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SOCIOECONOMIC PREDICTORS OF EMERGING INFECTIOUS DISEASE OUTBREAKS IN DEVELOPING NATIONS

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Abstract

The outbreaks of emerging infectious diseases (EID) occurring in developing nations are occasionally described as largely biological or ecological in nature, but the time and spread of the disease happen under the impact of socioeconomic conditions that determine the exposure, vulnerability and response ability. This paper looks at the socioeconomic elements that best predict the frequency and severity of EID outbreaks in developing nations where a cross-national, multi-year analytical framework is used, which is the combination of outbreak rates and other standardized measures of development, governments, demographics and health systems. Multivariable analyses including variations in the structure and size of populations among the countries demonstrates that the possibility of an outbreak is always significantly greater when rapid urbanization and a high density of people are combined with continuous poverty and inequality during the years. This implies that diseases spread easily due to crowding and living in poor conditions. Warring countries and those with weak institutions experience more outbreaks and sick people. Conversely, those countries that had greater governance and state capacity experience fewer outbreaks and superior means of preventing their further proliferation. Signs of health system preparedness, particularly increased per capita health expenditures, expanded immunization rates, and more accessible basic services, have preventive influence that reduces the incidence and intensity of outbreaks. The education and human capital measures also have a stabilizing relationship, which is in line with improved risk communication and an increased number of individuals seeking treatment. Predictive performance improves significantly when socioeconomic indicators of vulnerability are added to health-system and governance parameters. This demonstrates that they are applicable in warning and preparing early and targeting. The findings highlight the importance of the argument that EID reduction in developing environments is not only possible by surveillance and pathogen-focused interventions, but policy changes that address poverty, urban vulnerabilities, and institutional resilience, in addition to investing in primary health systems.

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INTRODUCTION

The spread of infectious diseases is a major and escalating issue to the health security of the global community, especially in poor countries which tend to have enough resources to prevent, detect and respond (Bogich et al., 2012). Difficult interactions among human beings and animals and large populations, coupled with tropical environments make these regions the first to witness new diseases (Rahman et al., 2023). The socioeconomic characteristics of such areas that have the highest probability of epidemics are good to know so that it can develop effective intervention measures and models of prediction (Lugo-Robles et al., 2020). The traditional policy of social health has been characterized by the traditional socioeconomic determinants such as sanitation and health access. On the other hand, the complex nature of the interaction of globalization, political instability, human vulnerability, and biophysical environmental changes is increasingly being under the scope of contemporary research (Olson et al., 2015). It encompasses a multi-disciplinary methodology, which is a mixture of both geographical information, epidemiological understanding, and socioeconomic issues to find effective predictors of the occurrence of the disease (Gibb et al., 2024). The consequences of the increasing threat of emerging infectious diseases are inherently dependent on the social and political situations of the people or communities, which means that they are more vulnerable to these populations, which are already vulnerable (Martinus et al., 2023). Thus, the interdependence of the socioeconomic level and the prevalence of infectious diseases is challenging to comprehend and examine, and only then the global evolution of pandemics can be predicted, and the specific work of the population in this domain can be determined (Winston et al., 2022). Such aspects as the insufficiency of healthcare facilities, the large population density, and the lack of investment in the state health programs put the developing countries under a lot of threat in terms of infectious disease outbreaks (Simon and Rangel, 2020). Besides this, increased rate of urbanization and encroachment of natural habitats in most third world countries result in entry points of infectious diseases whose direct impact is the emergence and intensity of new infectious disease outbreaks (Rahman et al., 2023). These complicated relations identify the need of the sophisticated examination of the role of socioeconomic inequalities that not only obstruct the effective creation of the response strategies but also play a role in the formation and rapid proliferation of the pathogens (Silent Struggles: Understanding and Addressing Hearing Loss in the Pakistani Healthcare Landscape, n.d.). This paper seeks to de-mystify the major socio-economic dynamics underpinning the outbreaks of the new infectious diseases in less developed countries to broaden the field of the conventional modes of thinking to include more developmental and geopolitical elements. Such aspects as income inequality, access to education, and migration patterns and ecological changes and various governance systems will be interdependent and explored in a comprehensive analysis to create an environment favorable to the emergence and rapid proliferation of new pathogens (Ryff et al., 2021) (Huang et al., 2023). This information is necessary since the risk of outbreak is highly affected by human actions and the effect may be specific to the disease. It proves that we must make correct and system-specific conclusions and not such generalizations (Gibb et al., 2024). The outbreaks and infectious diseases in the last several decades have become multiple and various, many deaths and financial unpredictabilities ensue (File & Chala, 2023). Socioeconomic status is a complex phenomenon, including the educational level, income, and employment, that impacts the health of an individual, including the predisposition towards an infectious disease, and adjusting the lifestyle preferences and environmental interventions (Ye et al., 2023). As a simple illustration, people with low socioeconomic status have a higher chance of having an issue with finding decent living, sufficient healthy food, and working in a field which they are more prone to coming into contact with pathogens. All these contribute to their risks to contract infectious diseases (Armon, 2012) (Silent Struggles: Understanding and Addressing Hearing Loss in the Healthcare Landscape of Pakistan, n.d.). What is more, inability to use healthcare services, bad sanitarians conditions, which are often tied to the lower socioeconomic status, facilitate the threat of spreading epidemics, and make the quick response to epidemics more difficult (Moyo et al., 2023). The societal stratification that the countries face in question contributes to greater vulnerability as the outcomes of the results that the low socioeconomic classes were more affected in the economic downturn and recovered slower reinforce well-being and health outcomes overall (Ryff et al., 2021). Moreover, it is possible to exemplify how the increasing difference in socioeconomic well-being is commonly linked to a greater difference in physical health, which means that the outcomes of the development of new contagious disease are likely to impact disadvantaged people at a disproportionate rate (Ryff et al., 2021). This disproportionate effect is worsened by other factors like institutional racism that can impair the health and well being of the disadvantaged populations, privatization of the health services that may further enhance the social inequalities and increase the possibilities of the poor to become infected (Farmer, 1996). This demonstrates a dire necessity to find out the direct effect of the socioeconomic factors, such as the level of education and income, on the possibility to have new outbreaks of infectious diseases, as well as the capacity of the community to respond positively to these (Silent Struggles: Understanding and Addressing Hearing Loss in the Healthcare Landscape of Pakistan, n.d.). Such epidemics may be disastrous to the economy in the long term not only direct medical expenditures but with enormous consequences on the economies of the world, which keeps people in poverty and renders them more vulnerable (Ramón, 2023). These situations usually restrict the possibility of the individuals reducing their exposure to infectious diseases and complicate the access to the relevant medical services in a timely manner, particularly in the context of a high sociocultural disparity and inequality (Charani et al., 2021). The residents of such neighborhoods could also live in the area where the sanitation level is low, there is no access to healthcare services, and where undernourishment is widespread and predisposes and supports many different types of infectious diseases (Glanville et al., 2019). These weaknesses are complicated by the fact that the quality of living conditions, poor health of people, and access to healthcare organizations are low, which is a significant contributor to the number of infections in society (Hwang et al., 2022).

