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Economic Vulnerability and Resilience of the World in the Face of the COVID-19 Pandemic

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ABSTRACT

The research looks at how the COVID-19 pandemic affected vulnerability and economic strength in 150 countries between 2020 and 2021. By using the Panel Smooth Transition Regression model, it discovered a complex connection between different factors. The pandemic made countries more vulnerable and weakened their economic resilience. This highlights the need for nations to boost their strength by taking steps such as broadening their economies, investing in healthcare, creating support programs, maintaining trade, and building stronger economic defenses against both pandemic-related vulnerabilities and natural disasters. Ultimately, the article stresses the importance of countries reinforcing their resilience through strong policies and actions that cover different aspects of their economies and healthcare systems, addressing the challenges brought on by the pandemic and potential future crises.

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1. Introduction

The emergence of the COVID-19 pandemic in 2019 unleashed a worldwide crisis that plunged the global environment into a state of turmoil and chaos. Governments across the globe responded with unprecedented measures, imposing not just temporary restrictions on people's movements but also mandatory limitations on business activities. COVID-19, caused by the highly contagious severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was swiftly declared a global pandemic. On March 11, 2020, the number of confirmed COVID-19 cases worldwide surged past 2.1 million, accompanied by a devastating toll of over 52,900 deaths. This viral scourge swiftly spread its reach to 212 countries and regions, sending shockwaves through societies and economies alike WHO). In the face of this relentless growth in confirmed cases, governments worldwide enacted a diverse array of 34 preventive and mitigation measures, neatly classified into five main categories: quarantine, travel restrictions, governance and economic measures, social distancing, and public health measures (OESD, 2020). These measures were designed to safeguard human lives by slowing the virus's spread, but they also exacted a toll on both micro and macroeconomic sectors (Atagub, 2020). The delicate balance between stringent policies aimed at preserving lives and the imperative to mitigate social and economic damages became apparent (Agbe, 2020). This trade-off bore significant weight because, without containment measures, the economic recession could have been even more profound (Correia et al., 2020). The curve of COVID-19 infections, when flattened, correspondingly steepened the curve of macroeconomic recession, and the implementation of necessary public health policies abruptly disrupted the economy (Gourinchas, 2020). This intensified spread of the pandemic, experienced by both developed and emerging economies, prompted severe lockdowns and unprecedented disruptions in economic activities, leaving nations grappling with substantial economic vulnerability (Baldwin et al., 2020). COVID-19's capacity to rapidly and disruptively impact the economy was undeniable

(same source). The actual extent of its economic repercussions and the relative significance of underlying channels, however, remained shrouded in uncertainty (Chen et al., 2020).

The susceptibility of economic systems to the COVID-19 shock hinged on their inherent vulnerability, a concept that encompasses a country's ability to withstand economic pressures and potential damages (Briguglio, 2014). Economic vulnerability can emanate from a nation's permanent characteristics as well as its economic decision-making and policies. In this context, the more adept an economy is at allocating resources to cope with such risks, the more resilient it becomes. Consequently, resilience takes center stage as a comprehensive strategy aimed at bolstering existing capacities and diminishing economic vulnerability in the face of various crises and environmental hazards. Economic resilience, as a matter of fact, originates from the manner in which economic policies are devised and possesses an accumulative nature. Thus, the imperative to focus on enhancing economic resilience becomes evident. Despite the undeniable economic impacts of the COVID-19 pandemic, economic policies and decisions necessitate the incorporation of indicators that gauge the impact and trajectory of such risks. The Economic Resilience Index stands out as one such critical indicator that policymakers must continually prioritize alongside the affected sectors. It serves as a compass in navigating the treacherous waters of economic uncertainties, offering valuable insights into a nation's ability to withstand and rebound from crises. In the post-pandemic world, this index becomes a vital tool for crafting policies and strategies that promote not just recovery but also the fortification of economies against future shocks.

In a series of comprehensive studies, various researchers have delved into the multifaceted dynamics surrounding infectious diseases, particularly with a focus on the recent COVID-19 pandemic and its impact on economies across the globe. Taking into account the investigations carried out in this particular domain, there are two notable aspects that set this study apart from

others. Firstly, it involves the creation of indices for two critical variables, namely vulnerability and economic resilience. Secondly, it employs a distinctive research methodology known as the Panel Smooth Transition Regression Approach. These two elements contribute to the unique character and innovative approach of this research when compared to its peers.

Te rest of this paper is organized as follows: “Literature review” section provides a brief overview of the related literature on the subject. “Data and methodology” section explains the data and methodology. “Results and discussion” section shows the results and discussions. “Conclusion” Section concludes the paper and presents the conclusion.

2. Literature Review

In this section, we first delve into the theoretical foundations concerning the development of two economic vulnerability and resilience indices. Following that, we explore how the COVID-19 pandemic is linked to these two indices.

2.1. Economic vulnerability index

Vulnerability, acknowledged across diverse fields like psychology, social sciences, and economics, signifies susceptibility to harm or disruption. In economics, it's viewed at micro and macro levels. Microeconomically, it relates to shocks impacting household income, potentially pushing it below poverty thresholds. Macroeconomically, it's a nation's susceptibility to external forces, encompassing environmental, trade, and political factors.

Understanding and addressing vulnerability is crucial for effective policy-making and risk management. To measure it, researchers and global organizations have developed various vulnerability indices:Briguglio et al.'s vulnerability index, United Nations' Committee on Development Policy (CDP) vulnerability index, Jonathan Atkins and colleagues' vulnerability index and The Brito vulnerability index.

