage of Scheduled Tribes (ST) population	+	
	Literacy rate	-	Literate people can access all information, warning messages of climate shocks. Their knowledge and skill increase the adaptive

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			capacity.
	Percentage rural population	+	Rural people have fewer access to information and limited resources to cope with the shocks and heavy dependency on agriculture also make them more vulnerable.
Occupational Structure	Percentage of small farmer	+	Small farmers and medium farmers generally possess small areas of cultivable land and bear losses due to extreme events. That leads to low income due to low adaptive capacity.
	Percentage medium farmer	+	
	Percentage of cultivators	-	Cultivators generally supervise and manage the cultivation process. They have land ownership, crop insurance, and access to resources.
	Percentage agricultural worker	+	Agricultural workers work on agricultural fields and get daily wages. They have no land ownership.
	Percentage landless farmer	+	Landless farmers engage themselves in farming on rented land. They also do not have any land ownership.
Agricultural Indicators	Percentage of irrigated land	-	Irrigated land is less vulnerable to extreme events like drought because irrigated land is fertile with improved soil quality.
	Diversification index	-	This deals with the scenario where a farmer does not depend on a specific livelihood option. Alternative options to earn reduce the vulnerability.
	Percentage net sown area	-	Increased sown area will increase the productivity of that region, which will ultimately lead to less vulnerability of that region.
	cropping intensity	-	Different crops are cultivated in different seasons help in reducing climate vulnerability.
Common Resources Base	Livestock units	+	Though livestock can be the asset and a diversified source of income, study suggest that during external shocks livestock are affected the most causing the owner more vulnerable.
	Percentage of forest area	-	Forest area, wetland, and open space are considered as the means of adaptive capacity, which will be helpful in minimizing the effects of extreme events.

3.1.1 Socio-Demographic Indicators

Under this major component, there are six indicators that share a positive relationship with vulnerability to extreme events. Only literacy rate as an indicator shows a negative relationship with vulnerability. Because when the literacy rate increases, people become aware of climate-related information, alerts, and warning messages. They can access resources, government schemes, credit related information easily with their knowledge and skills; exposure will decrease. Therefore, literacy rate establishes an indirect relationship with vulnerability to extreme events (Raju et al., 2017; Swami & Parthasarathy, 2021). On the other hand, other six indicators, such as household size, density of population, percentage of female population, percentage SC population, percentage ST population, and percentage rural population (Zou & Yoshino, 2017), share a positive relationship with vulnerability. SC, ST, and female population are considered vulnerable groups and disadvantaged sections of society. These vulnerable social groups face inequalities in terms of asset distribution, access

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to resources, and opportunities (Sridevi et al., 2014; Malakar & Mishra, 2016). This is the reason behind their exposure to extreme events.

3.1.2 Occupational Structure

This section focuses on five indicators, i.e., percentage of small farmers, percentage of medium farmers, percentage of agricultural workers, and percentage of landless farmers, which were found to be impacted by vulnerability positively (Sridevi et al., 2014; Bucherie et al., 2022). These are the sections of the population who possessed less ownership and farmers with no land. Generally, they cultivate rented land.

3.1.3 Agricultural Indicators

Under agricultural indicators there is percentage of irrigated land (Yusuf & Francisco, 2009), diversification index, percentage net sown area, and cropping intensity, which indicates a negative relationship with vulnerability (Sridevi et al., 2014; Jamshidi et al.,2019). In other words, the susceptibility to external shocks decreases as the value of these variables increases.

3.1.4 Common Resources Base

According to Wu (2021) forest area, wetland and open space considered as the means of adaptive capacity. Because the areas with high population density, low mangrove forest, low forest cover and wetland are generally vulnerable to hurricane and cyclone (Zou & Yoshino, 2017; Das & Vincent, 2009).