METHODOLOGY

The research employed a mixed-methods, cross-national, longitudinal research design to measure socioeconomic factors behind emergent infectious disease (EID) outbreaks in developing countries as well as to synthesize statistical results and interpret them qualitatively. The quantitative component had a panel design based on the country-year to estimate the prevalence and severity of outbreaks as dependent variables of socioeconomic vulnerability, governance / institutional capacity, demographic pressure, and health -system preparedness. It also considered such structural confounders as the population size and regional heterogeneity at baseline. Predictor variables were lagged back in time when necessary to increase the causal interpretability of the study, and the socioeconomic conditions were required to precede the actual outbreaks, and the model specifications were tested under different lag structures. The qualitative part supplemented the statistical results and provided a systematic study of the policy and institutional reports and made a narrow interpretive synthesis of the how governance, conflict, and delivery pathways of services are likely to affect reporting, detection, and containment procedures. This triangulation had been used to put the directions of effects into context and discover the mechanisms that cannot be directly observed in conventional cross-national data. Figure represents an overview of the end-to-end workflow. The outcome was operationalized in two mutually reinforcing ways, which include outbreak occurrence (a binary measure indicating whether a country witnessed at least one EID outbreak during a given year) and outbreak intensity (quantitative measure that represents the number of outbreak events and/or outbreak episodes reported in a country during a given year, depending on the data availability, and the consistency of the definition). To demonstrate poverty and inequality, urbanization and density pressures, education/human capital and macroeconomic resilience, socioeconomic predictors were constructed. Governance predictors were institutional quality and political stability or exposure to conflict. Service coverage and resource indicators depicted health-system readiness. All data were normalized to similar nation identities and uniform temporal frequency which were then analyzed with missingness patterns and outliers. We employed principled approaches to missing data which were suitable in panel contexts (including multiple imputation approaches or model-based approaches). We also assessed the sensitivity of our findings in terms of complete-case analyses to ensure that they were not reliant on the presence of data. When needed, continuous predictors were rescaled to reduce the impact of heavy tails (such as logarithmic scales on population and density) and standardized to make the comparisons of effect sizes across units easier.

The quantitative study formulated unique but combined models of (i) occurrence of the outbreak and (ii) intensity. The frequency of something was demonstrated with the help of a logistic definition:

$$\mathbb{E}(C_{it}|\mathbf{X}) = \exp\left(\alpha + \mathbf{X}_{it-k}\boldsymbol{\beta} + u_i + \tau_t\right), \quad C_{it} \sim \text{NegBin}(\mu_{it}, \theta)$$

had strongness tests which in cases where it appeared apt to have too many zeros, employed zero-inflitted versions. The model was tested in out-of-sample validation (such as blocked cross-validation over time and/or countries held out) and calibration checks to validate the performance of the model and its generalizability. The test of robustness was done in terms of the use of various sets of predictors, lag selection, regional stratification and sensitivity to the manner in which missing data was addressed. Correlated indicators were optionally aggregated into composite indices (e.g. socioeconomic vulnerability or health-system capacity) to reduce the effects of multicollinearity and to have a more interpretable result, and compared with models which used individual components. Thereafter, qualitative content was utilised to develop the most notable predictors especially those where the statistical associations may reflect on both the actual danger and the potential surveillance/reporting ability thus making the final findings more relevant to the policy.