Economic Vulnerability Index by Briguglio (2008): The Economic Vulnerability Index developed by Briguglio assesses the inherent characteristics, stability, and semi-stability of a country that render it highly susceptible to uncontrollable economic shocks (Briguglio, 1995; Briguglio & Galea, 2003). Some of these inherent characteristics include:

- **Economic Openness:** Economic openness is an inherent trait of an economy, with two primary aspects (Briguglio, 2008):
- The size of the domestic market, is influenced by export levels and their impact on domestic production.
- The ability to use resources for producing various goods and services to meet societal needs, contingent on import levels.

In countries with smaller domestic markets, exports are limited, whereas countries with scarce natural resources rely more heavily on imports. As a result, participating in international markets can lead to shocks in both exports and imports. Given the significance of foreign trade in the economy, economic openness is considered a component of economic vulnerability. In simpler terms, the higher the degree of economic openness, the greater the exposure to conditions over which the country has limited control.

- **Export Concentration:** Relying on a limited range of exports increases the risks associated with a lack of diversification and exacerbates the vulnerability linked to economic openness. These conditions are often a result of inherent characteristics within the economy's production base (Briguglio, 2008). The commonly used variable for addressing this is the UNCTAD Export Concentration Index. Briguglio suggests that export concentration can also be observed in the trade of services, particularly in financial services and tourism (Briguglio, 1997). It's worth noting that the Export Concentration Index includes the export of services as well (Briguglio & Galea, 2003).
- **Dependence on Strategic Imports:** Dependence on the import of strategic goods can potentially expose an economy to shocks related to access and import costs. These conditions are primarily inherent and depend on factors

like the country's size, available resources, and the potential for import substitution. In international trade, the principle is for each country to diversify its trading partners and avoid excessive reliance on any particular country. This strategy ensures that in the event of sanctions or disruptions, the domestic economy does not experience severe turbulence and can easily seek suitable alternatives (Briguglio, 2008).

Fig. 1 illustrates the average Economic Vulnerability Index for 2020 and 2021 calculated for the world. Countries are divided into three categories: countries with high economic vulnerability (Red), countries with medium economic vulnerability (Orange), and countries with low economic vulnerability (Blue). Austria, with an economic vulnerability index of 0.10197, has the lowest level of vulnerability, while Chad, with an index of 0.71104, has the highest level of vulnerability.

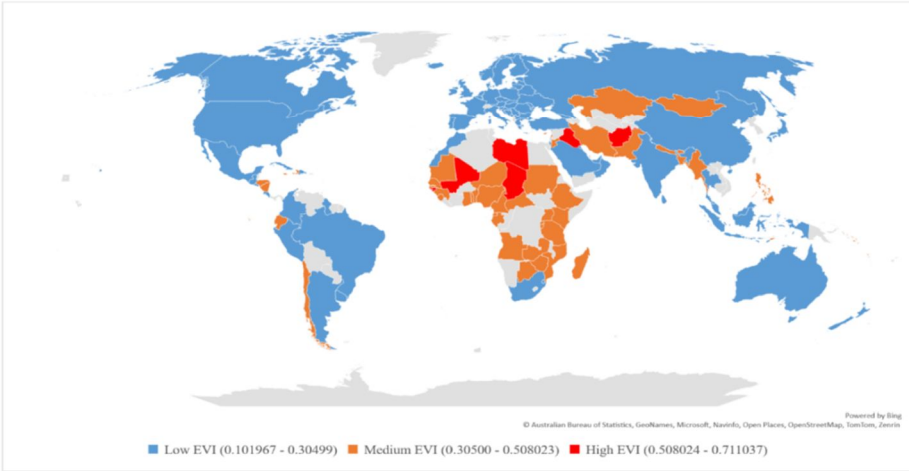

Fig 1. Calculated Economic Vulnerability Index

Source: Research results

2. 2. Economic resilience index

The term "resilience" derives from the Latin root "resile," meaning "to bounce back." Resilience, as a concept, refers to the speed at which a system

returns to its equilibrium state. This concept has found relevance in various fields of economics and social sciences. In the context of economics, the concept of economic resilience is widely discussed, particularly in literature related to economic stabilization.

Economic resilience can be defined as the ability of an economy to neutralize the impact of external economic shocks. In simpler terms, it refers to an economy's capacity to absorb external shocks while maintaining its economic flexibility, allowing it to recover and improve in the aftermath of such shocks (Briguglio et al., 2008). Baggio & Perrings (2015) define resilience as the "capacity of a system to maintain performance in the face of shocks," which can be measured by assessing how much disturbance a system can absorb without changing its fundamental characteristics.

Flexibility, especially concerning economic development and regional competition, focuses on the ability to resist, adapt, and respond to external disturbances and crises. An economically flexible system supports resilience by avoiding excessive fluctuations, reducing vulnerability, and fostering resilience against economic shocks.

Rose & Krausmann (2013) further distinguish resilience into two forms:

1. **Static economic resilience:** This refers to a system's ability to maintain stability during shocks.
2. **Dynamic resilience:** This relates to the speed of recovery, resilience against severe shocks, and the ability to return to a desirable state.

Notable indices related to resilience include:

1. Continental Resilience Index
2. Global Resilience Index by FM
3. Resilience Index by the United States Agency for International Development (USAID)

In their studies on the Economic Resilience Index, Briguglio and colleagues have generally considered components such as:

- **Macroeconomic stability:** This term refers to a state of the national economy in which economic vulnerabilities are minimized. It implies a

balance between aggregate demand and supply, leading to internal economic equilibrium (Briguglio et al., 2009). Macroeconomic stability is a necessary condition for economic growth, but it alone is not sufficient. Factors like exchange rate fluctuations, high debt levels, and uncontrolled inflation can lead to significant declines in gross domestic product and economic crises.