To construct the vulnerability, various methods are available, but the study uses a common standardized index (Kim et al., 2021; Ajtai et al., 2023). "Standardization refers to the transfer of criteria with different units to the same level so that they can be compared to each other (Nasrollahi et al., 2018)". Since the indicators are in different units, normalization through a standard index will be helpful for aggregation purposes. The standardized index value will vary between 0 to 1. Where vulnerability has a direct or positive relationship with the indicator, this study has used eq. (1):

$$\mathbf{SI} = \frac{Xi - MinXi}{MaxXi - MinXi} \tag{1}$$

When the vulnerability has an inverse or negative relationship with the indicator, that means if one indicator increases in value, then the level of vulnerability will decrease. Then the following equation (2) will be used.

$$\mathbf{SI} = \frac{MaxXi - Xi}{MaxXi - MinXi} \tag{2}$$

Where, **SI** is the standardized index score of each indicator, $\boldsymbol{X_i}$ is the observed value of the indicator, $\boldsymbol{Min\ X_i}$ is the minimum value of the indicator, $\boldsymbol{Max\ X_i}$ is the maximum value of the indicator.

After standardization of the dataset, indicators are normally assigned weights by using different techniques like dimension reduction (Tripathi & Singal, 2019) and here we have assigned equal weights to each indicators giving equal importance to all the indicators and calculated vulnerability index. After obtaining the standardized index for eighteen indicators, the value of the composite index for all the major components of vulnerability is obtained, and at last, the composite indicator index is obtained using the following equation (3). The composite index value for vulnerability will vary between 0 to 1. Where 0 represents that the district is not vulnerable to external shocks, as the value increases, the level of vulnerability of the district increases, and 1 represents a highly vulnerable district. Then all the districts are mapped according to their vulnerability composite indices. ArcMap 10.8 software is used for GIS mapping of the study area and highlighted the districts as per their index value.

$$\boldsymbol{Vci = \sum_{i=1}^{n} \frac{SIi}{n}} \tag{3}$$

Here, Vci is the value of vulnerability composite indices calculated from the standardized indices of eighteen vulnerability indicators under four major components of vulnerability. SIi is the standardized index of those eighteen indicators of vulnerability, calculated by using the normalization technique.

As per the availability of the data, twelve indicators have been selected to represent different categories of infrastructural facilities. Indicators have been selected following literature (Malakar & Mishra, 2016; Jamshidi et al., 2019). For infrastructure indices, we have normalized the data by using equation 1as stated above. Four major infrastructure indicators, namely, the Physical Infrastructure Composite Index (PICI), the Social Infrastructure Composite Index (SICI), the Financial Infrastructure Composite Index (FICI), and the Health Infrastructure Composite Index (HICI), were standardized, and composite indices were constructed using equation 3. The variables included under each infrastructure for each district of Odisha are given in Table 3.

In order to check the role of infrastructure in mitigating or reducing the possible vulnerability of external shocks, we have used a linear regression model where the vulnerability index of each district is considered a dependent variable and the score under four major infrastructure indices, such as PICI, SICI, FICI, and HICI, of 30 districts is considered an explanatory variable. Linear regression model has been used based on the available normalized data set and therefore the model is well fit to this study. The following regression equation has been used for this:

$$\boldsymbol{Vci = \alpha + \beta 1PICI + \beta 2SICI + \beta 3FICI + \beta 4HICI + Ui} \tag{4}$$

Where *Vci* is the value of the vulnerability composite index calculated from eighteen indicators for 30 districts separately. PICI is the value of the physical infrastructure index; SICI is the value of the social infrastructure index; FICI is the value of the financial infrastructure index; and HICI is the healthcare infrastructure index.

Table 3. Variables included under each infrastructure

Types of Infrastructure	Sub indicators
Physical Infrastructure index (PICI)	a. Road density/ sq. k.m.
	b. Railway density/ sq. k.m.
	c. Village electrified
Social Infrastructure index (SICI)	a. School/1000 population
	b. Hospital/10000 population
Financial Infrastructure index (FICI)	a. Credit-deposit ratio
	b. Scheduled commercial banks
	c. Post offices
	d. Number of Banks (%)
Health Infrastructure index (HICI)	a. Health Insurance (%)
	b. Sanitation facility (%)
	c. Improved drinking water (%)

4. RESULTS AND DISCUSSIONS

4.1 Vulnerability Score of Districts

A particular area is vulnerable to different types of exogenous factors. Therefore, in order to measure the level of vulnerability of the districts of Odisha to external shocks, we calculated the vulnerability index for each one of the districts. The calculated vulnerability composite index value for 30 districts is shown in Table 4. As the index value lies between 0 to 1, a higher value indicates a higher level of vulnerability, and vice versa. After obtaining the vulnerability index value, we rank the districts on the basis of their vulnerability scores. Rank one shows the most vulnerable district, and vulnerability decreases when we increase the rank. Rank one represents the most vulnerable district to external shocks, and rank thirty is the least vulnerable district.