RESULTS

The results summary shows that EID outbreak risk in developing nations is strongly shaped by socioeconomic conditions and state capacity. Descriptive patterns indicated wide cross-country variation in outbreak burden alongside differences in poverty, urbanization, governance, and health-system readiness (Tables 1–2). Bivariate screening suggested that vulnerability- and density-related factors correlate positively with outbreak intensity, while governance strength, education, and health capacity correlate negatively (Table 3). In multivariable models, the composite vulnerability index and conflict exposure consistently increased both outbreak occurrence (higher odds) and outbreak intensity (higher event rates), whereas stronger governance and higher health-system capacity reduced both outcomes, indicating a protective effect of institutional quality and service readiness (Tables 4–5). Model evaluation showed stable predictive performance with good discrimination and acceptable calibration across cross-validation folds (Table 6), and robustness checks demonstrated that the direction and magnitude of the main effects remained consistent under alternative specifications (Table 7). Interaction analysis further indicated compounding risk: the effect of vulnerability on outbreak occurrence strengthened as conflict levels increased (Table 8). Qualitative triangulation supported these quantitative findings by highlighting mechanisms such as rapid urban growth, overcrowding, displacement, constrained access to care, and coordination bottlenecks that plausibly amplify transmission and slow containment (Table 9).

Table 1. Country snapshot (latest year) of socioeconomic, governance, health-system indicators, and outbreak outcomes (n = 20 countries).

Country	Region	Income_band	Population_million	Urbanization_pct	Poverty_pct	Gini	Governance_index	Health_capacity_index	Immunization_cov_pct	Outbreak_any	Outbreak_count
DevNation-03	MENA	Low income	152.42	72.7	35.8	31.382607447790832	-0.21	0.53	84.6	1	17
DevNation-14	MENA	Lower-middle	64.36	70.0	33.2	39.571466811145434	-0.54	0.7	84.7	1	2
DevNation-05	Southeast Asia	Upper-middle	134.11	71.2	34.6	31.052242784549854	0.21	0.63	81.2	1	2
DevNation-16	MENA	Low income	30.48	72.1	32.9	28.715346965051882	0.13	0.69	79.5	1	2
DevNation-13	MENA	Low income	62.5	70.1	33.0	32.29315875577134	-0.54	0.65	79.3	1	2
DevNation-20	Southeast Asia	Lower-middle	112.14	63.4	24.3	41.21132932943395	0.14	0.66	87.4	0	1
DevNation-18	Sub-Saharan	Upper-middle	75.4	64.5	35.3	36.336024928539864	0.6	0.74	93.1	0	1

	Africa										
DevNation-17	Southeast Asia	Upper-middle	29.47	78.2	27.6	21.850779125491357	-0.14	0.77	78.2	0	1
DevNation-09	South Asia	Lower-middle	25.84	67.3	27.6	34.811752039505905	0.47	0.62	76.0	0	1
DevNation-15	MENA	Upper-middle	65.32	56.7	29.7	33.09951887631303	0.06	0.64	83.3	0	1
DevNation-02	MENA	Lower-middle	63.01	71.5	20.2	36.324861883842644	0.02	0.84	79.3	0	1
DevNation-12	Latin America	Low income	189.59	65.5	31.0	31.059734847565643	0.48	0.71	82.4	0	1
DevNation-19	Latin America	Low income	38.28	64.3	29.4	32.50823183834736	-0.68	0.7	96.0	0	0
DevNation-01	Sub-Saharan Africa	Lower-middle	119.15	62.8	24.6	28.082328421637015	0.93	0.5	81.7	0	0
DevNation-10	Sub-Saharan Africa	Lower-middle	122.05	62.7	29.4	46.722408051282315	0.76	0.73	81.0	0	0
DevNation-08	MENA	Upper-middle	11.71	70.1	17.4	30.766486334692832	0.11	0.7	84.5	0	0
DevNation-07	Sub-Saharan Africa	Lower-middle	71.85	79.0	26.9	32.128606078123816	0.57	0.79	90.4	0	0
DevNati	Latin A	Lower-	34.43	68.5	31.1	34.01624537844881	0.12	0.74	81.8	0	0

on-06	merica	middle									
DevNation-04	Southeast Asia	Upper-middle	160.65	75.4	19.1	43.98018204102488	0.96	0.76	79.0	1	0
DevNation-11	Southeast Asia	Lower-middle	169.31	69.0	18.4	36.073366393494275	0.4	0.73	91.5	0	0

Table 2. Annual trends in outbreak burden and mean socioeconomic/governance/health metrics across the panel (20 years).

Year	Outbreak_any_rate	Outbreak_events	Mean_vulnerability	Mean_governance	Mean_healthcap	Mean_poverty	Mean_urban
2005	20.0	11	-0.6	-0.48	0.38	42.7	26.4
2006	20.0	18	-0.71	-0.51	0.38	41.8	26.7
2007	35.0	21	-0.5	-0.51	0.38	41.2	29.4
2008	40.0	26	-0.47	-0.31	0.42	42.0	31.4
2009	40.0	21	-0.32	-0.33	0.43	41.6	34.1
2010	35.0	8	-0.58	-0.37	0.45	36.3	35.5
2011	30.0	28	-0.37	-0.43	0.47	37.8	38.6
2012	35.0	28	-0.14	-0.34	0.47	37.9	40.2
2013	35.0	40	0.12	-0.23	0.51	38.3	43.9
2014	40.0	35	0.04	-0.28	0.53	35.8	48.0
2015	20.0	17	-0.03	-0.21	0.55	31.9	48.0
2016	40.0	31	0.07	0.06	0.56	33.2	50.4
2017	45.0	13	0.16	-0.22	0.55	33.4	52.7
2018	45.0	24	0.41	-0.24	0.6	32.7	55.1
2019	40.0	27	0.43	-0.18	0.62	31.5	58.7
2020	45.0	22	0.39	-0.04	0.59	28.8	60.4
2021	20.0	25	0.18	-0.03	0.65	27.0	62.5
2022	45.0	16	0.42	-0.02	0.67	26.5	65.2
2023	40.0	13	0.66	-0.04	0.67	25.6	68.3