- **Market efficiency:** The efficient functioning of market mechanisms is crucial for supply and demand to reach equilibrium quickly within an economy. Efficient markets can reduce the negative impact of external shocks. However, slow market adjustments or persistent imbalances can result in resource misallocation, shortages, capital outflows, and unemployment. Countries with advanced market reforms tend to have higher economic resilience. Financial markets play a critical role in responding to shocks by making effective adjustments in interest rates and asset prices. Failure to regulate financial markets properly can increase the risk of capital outflows (Briguglio et al., 2008).
- **Good governance:** Good governance is considered essential for the proper functioning and resilience of an economic system. It encompasses aspects such as the rule of law and property rights. Without adequate governance mechanisms in place, negative shocks can easily lead to economic disruptions and turmoil, increasing vulnerability to external shocks (Briguglio et al., 2008). Conversely, good governance contributes to increased economic resilience. It is argued that external shocks can be better absorbed and mitigated within a framework of predictable laws and credible policies. The World Bank defines good governance based on six indicators, including voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption.
- **Social development:** Social development is a vital dimension of the development process, representing the journey of the social system towards social justice, cohesion, societal integration, and the improvement

of people's quality of life. Social development emphasizes two key indicators: health and education. A society with good health and education systems is better equipped to respond effectively to shocks. According to Briguglio et al. (2009), social development and cohesion are essential components of economic resilience because they indicate that relationships within a society have developed properly, enabling economic systems to function without social disruptions (Amani et al., 2022).

Fig. 2 illustrates the average Economic Resilience Index for 2020 and 2021 calculated for the world. Countries are divided into three categories: countries with high economic resilience (Blue), countries with medium economic resilience (Orange), and countries with low economic resilience (Red). Central African Republic, with an economic resilience index of 0.27185, has the lowest level of resilience, while the Netherlands, with an index of 0.89239, has the highest level of resilience.

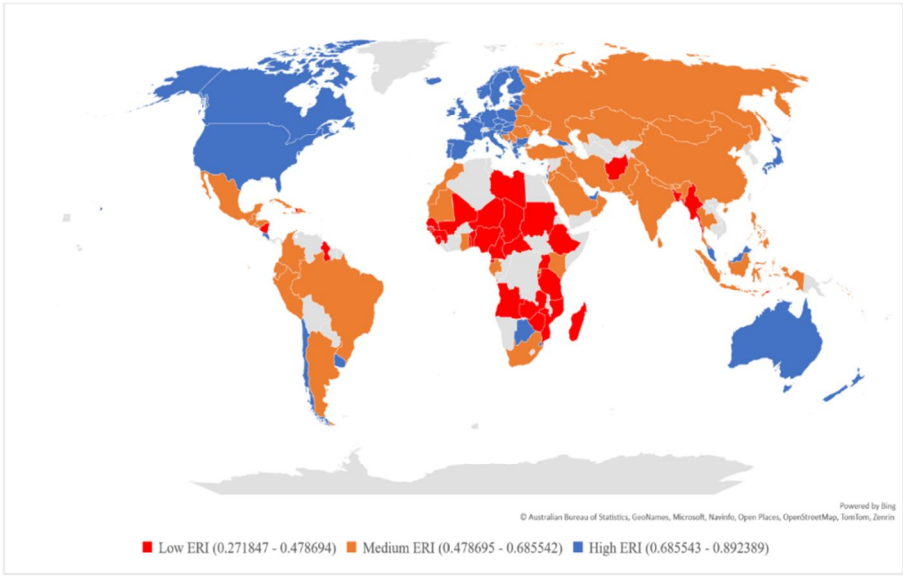

Fig 2. Calculated Economic Resilience Index

Source: Research results

2.3. The Covid-19 Pandemic and the Economy

The COVID-19 pandemic has profoundly impacted global industries and economies, imposing abrupt standstills and triggering reductions in income, heightened unemployment rates, and disruptions across transportation and various sectors (Novoa, 2021). Its impacts vary based on economic activity types, pandemic duration, domestic economic size, affected zones, population density, and time frames (Ruiz Estrada et al., 2022). This crisis has rendered economies susceptible, necessitating identification of vulnerabilities across sectors and international preventive measures (Diop et al., 2021). Pandemics like COVID-19 exert significant influence on macroeconomics by simultaneously affecting supply and demand. Factory closures and supply chain disruptions create supply shocks, while restrictions lead to decreased demand in sectors like transportation, restaurants, and tourism (Fonaro & Wolf, 2020). This results in income losses, reduced consumption, and diminished production and labor demand across industries (Chitiga-Mabugu et al., 2021). The pandemic significantly impacts both labor supply and consumption demand, affecting production, working hours, and investment (Ali et al., 2022). Micro, Small, and Medium Enterprises (MSMEs) have faced severe challenges due to financial hardships, supply chain disruptions, reduced sales, and declining profits, impacting economies worldwide (Wiliames & Shafer, 2013). These businesses, spread across various sectors, face cash flow disruptions, labor shortages, reduced production, and transportation constraints. Understanding the channels of these shocks is crucial; decreased consumption, financial market impacts, and disruptions in the supply side hamper supply chains, labor demand, and employment (Carlsson, 2020). These lead to prolonged layoffs and increased unemployment, amplifying the pandemic's economic repercussions.