Table 4 represents the vulnerability index score of all the 30 districts of Odisha, which has been calculated using eighteen vulnerability indicators as mentioned in Table 2. Table 4 shows that the vulnerability score of all the districts lies between 0.406 to 0.624, making each district moderately to highly vulnerable. The districts that score lies between 0.55 to 0.65 are classified as highly vulnerable districts, and the districts that score less than 0.55 and greater than 0.45 are considered moderately vulnerable districts. Rest of the districts score lies between 0.41 to 0.45 are considered as less vulnerable. Accordingly, it is very interesting to note that seven districts fall under the category of high-vulnerable districts followed by 14 districts are moderately vulnerable, whereas the rest of the 9 districts fall under the less vulnerable category. It is observed that among all the districts, Nabarangpur is the most vulnerable district to external shocks, and accordingly, it is ranked as the most vulnerable district with a composite vulnerability index value of 0.624. Mayurbhanj is the second-most vulnerable district, followed by Bargarh, Kalahandi, Malkangir, Rayagada, and Bolangir, respectively. Among the top five most vulnerable districts, three are from backward regions, popularly known as (Kalahandi-Bolangir-Koraput region districts) KBK regions. According to the vulnerability composite indices, Jharsuguda is the least vulnerable district, with a value of 0.406, followed by Jagatsinghpur, Anugul, Khurda, Nayagarh, and Puri. Having viewed the district-wise vulnerability, it is clear that vulnerability is caused by higher composite indices value in the four major components, i.e., socio-demographic, occupational, agricultural, and resource base indicators. All these three categories of districts i.e. highly vulnerable, moderately vulnerable and less vulnerable districts of Odisha & the study area are represented in the Figure 2.

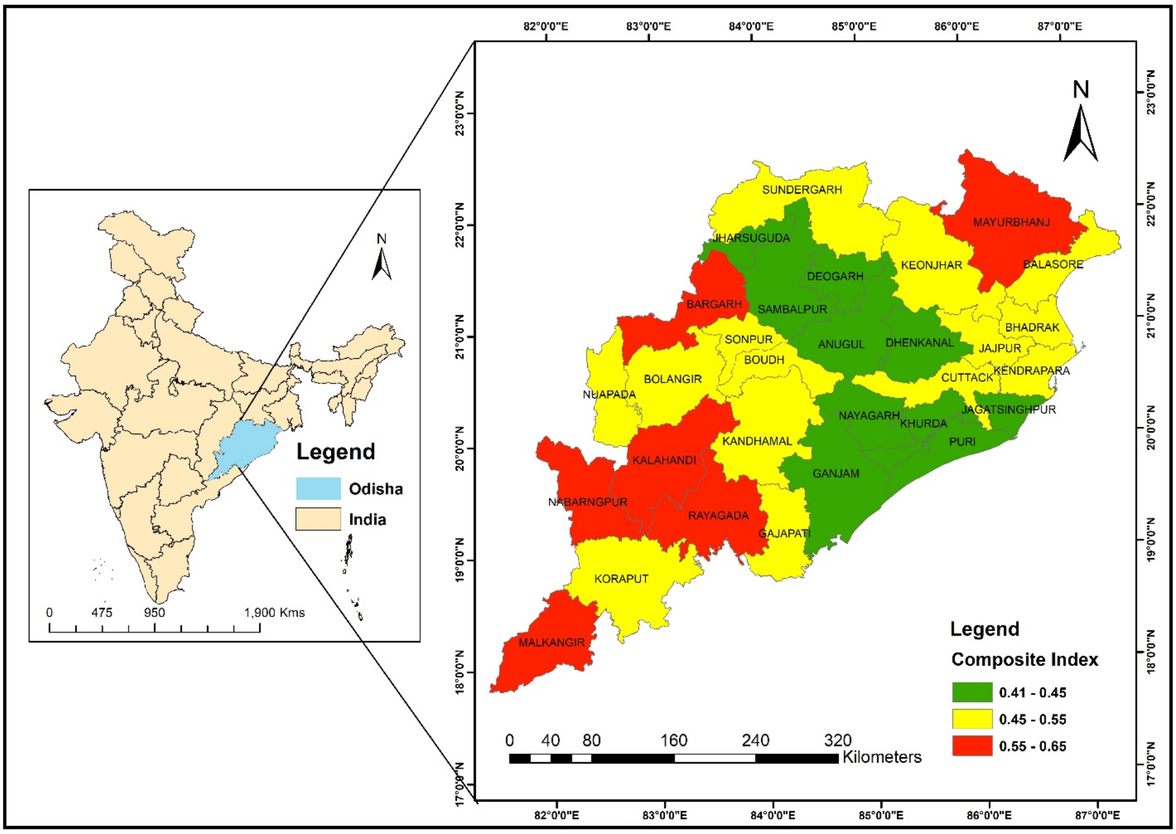
Table 4. Vulnerability indices and ranking of the districts of Odisha