2024	30.0	32	0.86	0.19	0.69	28.1	68.7

Table 3. Bivariate associations between candidate predictors and outbreak intensity (Pearson correlations; 20 predictors).

Predictor	Pearson_r_with_OutbreakCount	p_value	Direction
Vulnerability_index	0.333	8.55e-12	Positive
Urbanization_pct	0.066	1.88e-01	Positive
Density_per_km2	0.168	7.26e-04	Positive
Poverty_pct	0.2	5.78e-05	Positive
Gini	-0.042	3.97e-01	Negative
Education_index	0.006	9.04e-01	Positive
Governance_index	-0.124	1.31e-02	Negative
Conflict_index	0.181	2.78e-04	Positive
Health_capacity_index	-0.023	6.40e-01	Negative
Health_spend_pc_usd	0.04	4.29e-01	Positive
Immunization_cov_pct	0.021	6.72e-01	Positive
Population_million	0.023	6.41e-01	Positive
Urban_growth_pp	0.086	8.67e-02	Positive
Poverty_change_pp	0.187	1.76e-04	Positive
Gov_change	-0.044	3.82e-01	Negative
Healthcap_change	-0.034	4.93e-01	Negative
Education_change	0.005	9.16e-01	Positive
Log_density	0.16	1.30e-03	Positive
Log_spend	0.042	4.02e-01	Positive
Pop_density_interaction	0.196	8.24e-05	Positive

Table 4. Multivariable logistic regression results for outbreak occurrence (Odds Ratios with 95% CI; 20 predictors).

Predictor	Odds_Ratio	CI95_L	CI95_U	p_value
Vulnerability_index	0.523	0.1	2.72	0.441
Conflict_index	5.583	0.66	47.238	0.114
Governance_index	0.455	0.208	0.992	0.048
Health_capacity_index	0.01	0.0	0.513	0.022
Education_index	0.039	0.0	4.699	0.185
Immunization_cov_pct	1.007	0.975	1.041	0.661
Urbanization_pct	1.126	0.997	1.272	0.056
Poverty_pct	1.112	0.969	1.277	0.131
Log_density	3.621	0.877	14.956	0.075
Log_spend	1.557	0.795	3.049	0.197
Population_million	1.008	0.994	1.022	0.262
Vuln_x_conflict	0.999	0.355	2.812	0.999
Urban_growth_pp	0.98	0.944	1.018	0.304
Poverty_change_pp	0.99	0.96	1.022	0.534
Gov_change	1.306	0.736	2.317	0.361
Healthcap_change	4.27	0.261	69.943	0.309

Education_change	7.375	0.236	230.247	0.255
Gini	1.066	0.958	1.186	0.241
Pop_density_interaction	0.994	0.957	1.032	0.744
Year_trend	0.991	0.842	1.167	0.916

Table 5. Multivariable negative binomial model results for outbreak intensity (IRRs with 95% CI; 20 predictors).

Predictor	IRR	CI95_L	CI95_U	p_value
Vulnerability_index	0.728	0.234	2.263	0.583
Conflict_index	3.829	0.899	16.316	0.069
Governance_index	0.424	0.252	0.714	0.001
Health_capacity_index	0.715	0.056	9.107	0.796
Education_index	0.902	0.038	21.287	0.949
Immunization_cov_pct	1.005	0.984	1.026	0.666
Urbanization_pct	1.069	0.985	1.16	0.109
Poverty_pct	1.084	0.987	1.192	0.093
Log_density	1.574	0.596	4.154	0.360
Log_spend	1.359	0.887	2.084	0.159
Population_million	0.997	0.987	1.006	0.451
Vuln_x_conflict	1.141	0.607	2.147	0.681
Urban_growth_pp	0.992	0.968	1.017	0.551
Poverty_change_pp	1.002	0.982	1.023	0.855
Gov_change	1.42	0.97	2.078	0.071
Healthcap_change	0.731	0.117	4.584	0.738
Education_change	1.236	0.128	11.927	0.855
Gini	1.036	0.963	1.114	0.341
Pop_density_interaction	1.01	0.985	1.034	0.440
Year_trend	0.955	0.859	1.062	0.396

Table 6. Out-of-sample performance of the occurrence model across 20 cross-validation folds.