2.3.1. Direct Impact of Covid-19 on the Economy

The COVID-19 pandemic has triggered disruptions in supply chains, impacting businesses and reducing efficiency across global supply chains

(Guan et al., 2020; Ivanov, 2020; Ivanov & Dolgi, 2021). These disruptions stem from challenges like supply market quarantines, labor shortages, distancing requirements in manufacturing, and transportation disruptions, significantly affecting international trade (Pol & Choderi, 2021; Salvatore, 2020). As a result, vulnerabilities in the supply chain can hinder productivity and economic growth.

International trade and capital flows have significantly declined due to the pandemic, with stringent trade barriers and heightened biosafety requirements impacting exports more than imports (Donto et al., 2021). Lockdown measures have led to a 25% reduction in global travel, affecting service trade, while investment plans, including foreign direct investment (FDI), have been disrupted, leading to increased capital costs (OECD, 2020; UNCTAD, 2020; Baldwin, 2020). The pandemic's supply and demand shocks have led to job losses, income inequality, and reduced production, particularly impacting workers without access to paid leave and social protection (Lee & Cho, 2016; Chen & Hong, 2020; IMF, 2020). Governments have directed financial support, income transfers, and wage subsidies to individuals to mitigate short-term unemployment (Velde, 2021). Notably, advanced economies have seen greater financial responses compared to emerging economies (Harjes et al., 2020). Financial systems worldwide have faced significant risks, with stock markets experiencing unprecedented declines and banks encountering heightened credit risk, leading to debt defaults and financial instability (Beck, 2020; Cecchetti & Schoenholtz, 2020; Cochrane, 2020). These vulnerabilities highlight the financial sector's susceptibility to economic shocks and global crises, impacting the broader global economy.

2.3.2. Indirect Impact of Covid-19 on the Economy

The COVID-19 pandemic has sparked price fluctuations in goods, affecting both essential and non-essential items' supply and demand dynamics (McKibbin & Fernando, 2021). The heightened demand for essentials can

lead to price hikes, while reduced demand for non-essentials might cause price reductions. However, disruptions in trade flows could offset these fluctuations, potentially resulting in significant price reductions globally.

Foreign currency values depreciated against the US dollar during the pandemic's onset, impacting international trade and potentially reducing overall trade volumes (Barua, 2020).

The pandemic's impact on human health and productivity weakens economic growth by limiting human capital accumulation and reducing productivity (Nokes et al., 1992; Holding & Snow, 2001). The illness affects individuals' ability to work, leading to lower income, reduced labor supply, and a decline in investment, culminating in suppressed economic growth. Predictions suggest a substantial reduction in countries' GDP, estimating a 3-5% decrease based on economic types, with service-oriented economies, particularly tourism-dependent countries like Portugal and Spain, facing severe consequences (Fernandes, 2020). Global annual GDP growth is expected to decrease by 2.4%.

Bloom et al. (2022) took a comprehensive approach, examining the connection between infectious diseases and the economy. Through data analysis, they emphasized health's role in driving economic growth, constructing a framework to evaluate the economic consequences of AIDS, malaria, tuberculosis, influenza, and COVID-19. Their study highlighted disparities in countries' economic vulnerability during pandemics, emphasizing the influence of institutional strength and economic resilience.

Brzyska & Szamrej (2021) focused on constructing the COVID-19 Economic Vulnerability Index (CVEI) for European Union nations. Their methods identified Southern European countries heavily reliant on tourism, like Spain, Croatia, Greece, and Italy, as particularly vulnerable, contrasting with less sensitive countries like Germany and Scandinavia.

Asongu et al. (2021) and Diop et al. (2021) conducted global studies evaluating COVID-19 interventions' effectiveness. They found European countries benefited more from movement restrictions and governmental/

economic interventions, whereas the impact varied across continents, emphasizing limited effectiveness of global quarantine measures.

Marti and Puertas (2021) evaluated vulnerability within the European Union using 15 indicators across health, social, and job domains. They revealed wealth levels' relationship with vulnerability in health and social domains, highlighting economic development's impact. They also noted economic progress might lead to precarious employment, rendering economies more fragile during crises like pandemics.

Davaradakis et al. (2020) developed the COVID-19 Economic Vulnerability Index (EBI) for non-European Union countries, emphasizing low-income countries' high vulnerability due to specific income sources and underscoring the significance of economic system resilience and healthcare quality in mitigating vulnerability.

These studies collectively contribute diverse perspectives on the economic impacts of infectious diseases, particularly COVID-19, underscoring the importance of economic resilience and vulnerability assessment in mitigating their effects.

3. Data and Methodology

3.1. Data

This study zeroes in on unraveling the repercussions of the COVID-19 pandemic on economic resilience. Rigorous research and data gathering have led to a curated sample of 150 countries spanning the period 2020-2021, chosen based on data availability. The research draws from esteemed sources like the World Bank, the International Monetary Fund, and the United Nations Development Organization. In cases where needed, central bank and national statistics websites have been tapped for data. The crux of the study revolves around the Vulnerability Index and Economic Resilience Index. The Vulnerability Index, shaped by the Briguglio method, delves into trade openness, export concentration, dependency on strategic imports, and exposure to natural disasters. Meanwhile, the Economic Resilience Index

taps into macroeconomic stability, market flexibility, good governance, and social development. Both indices undergo normalization for a comprehensive evaluation. The model also incorporates additional variables—COVID-19 deaths, per capita GDP, foreign direct investment, and remittances as a percentage of GDP—sourced from reputable outlets like the World Bank. These variables serve as explanatory elements within the model, contributing to a nuanced analysis.