Districts	Vulnerability Index	Rank	Districts	Vulnerability Index	Rank
Nabarangpur	0.624	1	Sundargarh	0.496	16
Mayurbhanj	0.588	2	Nuapada	0.486	17
Bargarh	0.588	3	Cuttack	0.473	18
Kalahandi	0.574	4	Sonepur	0.473	19
Malkangir	0.565	5	Kandhamal	0.472	20
Rayagada	0.558	6	Gajapati	0.469	21
Bolangir	0.551	7	Deogarh	0.437	22
Bhadrak	0.549	8	Dhenkanal	0.437	23
Jajpur	0.546	9	Sambalpur	0.431	24
Ganjam	0.523	10	Puri	0.425	25
Kendrapara	0.522	11	Nayagarh	0.414	26
Balasore	0.522	12	Khurda	0.409	27
Koraput	0.521	13	Angul	0.408	28
Boudh	0.507	14	Jagatsinghpur	0.408	29
Keonjhar	0.506	15	Jharsuguda	0.406	30

Source: Calculated by author

4.2 Infrastructure Indices of the Districts of Odisha

The role of infrastructure in economic development and reducing vulnerability to different shocks is very important. When one area has better physical, social, financial, and health infrastructure, then the area is well developed and can face any type of shock with minimum costs. Therefore, recognizing the role of infrastructure, in this section we have constructed the infrastructure indices for physical, social, financial, and health infrastructure, taking different sub-indicators under each index as per Table 3. Now the estimated infrastructure index for the major four indices of all the 30 districts is shown in Table 5, along with the ranking of each district against each category of infrastructure index.



Source: Authors interpretation by using ArcMap GIS

Figure 2. Study area location map and vulnerability composite index

Table 5 depicts that in terms of physical infrastructure, Jagatsinghpur district is in rank one, followed by Khurda, Jajpur, Balasore, and Puri. All these districts are in the coastal areas of Odisha, and therefore, it reflects that coastal districts have better physical infrastructure (Figure 3). Similarly, Nabarangpur is in the lowest position, followed by Kandhamal, Deogarh, Bargarh, and Maurbhanj under physical infrastructure. In the case of SICI, Kandhamal is in the top position, followed by Malkangir and Nayagarh. Overall composite indices of financial infrastructure depict that Jharsuguda is in the highest position and Koraput is in the lowest rank. In the case of HICI, Puri and Jagatsinghpur are in the first and second ranks, respectively, and Gajapati, Kandhamal, Mayurbhanj, Keonjhar, and Malkangir are in the lower ranks due to the low level of health infrastructure. Further, it is observed from the Table 5 that districts having overall better infrastructure facilities are less vulnerable to external shocks which is evident from the overall ranking of infrastructure (TICI) and overall vulnerability ranking (Vci) of the districts. With regards to Vci, the districts like Jharsuguda, followed by Jagatsinghpur, Angul, and Khurda, are found to be less vulnerable districts along with better infrastructure facilities. Similarly, districts with lagging infrastructural facilities are categorized as more vulnerable districts. Therefore, it can be said that districts with a well-distributed infrastructure are less vulnerable to extreme events as observed by Schweikert & Deinert (2021) assigning the important role to infrastructure in improving the coping capacity of a region. Infrastructure facilities act as security and well established medium to cope against shock and stress (Malakar & Mishra, 2016) and therefore make a region less vulnerable. The finding of this study is also corroborate with the finding of other studies (Kayaga et al., 2021; Pescaroli & Alexander, 2016). Figure 2 points out the picture where the backward regions of the KBK districts of Odisha are lagging behind in PICI and FICI. In the HICI ranking, those KBK districts are also in underdeveloped conditions and rank lower than the coastal districts.