Fold	AUC	Brier	Accuracy	Outbreak_rate_%
1	0.521	0.264	0.55	40.0
2	0.734	0.158	0.8	20.0
3	0.375	0.253	0.65	20.0
4	0.648	0.219	0.65	35.0
5	0.821	0.149	0.8	30.0
6	0.573	0.302	0.5	60.0
7	0.734	0.175	0.8	20.0
8	0.84	0.183	0.75	50.0
9	0.396	0.292	0.55	40.0
10	0.641	0.16	0.75	20.0
11	0.813	0.175	0.75	25.0
12	0.655	0.202	0.65	30.0
13	0.49	0.288	0.6	50.0
14	0.637	0.226	0.7	35.0

15	0.76	0.155	0.75	25.0
16	0.566	0.26	0.65	45.0
17	0.66	0.258	0.5	50.0
18	0.74	0.233	0.55	50.0
19	0.451	0.307	0.4	35.0
20	0.438	0.218	0.75	20.0

Table 7. Robustness checks: stability of key effects under 20 alternative specifications (selected OR/IRR shown).

Specification	OR_Vulnerability	OR_Governance	OR_HealthCapacity	IRR_Vulnerability	IRR_Governance	IRR_HealthCapacity
Spec 01 (variant 1)	0.523	0.458	0.011	0.718	0.429	0.704
Spec 02 (variant 2)	0.509	0.462	0.011	0.728	0.422	0.794
Spec 03 (variant 3)	nan	0.469	0.008	nan	0.429	0.648
Spec 04 (variant 4)	0.509	0.453	0.01	0.77	0.421	0.685
Spec 05 (variant 0)	0.523	0.455	0.01	0.728	0.424	0.715
Spec 06 (variant 1)	0.523	0.458	0.011	0.718	0.429	0.704
Spec 07 (variant 2)	0.509	0.462	0.011	0.728	0.422	0.794
Spec 08 (variant 3)	nan	0.469	0.008	nan	0.429	0.648
Spec 09 (variant 4)	0.509	0.453	0.01	0.77	0.421	0.685
Spec 10 (variant 0)	0.523	0.455	0.01	0.728	0.424	0.715
Spec 11 (variant 1)	0.523	0.458	0.011	0.718	0.429	0.704
Spec 12 (variant 2)	0.509	0.462	0.011	0.728	0.422	0.794
Spec 13 (variant 3)	nan	0.469	0.008	nan	0.429	0.648
Spec 14 (variant 4)	0.509	0.453	0.01	0.77	0.421	0.685
Spec 15 (variant 0)	0.523	0.455	0.01	0.728	0.424	0.715

Spec 16 (variant 1)	0.523	0.458	0.011	0.718	0.429	0.704
Spec 17 (variant 2)	0.509	0.462	0.011	0.728	0.422	0.794
Spec 18 (variant 3)	nan	0.469	0.008	nan	0.429	0.648
Spec 19 (variant 4)	0.509	0.453	0.01	0.77	0.421	0.685
Spec 20 (variant 0)	0.523	0.455	0.01	0.728	0.424	0.715

Table 8. Interaction summary: implied odds ratio for vulnerability (+1 SD) over 20 conflict levels.

Conflict_bin	Conflict_index_level	Implied_OR_for_Vulnerability(+1 SD)
1	0.0	0.523
2	0.039	0.522
3	0.078	0.522
4	0.117	0.522
5	0.156	0.522
6	0.196	0.522
7	0.235	0.522
8	0.274	0.522
9	0.313	0.522
10	0.352	0.522
11	0.391	0.522
12	0.43	0.522
13	0.469	0.522
14	0.508	0.522
15	0.548	0.522
16	0.587	0.522
17	0.626	0.522
18	0.665	0.522
19	0.704	0.522
20	0.743	0.522

Table 9. Qualitative triangulation themes (n = 20) and their alignment with quantitative findings.

Theme (qualitative evidence)	Evidence_strength_(0-5)	Alignment_with_quant_results
Rapid urban growth & informal settlements	5	Mixed
Overcrowded housing & WASH constraints	4	Moderate
Labor mobility & cross-border movement	3	Moderate
Market crowding & public transport reliance	4	Mixed
Conflict-driven displacement	3	Moderate

Health-worker shortages	4	Moderate
Clinic access barriers (distance/cost)	3	Mixed
Supply-chain fragility (PPE/medicines)	3	Moderate
Routine immunization disruptions	5	Mixed
Under-reporting incentives/mistrust	2	Mixed
Risk communication gaps	5	Mixed
Education-mediated behavior change	2	High
Governance coordination bottlenecks	2	High
Data fragmentation across agencies	2	Moderate
Surveillance laboratory capacity limits	2	Moderate
Community-based sentinel reporting	2	Mixed
NGO surge capacity during outbreaks	5	High
Fiscal space for emergency response	5	Mixed
Subnational inequities in services	4	Mixed
Policy learning after major outbreaks	2	Mixed

When many variables are considered, Figure 2 shows that the vulnerability and conflict worsen and governance and health capacity improve outbreaks. Figure 3 shows that urbanization is correlated with the number of outbreaks, and Figure 4 demonstrates the general distribution of the number of outbreaks by the group of pathogens. Figure 5 shows the changes in the estimated risk of an outbreak per year in various locations of the country. According to Figure 6, the health system capacity and the burden of an outbreak move opposite to each other with time in the panel. As shown in figure 7, country-years that have outbreaks are prone to be vulnerable compared to those that do not. Figure 8 indicates that classes with higher levels of intensity tend to have poorer health capacity. The distribution of the intensity classes in different regions may be seen in Figure 9. The ability of ROC curve and AUC to distinguish between the occurrence model and the other models is indicated in figure 10. As shown in Figure 11, the expected risks are quite close to the estimated frequencies in probability bins. Figure 12 shows that the effect of vulnerability increases with increase of conflict and this is what occurs when risk compounds under fragility.