Table 1. Economic Vulnerability Index (EVI) Variables

Variables	Measures	Source	Abbreviations
Trade openness	Average export and import (percentage of GDP)	Unctad.org	OPEN
Export concentration	Export concentration index (percentage of total imports and exports)	Unctad.org	EXI
Dependency on strategic imports	Fuel and food imports (percentage of total imports)	Unctad.org	DSI
Exposure to natural disasters	Natural disaster probability index	EMDAT	DST

Source: Research results

Table 2. Economic resilience Index (ERI) Variables

Variables	Measures	Source	Abbreviations
Macroeconomic stability	Gross government debt (percentage of GDP)	Worldbank.com	MAC
	Inflation (percentage of GDP)	Worldbank.com	
	Unemployment (percentage of GDP)	Worldbank.com	
Market flexibility	Freedom of business	Freetheworld.com	MFX
Good governance	Voice and Accountability	WGI.org	GOG
	Political Stability and Absence of Violence	WGI.org	

Variables	Measures	Source	Abbreviations
	Government Effectiveness	WGI.org	
	Regulatory Quality	WGI.org	
	Rule of Law	WGI.org	
	Control of Corruption	WGI.org	
Social development	Average years of education	Hdr.undp.org	SOC
	Expected years of education	Hdr.undp.org	
	Life expectancy at birth	Hdr.undp.org	

Source: Research results

Table 3. Variables Definition

Variables	Measures	Source	Abbreviations
Covid-19	Death rate	ourworldindata.org	Covid-19
Foreign direct investment	Foreign direct investment, net inflows (% of GDP)	Worldbank.com	FDI
Personal remittances, received	Personal remittances, received (% of GDP)	Worldbank.com	REM
GDP.P.P	GDP per capita (constant 2015 US$)	Worldbank.com	GDP.P.P

Source: Research results

3.2. Methodology

In delving into panel data using the simple panel regression model, researchers frequently grapple with the challenge of heterogeneity in time and cross-sectional effects. To tackle this issue, various approaches have emerged in amalgamated data, allowing regression coefficients to fluctuate across time and diverse cross-sectional periods. A seminal solution to this challenge is the Panel Threshold Regression (PTR) model, first introduced by Hansen in 1999. This model categorizes panel observations into homogeneous regimes based on threshold variable values—whether they fall below or above a specified threshold level. It's essential to highlight that observations very close to the threshold value are assigned to different regimes, resulting in a marked shift in the direction of their effects, as noted by Chio et al. in 2011. Recognizing the constraints of the Hansen model, Fok

et al. in 2004 introduced the Panel Smooth Transition Regression (PSTR) model, subsequently refined by Gonzalez et al. in 2005 and Golletaz & Hurllin in 2007. The PSTR model expands upon the PTR model by integrating a known transition function. This model articulates the relationship as a function of two extreme regimes and a transition function, expressed as follows:

$$Y_{it} = \mu_i + \beta_0^{'} X_{it} \sum_{j=1}^{r} \left[\beta_j^{'} X_{it}\right] g_j\left(q_{it}^{j}; \gamma_j; c_j\right) + u_{it} \quad (1)$$

Where i = 1,. . . N and t = 1, ..., T denote the cross-section and time dimensions of the panel, respectively. In this model, yit represents the dependent variable. μi indicate the fixed individual effects and εit are the error terms. xit is a vector of k explanatory variables.

The PSTR model is based on a transition function $G(q_{it}; \gamma.c)$ which depends on a transition variable denoted qit. Gonzalez et al. (2005) consider the following logistic transition function:

$$G(q_{it}; \gamma.c) = \left[1 = exp\left(-\gamma \prod_{j=1}^{m}\left(q_{it} - c_j\right)\right)\right]^{-1} \quad \text{with} \quad \gamma > 0 \quad \text{and} \quad c_1 \leq c_2 \leq \cdots \leq c_m \quad (2)$$

Where cj and γ represent the parameters of the threshold and the smooth transition parameter, respectively. zit represent a vector of explanatory variables that will have constant coefficients over time and individuals and will not enter the nonlinear part of the model. The coefficient of a variable is $\beta_0$if the transition function is equal to 0 and it is $\beta_1$if the transition function is equal to 1. Between the two extreme regimes, the coefficient is equal to $\beta_0 + \beta_1 g(FO_{it}, \gamma, c)$.

This study seeks to explore the threshold impact of the COVID-19 pandemic on the vulnerability and economic resilience of countries, employing the Panel Smooth Transition Regression (PSTR) econometric technique. The chosen modeling approach is both static and nonlinear, facilitating a nuanced and unrestricted relationship among the variables. To capture the intricacies of this relationship, the introduced variables are

delineated in two models for the countries under examination within the framework of the PSTR model, as outlined below:

$$LOGEVI_{it} = \beta_0 LOG\ COVID-19_{it} + \beta_1 LOGGDPP_{it} + \beta_2 LOGREM_{it} + \beta_3 LOGFDI_{it} + G(q_{it} \cdot \gamma \cdot C)[\alpha_0 LOGCOVID-19_{it} + \alpha_1 LOGGDPP_{it} + \alpha_2 LOGREM_{it} + \alpha_3 LOGFDI_{it}] \quad (3)$$

$$LOGERI_{it} = \beta_0 LOG\ COVID-19_{it} + \beta_1 LOGGDPP_{it} + \beta_2 LOGREM_{it} + \beta_3 LOGFDI_{it} + G(q_{it} \cdot \gamma \cdot C)[\alpha_0 LOGCOVID-19_{it} + \alpha_1 LOGGDPP_{it} + \alpha_2 LOGREM_{it} + \alpha_3 LOGFDI_{it}] + u_{it} \quad (4)$$

The variables used in both models are Vulnerability (EVI) and Economic Resilience (ERI) as the dependent variables. The transitional variable is COVID-19 (Death rate), and the research hypotheses state that the COVID-19 pandemic has a significant impact on the vulnerability and economic resilience of countries. The control variables include Gross Domestic Product per capita (GDP), Remittances (REM), and Foreign Direct Investment (FDI).