Table 5. Infrastructure indices and vulnerability ranking of the districts of Odisha

Districts	PICI Score	PICI Rank	SICI Score	SICI Rank	FICI Score	FICI Rank	HICI Score	HICI Rank	TICI Score	TICI Rank	Vci Rank
Angul	0.273	20	0.266	20	0.189	15	0.716	5	0.355	19	28
Balasore	0.700	4	0.237	24	0.086	28	0.617	14	0.397	10	12
Bargarh	0.192	27	0.111	29	0.281	7	0.668	9	0.327	22	3
Bhadrak	0.571	6	0.239	23	0.139	22	0.639	13	0.389	13	8
Bolangir	0.257	22	0.327	17	0.197	14	0.490	22	0.307	24	7
Boudh	0.278	18	0.550	5	0.323	3	0.651	11	0.432	5	14
Cuttack	0.527	7	0.128	28	0.163	18	0.529	20	0.340	20	18
Deogarh	0.174	28	0.454	8	0.277	8	0.768	3	0.404	9	22
Dhenkanal	0.214	25	0.292	19	0.206	12	0.415	28	0.275	26	23
Gajapati	0.317	13	0.607	4	0.157	19	0.345	30	0.319	23	21
Ganjam	0.319	12	0.129	27	0.125	23	0.755	4	0.332	21	10
Jagatsinghpur	0.834	1	0.143	26	0.156	20	0.784	2	0.480	2	29
Jajpur	0.756	3	0.197	25	0.184	16	0.552	17	0.421	7	9
Jharsuguda	0.384	9	0.352	16	0.467	1	0.529	19	0.443	4	30
Kalahandi	0.260	21	0.396	14	0.168	17	0.691	6	0.360	16	4
Kandhamal	0.086	29	1.000	1	0.239	9	0.358	29	0.358	17	20
Kendrapara	0.452	8	0.323	18	0.142	21	0.669	8	0.381	14	11
Keonjhar	0.223	24	0.379	15	0.107	24	0.423	26	0.260	28	15
Khurda	0.826	2	0.002	30	0.283	6	0.690	7	0.474	3	27
Koraput	0.274	19	0.439	10	0.054	30	0.459	24	0.275	27	13
Malkangir	0.240	23	0.757	2	0.306	5	0.427	25	0.395	12	5
Mayurbhanj	0.194	26	0.453	9	0.054	29	0.416	27	0.246	29	2
Nabarangpur	0.053	30	0.259	21	0.091	27	0.512	21	0.215	30	1
Nayagarh	0.279	17	0.628	3	0.312	4	0.603	15	0.429	6	26
Nuapada	0.299	16	0.406	13	0.343	2	0.598	16	0.406	8	17
Puri	0.591	5	0.432	11	0.104	26	0.907	1	0.481	1	25
Rayagada	0.341	10	0.511	6	0.212	11	0.466	23	0.358	18	6
Sambalpur	0.331	11	0.482	7	0.215	10	0.649	12	0.397	11	24
Sonepur	0.301	15	0.411	12	0.204	13	0.656	10	0.376	15	19
Sundargarh	0.314	14	0.240	22	0.107	25	0.534	18	0.288	25	16