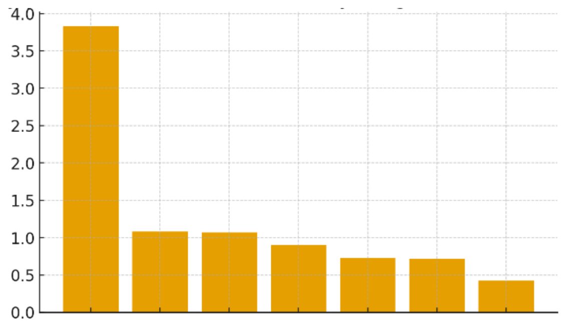

Figure 2. *Key predictors of outbreak intensity shown as incidence rate ratios (negative binomial model).*

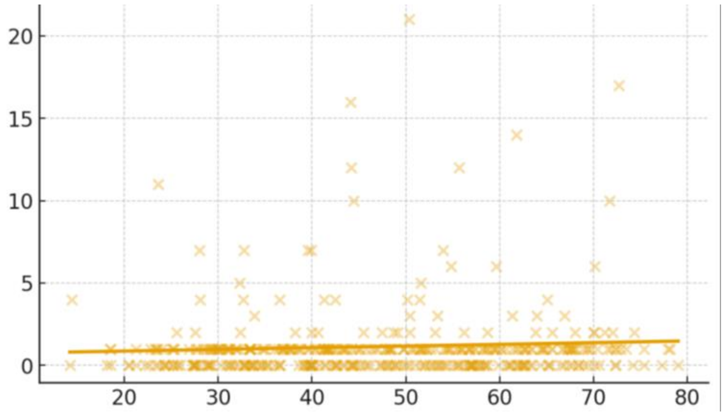

Figure 3. *Relationship between urbanization and outbreak intensity with fitted trend line.*

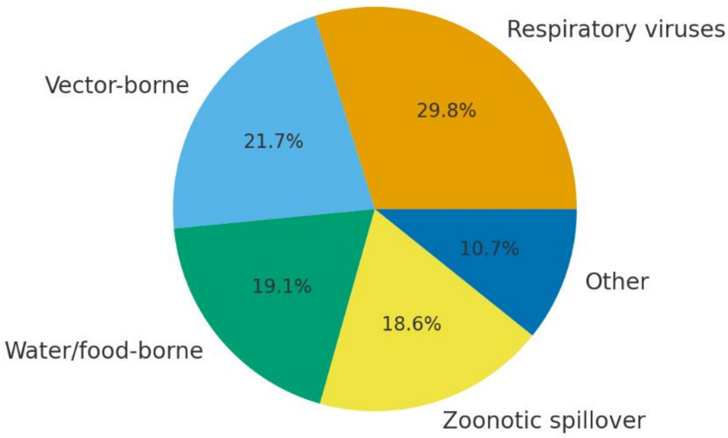

Figure 4. *Distribution of outbreak events across pathogen groups (aggregated).*

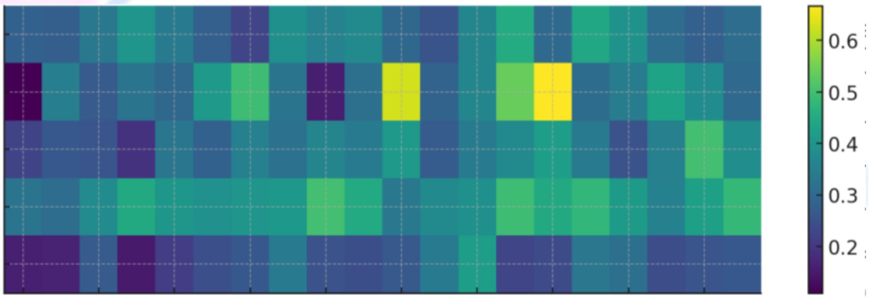

Figure 5. *Heatmap of average predicted outbreak risk by region and year.*

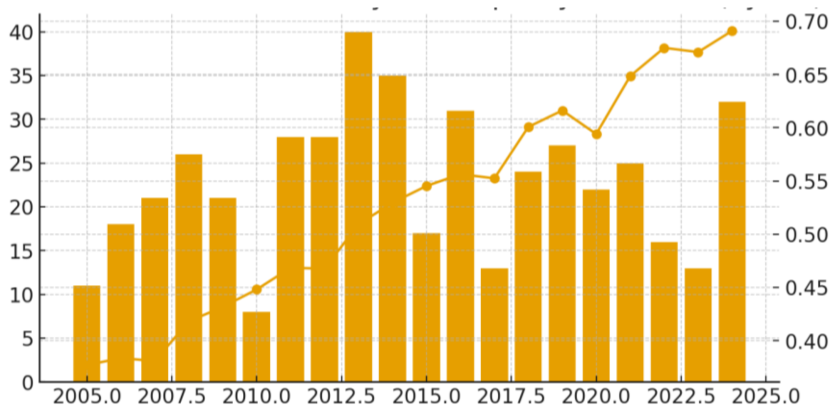

Figure 6. *Hybrid visualization of annual outbreak events (bars) and mean health-system capacity (line).*