4. Results and Discussion

In the context of classifying countries based on their economic characteristics, this research employs the vulnerability and economic resilience indices. These indices are derived through the application of the Max-Min method, a computational approach used to assess and quantify the relative performance of nations in terms of vulnerability and economic resilience. The findings are then meticulously recalibrated and displayed in Table 4 for comprehensive analysis.

Over the span of the two years scrutinized in this study, Singapore consistently emerges as a trailblazer in economic openness, demonstrating a sustained commitment to fostering international economic engagement. Moreover, the nation secures the noteworthy second position in market efficiency, indicating a robust and well-functioning marketplace. Notably,

Singapore distinguishes itself by earning commendable scores in economic resilience, showcasing its capacity to withstand economic shocks and uncertainties. This resilience is particularly noteworthy given the challenging global economic landscape. Contrarily, the vulnerability index reveals relatively lower scores for Singapore, implying a reduced susceptibility to economic downturns or external pressures. The juxtaposition of these findings validates the existence of the anticipated "Singapore paradox." This paradox suggests that Singapore, despite its high economic openness and efficiency, manages to maintain a resilient economic profile with lower vulnerability—a seemingly contradictory yet distinctive feature that sets it apart in the realm of global economics. The study's affirmation of this paradox underscores the complex and multifaceted nature of Singapore's economic dynamics, providing valuable insights into the interplay between openness, efficiency, resilience, and vulnerability in the context of a rapidly evolving global economic landscape.

In this current investigation, the outcomes of the tests are meticulously outlined and detailed in Table (5). The examination of the test results, encompassing Lagrange multiplier statistics, Fisher Lagrange multiplier, and likelihood ratio, consistently reveals a consistent trend for threshold points m=1 and m=2. These statistical measures collectively point to a discernible nonlinear pattern characterizing the relationship between the variables under scrutiny.

In light of the comprehensive statistical analysis, the null hypothesis is unequivocally discarded, as indicated by the probabilities associated with each statistical measure at a 5% significance level. Simultaneously, the alternative hypothesis of r=1 is embraced, further confirming that a nonlinear relationship is indeed prevalent among the variables in question. This pivotal outcome emphasizes that the conventional linear relationship assumption is not tenable in this context.

Table 4. Countries Classification in Economic Vulnerability and Resilienc

Vulneriblitiy index	Angola, Bangladesh, Belzia, Benin, Bhutan, Cabo Verde, Cameroon, Comoroso, Congo .Rep, Cote d'lvoire, Ecuador, Equatorial Guinea, Gabon, Ghana, Haiti, Honduras, Iran, Islamic Rep, Iraq, Kenya, Lebanon, Maldives, Marshall Islands, Mauritania, Myanmar, Nepal, Nicaragua, Nigeria, Philippines, Senegal, Solomon Island, Tanzania, Timor-Leste, Tonga, Vanuatu, Zimbia, Afghanistan, Burundi, Central African , Chad, Ethiopia, Gambia, Guinea, Guinea-Bissau, Madagascar, Mali, Mozabique, Niger, Rwanda, Sierraleon, Sudan, Tago, Uganda, Yemen, Rep, Zimbabwe	Chili, Monaco, Malta, Armania, Botswana, Dominica, Georgia, Jamica, Jordan, Kazakstan, Mongolia
	Brazil, Combodia, Cuba, Dominican Republic, Egypt, Arab Rep, El Salvador, Guatemala, Guyana, India, Indonesia, Kosovo, Libya, Morocco, Nambia, Pakistan, Sri lanka, Ukraine, Vitnam, West Bank&Gaze	Australia, Austria, Bahamas, Belgium, Bermuda, Canada, Cortia, Cyprus, Czech, Denmark, Estonia, Finland, Farance, Germany, Greece, Hong Kong, Hungary, Iceland, Irland, Israel, Itly, Japan, Kuwait, Latvia, Lithuania, Luxembourg, Netherlands, New zeland, Norway, Oman, Poland, Portugal, Saudia arabia, Singapoor, Slovak .Rep, Slovenia, Spain, Sweden, Switerland2019, United Arab Emirates, United Kingdom, United States, Uruguay, Argentin, Belaruse, Bosnia, Bulgaria, China, Colombia, Costarica, Eswatini, Korea. Rep, Malzysia, Mauritius, Mexico, Moldova, Montenegro, North Macedonia, Peru, Romania, Russian Federation, Serbia, South Africa, Thailand, Turkiye, Uzbakistan
	Resilience index →	

Therefore, based on the robust evidence provided by the Lagrange multiplier statistics, Fisher Lagrange multiplier, and likelihood ratio, it can be confidently asserted that the variables exhibit a nonlinear relationship. This discernment enhances our understanding of the intricate dynamics governing the interplay between these variables, paving the way for nuanced and sophisticated interpretations within the framework of the study.

Table 5. Linearity Test

$H_0: r = 0$ vs $H_1: r = 1$	M=1			M=2		
	LM_F	LM_w	LRT	LM_F	LM_w	LRT
vulnerability	39.906^{***}	5.600^{***}	42.822^{***}	63.428^{***}	4.759^{**}	71.258^{***}
Resilience	15.839^{***}	17.081^{***}	16.626^{***}	74.246^{***}	5.838^{***}	85.301^{***}

Note: Significance levels are denoted as ***, **, and *, representing statistical significance at 1%, 5%, and 10%, respectively. The variable "M" signifies the count of threshold points, while "r" denotes the number of transition functions, signifying limit regimes in the context of the study.