Sources: Calculated by Author

4.3 Role of Infrastructure and the Level of Vulnerability

To understand the role of infrastructure in reducing the vulnerability of the districts to shocks of different types, this study estimated the regression equation by considering four major infrastructure indices as independent variables and vulnerability composite indices as dependent variables. In order to figure out the role of infrastructure, the estimated linear regression model equation is as follows, and the calculated result of the regression model is presented in Table 6.

$$\boldsymbol{CI = 0.673 - 0.1086PICI - 0.0722SICI - 0.219FICI - 0.116\,HICI + Ui} \quad \textbf{(5)}$$

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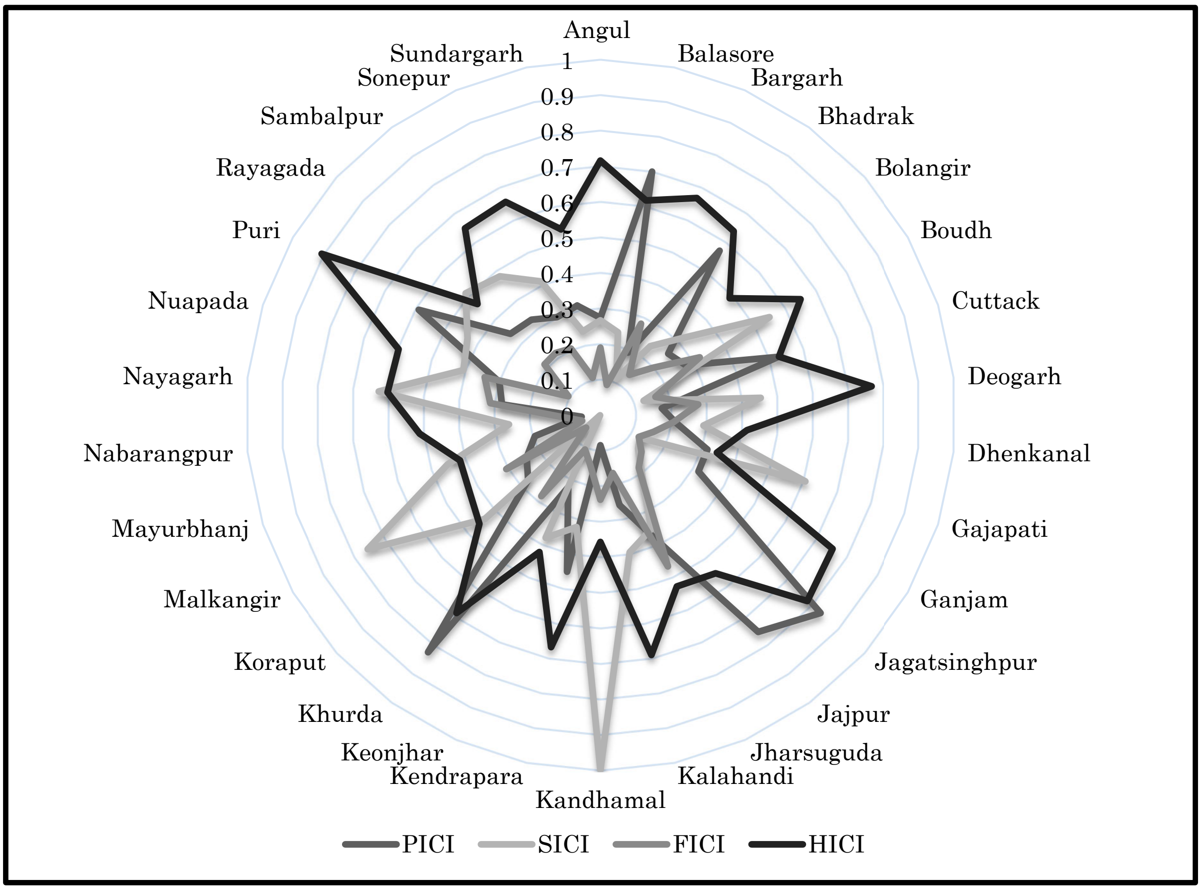