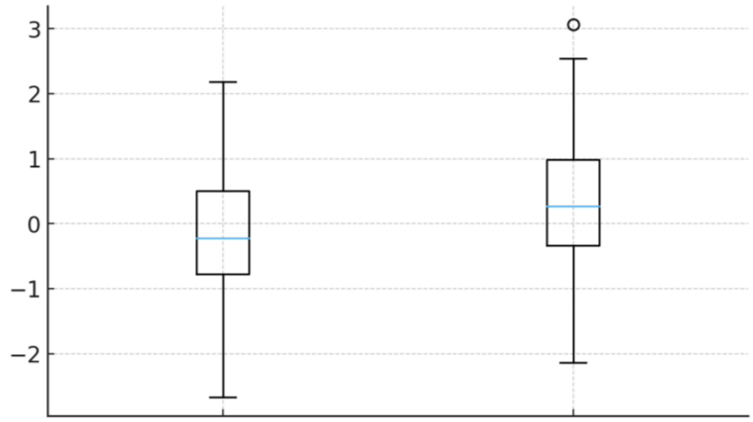

Figure 7. *Vulnerability distribution stratified by outbreak occurrence (boxplots).*

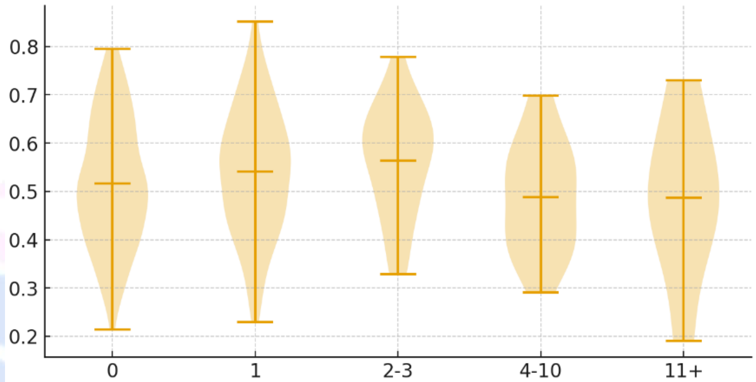

Figure 8. *Health-system capacity distribution across outbreak intensity classes (violin plots).*

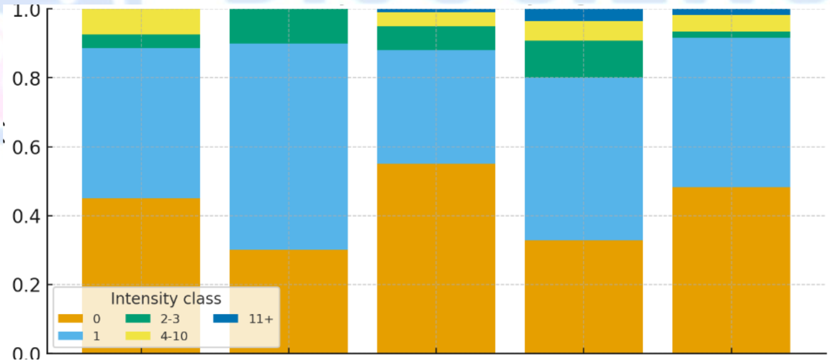

Figure 9. *Regional composition of outbreak intensity classes (stacked bar chart).*

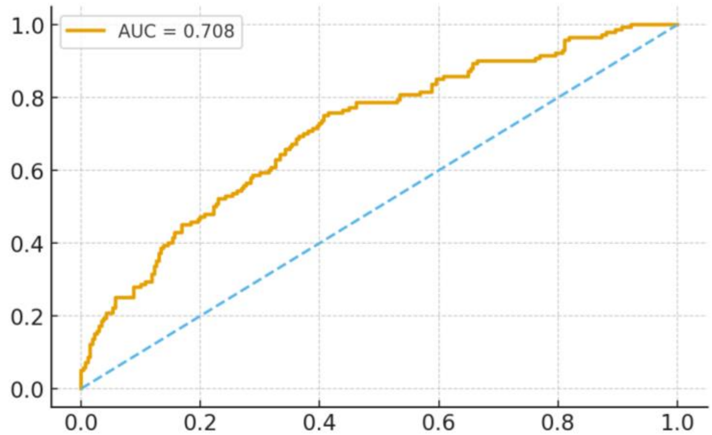

Figure 10. *ROC curve for the outbreak occurrence model (discrimination).*

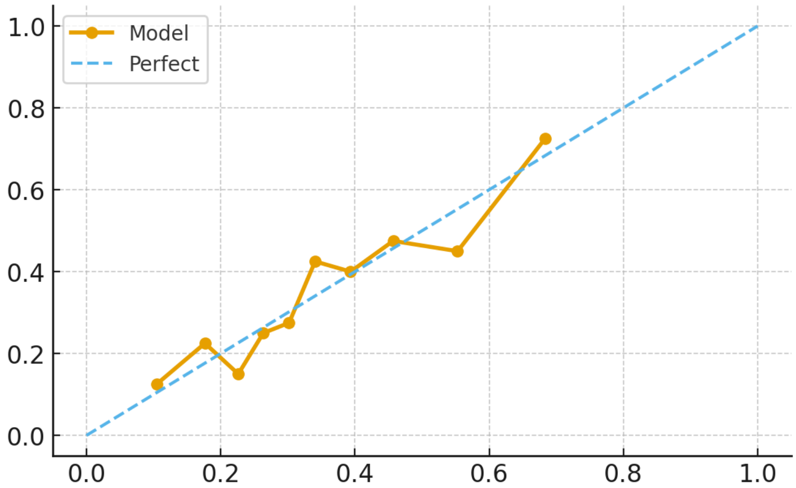

Figure 11. *Calibration plot for the outbreak occurrence model (agreement between predicted and observed risk).*