As per the findings presented in Table (6), the model under consideration reveals that a single transfer function suffices for both the vulnerability and resilience models. This implies the absence of any discernible nonlinear residual relationship in the models. The statistical analyses, including Lagrange multiplier, Fisher, and likelihood ratio statistics, collectively support the conclusion that incorporating two LSTR1 transfer functions adequately captures and elucidates the nonlinear relationship between the variables in both the vulnerability and resilience models. The robust results derived from these statistical measures affirm that the inclusion of two LSTR1 transfer functions is not only satisfactory but also optimal for characterizing the intricate and nonlinear dynamics inherent in the relationships between the variables. This significant insight contributes to a more refined and nuanced understanding of the complexities governing the vulnerability and resilience models under investigation. Consequently, the study attests that the chosen model structure effectively encapsulates the nonlinear features within the variables, laying the

groundwork for insightful interpretations and implications in the realm of vulnerability and resilience analysis.

Table 6. Residuals Non-Linear Test

$H_0: r = 1$ vs $H_1: r = 2$	M=1			M=2		
	LM_F	LM_w	LRT	LM_F	LM_w	LRT
vulnerability	22.894^{***}	2.850^{**}	23.814^{***}	0.553^{*}	0.060^{*}	0.55^{*}
Resilience	32.830^{***}	2.564^{*}	42.734^{***}	3.833^{***}	0.323^{*}	3.877^{*}

Note: Significance levels are denoted as ***, **, and *, representing statistical significance at 1%, 5%, and 10%, respectively.

By employing the criteria of squared residuals, Schwarz, and Akaike, the most suitable number of threshold values can be discerned. In this analysis, a smooth panel threshold regression (PSTR) model with one regime is taken into account. The outcomes extracted from the data presented in Table (7) offer compelling evidence that, according to the specified criteria, the optimal model for both the vulnerability and resilience models is the PSTR model incorporating a singular threshold value, denoted as m=1.

The evaluation based on squared residuals, Schwarz criterion, and Akaike criterion consistently points towards the efficacy and appropriateness of the PSTR model with one threshold value. This implies that, in the context of the study, a singular threshold adequately captures the underlying dynamics of the relationships within the vulnerability and resilience models. These findings are pivotal in refining the model selection process, providing valuable insights into the nuanced structure of the data and enhancing the accuracy of predictions within the framework of the specified panel threshold regression analysis.

Table 7. Number of Regimes

	M=1			M=2		
	Residual Sum of Squares	AIC Criterion	Schwarz Criterion	Residual Sum of Squares	AIC Criterion	Schwarz Criterion
vulnerability	0.445	-6.876	-6.240	0.455	-6.373	-6.240
Resilience	0.233	-6.905	-6.770	0.236	-6.90	-6.680

According to the information provided in Table (8), the vulnerability model unveils significant insights into the intricate dynamics of various variables in the context of the COVID-19 pandemic. The slope parameter, indicative of the speed of transition between different regimes, is determined to be 1191/414, with a regime change location at 435/6 and an anti-logarithm value of 2213094. This information is crucial for understanding the behavior of the studied variables under different conditions.

Given that the coefficients of the variables fluctuate with the magnitude of the transmission variable and the slope parameter, and these coefficients differ across countries and over time, the numerical values presented in Table (8) lack direct interpretability. It is advisable to solely analyze and scrutinize their signs. Hence, to offer a clearer comprehension of the obtained results, we examine two extreme scenarios for countries categorized by high, medium, and low incomes, with a focus on the COVID-19 pandemic's impact on economic resilience. The first extreme scenario entails an approach where the slope parameter tends towards infinity, and the value of the transmission variable (COVID-19) remains below a certain threshold. Under such circumstances, the transmission function yields a numerical value of zero. The models are explicitly delineated as follows:

First Extreme Regime of Vulnerability:

$$LOGEvI_{it} = +0.052LOGCOVID19_{it}+0.023LOGGDPP_{it}+0.249LOGREM_{it}+0.007LOGFDI_{it}$$

First Extreme Regime of Resilience:

$$LOGERI_{it} = -0.023LOGCOVID19_{it}-0.013LOGGDPP_{it}-0.062LOGREM_{it}-0.019LOGFDI_{it}$$

The second extreme regime also corresponds to an approach where the slope parameter tends towards infinity, but the value of the transmission variable (COVID-19) exceeds a certain threshold. In this instance, the transmission function attains a numerical value of one, and the models are explicitly delineated as follows:

Second Extreme Regime of Vulnerability:

$$LOGEvI_{it} = +0.212LOGCOVID19_{it} - 0.019LOGGDPP_{it} - 0.188LOGREM_{it} - 0.0062LOGFDI_{it}$$

Second Extreme Regime of Resilience:

$$LOGERI_{it} = -0.122LOGCOVID19_{it} + 0.147LOGGDPP_{it} + 0.0142LOGREM_{it} + 0.008LOGFDI_{it}$$

In the vulnerability model, it is observed that the COVID-19 pandemic variable exhibits a substantial and statistically significant impact on countries. Specifically, as long as the mortality from the pandemic remains below the anti-logarithm values, the variables adhere to the dynamics of the first regime. Conversely, if the mortality surpasses these values, the variables shift to the second regime. The results affirm a positive and significant influence of the COVID-19 pandemic on the economic vulnerability of countries, implying that an escalation in pandemic-related casualties corresponds to an increase in economic vulnerability.