Figure 3. Composite infrastructure index

Table 6 shows that the explanatory variable caused 31 percent of the variation in the explained variable. Physical and financial infrastructure have statistically significant coefficients, both of which are negative. This implies that with the progress in physical and financial infrastructure, the vulnerability of the district to different shocks decreases. Therefore, appropriate policy intervention is required to improve the physical and financial infrastructure in each district. Further to check the reliability of the regression results, diagnostic and specification tests are conducted. The diagnostic test reveals there is no heteroscedasticity and multicollinearity (Table 7 in the appendix). However, the specification test (Ramsey RESET test) reveals that there is a specification error at the ten percent level of significance. Therefore, to deal with such issues, a dummy variable coastal districts (costal=1 and non-coastal=0) were introduced, and again the model has been estimated, followed by further diagnostic and specification tests. The results (Table 8 in the appendix) satisfy both the diagnostic and specification tests. But here the result reveals that only the physical infrastructure index is significant in reducing the vulnerability to different shocks. Thus, adequate provisioning of physical infrastructure such as roads, railways and electrification is important in reducing the vulnerability of an area to climate shocks, as evident from the results.

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Table 6. OLS regression result

Regressors	Coefficient	Standard error	P value
PICI	-.108*	.061	0.092
SICI	-.072	.063	0.266
FICI	-.219*	.113	0.065
HICI	-.116	.088	0.200
Constant	.673	.065	0.000

R-squared = 0.311, Adj R-squared= 0.201 * Significant at 10% level

Source – Authors calculation

5. CONCLUSION

This study assessed the level of vulnerability of districts of Odisha to external shocks and identified the role of different infrastructures in influencing such vulnerabilities. Vulnerability assessment result reveals that Nabarangpur district, followed by Mayurbhanj, Bargarh, Kalahandi and Malkangir districts, are highly vulnerable districts. These districts are also historically more exposed to drought and confront the highest variability in minimum and maximum temperature along with high variability in rainfall distribution pattern. Therefore, exposure of a district is related to vulnerability in determining the level of risk of a region to external climatic events. Besides this, physical infrastructure (density of road length, density of railway length, village electrified) and financial infrastructure (i.e., credit-deposit ratio, scheduled commercial banks, post offices, and number of banks per 100 k.m. area) are showing statistically significant results in influencing vulnerability. That means that the negative coefficient of these two major indicators shows that they establish a negative relationship with vulnerability. This suggests that it is essential to increase the physical and financial infrastructure in order to reduce the level of vulnerability to external shocks. More precisely, we have to focus more on the development density of road length and railway length, and a greater number of villages should be electrified. On the other hand, the financial aspect should be strong in order to reduce the level of vulnerability to external shocks. Because at the time of post-climatic hazards, poor rural households face the problems of yield loss, household damage, loss of occupation, and wealth loss, they need better banking facilities for credit and to revive their vulnerable condition. The number of banks should increase on a regional basis, and bank credit should be provided to the poor and needy farmers during the post-devastation period. From an analytical point of view, the backward region of Odisha, known as KBK districts, should be in focus because they are lagging behind almost in every indicator and mostly in physical indicators.

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APPENDIX

Table 7. Diagnostic and specification test result

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity		Variable	VIF	1/VIF
Ho: Constant variance		SICI	1.58	0.632
Variables: fitted values of Vci		PICI	1.47	0.678
chi2(1)	0.13	HICI	1.35	0.741
Prob > chi2	0.7170	FICI	1.08	0.929
Ramsey RESET test	Prob > F = 0.0380			

Table 8. OLS regression result including the dummy variable

Regressors	Coefficient	Standard error	P value
PICI	-.134*	.069	0.076
SICI	-.085	.065	0.209
FICI	-.165	.113	0.225
HICI	-.160	.104	0.138
Coastal district	.031	.039	0.428
Constant	.696	.071	0.000

R-squared = 0.329, Adj R-squared= 0.190 * Significant at 10% level
No multicollinearity and heteroscedasticity
Ramsey RESET test using powers of the fitted values of Vci
Ho: model has no omitted variables
F(3, 21) = 1.77
Prob > F = 0.1836
Source – Authors calculation