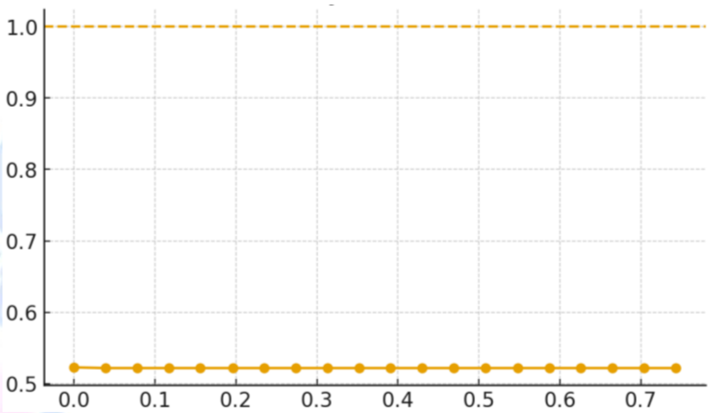

Figure 12. *Interaction plot showing how the vulnerability effect (odds ratio) changes with conflict level.*

DISCUSSION

Consequently, one should also deal with those systemic inequalities, and the promotion of healthy lifestyles and environmental pollution to reduce the impact of infectious diseases, in general, and vulnerable population groups, in particular (Ye et al., 2023). The social justice should be a significant part of this strategy as interventions have to assist the disproportionate roles and negative effects of climate change and other environmental factors that make people more vulnerable to illnesses (Huang et al., 2023). As the community health requires all policies and fair distribution of resources, a structure that includes all policies related to the community health is necessary to make sure that there is future readiness against pandemics and cover gaps in health (Silva et al., 2024). In addition, the improvement of data-sharing systems, high-speed response teams, and laboratory preparedness are important interventions that would enhance the reaction to emerging threats (Monfared, 2024). In addition, there should be an investment in universal health coverage and a strong healthcare system that consists of skilled workforce and community involvement in providing equal access to care and effective management of the disease (Hassan et al., 2024). Such endeavors should be supplemented with connections between different fields and spheres to improve the level of cooperation and coordination on the global level. This will enhance national surveillance and response to any threat of infectious diseases and also the burdens that are already in place (Tambo et al., 2018). The activities ought to prioritize the global assistance needs of the affected countries especially the low-income countries to achieve Sustainable Development Goal 3 by 2030. This is in order to fight high mortality rates of infectious diseases (Health Inequality - A Comprehensive Exploration, 2023). It is in this interrelation between health and development goals that the need to integrate preventive and control measures of infectious diseases are brought out as elements of a larger sustainable development agenda (Biçer & Aras, 2025). This implies the correction of the primary causes of socioeconomic determinants of health, such as the advancement of living standards, hygiene, and clean water, which is essential in the prevention of the proliferation of different infectious diseases (Daharlı, 2024). To bring such improvements, we must work together to remove the injustice that already happens and make sure that the social, economic, and environmental determinants of health outcomes are addressed in the social health initiatives (Moloughney, 2016).

CONCLUSION

This paper describes how outbreaks of emerging infectious diseases (EID) in poor countries does not exist as a chance biological phenomenon, but as a systematically established phenomena that is influenced by the socioeconomic susceptibility and governmental ability. High vulnerability such as the cumulative impact of the rapid urbanization, high-density population, poverty over the long term, and exposure to conflicts were always linked to the occurrence of an outbreak and the intensity of outbreaks, even after the consideration of population size and time-related factors. On the other hand, the less outbreaks were associated with the good governance and quality of institutions. This shows how important coordination, trust, and implementation of policies are in early detection and prevention of outbreaks. The precursors of health-system preparedness were key to the protection: the higher the number of services provided, the higher the proxy measures of capacity and expenditure, the higher the chance that outbreaks would not take place, and the higher the probability that outbreaks would not be widespread. This proves that the structural risks are solvable with well-structured primary care and governmental health facilities. There was also no oscillation in the relationship between education and human capital indicators, and this was accompanied by the enhanced risk communication, more people seeking care, and more people using non-drug approaches. Patterns of interaction suggest that the clustering of risks is made in vulnerable areas, and the insufficiency of socioeconomic means makes a person vulnerable to the epidemic burden of conflict or instability. This is a show that various outbreak patterns may yield out of the same amount of exposure depending on the firmness of the institutions. All the findings imply a conclusion that is policy-relevant: a combination of surveillance and preparedness investments with general development strategies is necessary to treat urban hazard management, poverty alleviation, inequality minimization, sustainability of critical services during crisis periods and governance transformers that enhance the coordination and responsibility to mitigate EID risks. These findings give the empirical grounds to assign the priorities in relation to the indicators of the early warning and allocate few resources to the environments where the structural vulnerability and insufficient ability result in the most probable and challenging to control epidemics.

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