Corroborating these findings, previous studies by Brzyska & Szamrej (2021), Marti (2021), and Puertas have indicated a similar positive and significant effect of the COVID-19 pandemic on the vulnerability of European Union countries, predominantly comprising high-income nations. Additionally, research by Asongu et al. (2021) and Diop et al. (2020) on various countries, mainly in the developing and less developed category, aligns with the notion that the pandemic has heightened economic vulnerability in these regions. The per capita gross domestic product (GDP) variable, within a linear regime, exhibits a positive impact on economic vulnerability, implying that a decline in per capita GDP below the threshold corresponds to an increase in vulnerability. However, in a non-linear regime, surpassing the threshold of 2,213,094 deaths reverses this effect, leading to a negative and diminishing impact on economic vulnerability. This finding resonates with the observations made by Zagurska et al. (2020), who demonstrated a reduction in per capita GDP in the European Union due to the COVID-19 outbreak.

In the linear regime, the remittances variable shows a positive and direct impact on economic vulnerability. This is attributed to government measures, such as quarantine policies and travel restrictions, reducing the economic activities of migrant workers and consequently increasing the vulnerability of the respective countries. Nevertheless, once a threshold is exceeded, an increase in remittances exhibits a reverse effect, mitigating economic vulnerability. Notably, Kpodar et al. (2022) have provided evidence supporting the significant impact of the COVID-19 pandemic on remittances in developing countries, with increased quarantine measures and travel restrictions contributing to reduced remittance amounts. Foreign direct investment (FDI) in a linear regime demonstrates a direct positive effect on economic vulnerability. The pandemic-induced decrease in FDI prior to reaching a threshold contributes to increased economic vulnerability. However, in a non-linear regime, post-threshold surpassing, FDI exhibits a negative effect on economic vulnerability, implying that a reduction in the pandemic has led to increased FDI and reduced economic vulnerability.

Transitioning to the economic resilience model, the slope parameter is identified as 6002/866, with a regime change location at 546/6 and an anti-logarithm value of 3,515,604 deaths. Notably, the COVID-19 pandemic variable exerts a negative impact on economic resilience in both linear and nonlinear regimes, indicating that an increase in the pandemic correlates with a decrease in the level of economic resilience in countries. This aligns with research conducted by Diop et al. (2021), which similarly identified a negative and significant effect of the COVID-19 pandemic on the resilience of countries.

The per capita GDP variable demonstrates a negative effect on economic resilience in the first linear regime, signifying that a decrease in per capita GDP leads to a reduction in economic resilience within this regime. However, in the second linear regime, post-threshold surpassing, per capita GDP exerts a positive effect on economic resilience. Consequently, a decrease in the COVID-19 pandemic corresponds to an increase in per capita

GDP, contributing to an upsurge in economic resilience. In the linear regime, the remittances variable exerts a negative effect on economic resilience. This is attributed to the implementation of government measures to combat the pandemic, which negatively impact the economic activities of migrant workers, thereby increasing economic vulnerability. Yet, post-threshold surpassing, the effect of remittances becomes positive and directly contributes to an increase in economic resilience.

In the first linear regime, the FDI variable exhibits a negative and decreasing effect on economic resilience. However, post-threshold surpassing and in the nonlinear regime, FDI demonstrates a positive and significant impact on increasing economic resilience. This implies that a reduction in disease outbreaks leads to an increase in economic activities, foreign direct investment, and ultimately, economic resilience in countries. This comprehensive analysis sheds light on the intricate relationships between various variables, providing valuable insights into the multifaceted impacts of the COVID-19 pandemic on economic vulnerability and resilience across different regimes and conditions.

Table 8. Estimated results of the PSTR models

Variables	**Model of the effect of covid-19 on vulnerability (transmission variable: death rate of covid-19)**		**Model of the effect of covid-19 on Resilience (transmission variable: death rate of covid-19)**	
	Linear section	**Non-linear section**	**Linear section**	**Non-linear section**
Covid-19	0.0525^{***}	0.1604^{***}	-0.0232^{***}	-0.0997^{***}
GDP.P	0.0236^{***}	-0.0426^{***}	-0.0133^{***}	0.1604^{***}
REM	0.2492^{***}	-0.4372^{***}	-0.0627^{**}	0.07692^{***}
FDI	0.0071^{***}	-0.0133^{***}	-0.0196^{***}	0.0285^{***}
	Transition parameters		Transition parameters	
C	6.3450 = 2213094		6.546 = 3515604	
γ	414.1191		866.6002	

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively

5. Conclusion and policy recommendations

Amidst the global landscape, the COVID-19 pandemic has emerged as a formidable crisis, exacting profound economic costs on nations worldwide. This has spurred a keen ڑیمexamination by researchers and policymakers who seek to evaluate the ramifications of this external shock in terms of both vulnerability and economic resilience. The deployment of warning indicators has become pivotal in this assessment, with a particular focus on the construction of composite indices designed to capture the nuanced aspects of vulnerability and resilience. At the core of this study lies the overarching goal of delving into the intricate repercussions of the COVID-19 pandemic on the economic fabric of nations. Spanning across 150 countries, this investigation employs the Panel Smooth Transition Regression (PSTR) model to navigate through the economic complexities brought about by the pandemic, covering the critical timeframe of 2020-2021. The outcomes of the linearity test emerge as a crucial validation, affirming the existence of a nonlinear relationship among the variables under scrutiny. The exploration goes further, incorporating a transition function characterized by a threshold parameter, emblematic of a two-regime model. Remarkably, this proves to be a sufficient and illuminating approach to unravel the nonlinear intricacies between the variables, manifesting in two distinct patterns.

Within the framework of the economic vulnerability pattern, the calculated slope parameter stands at 6.4350. The estimations gleaned from this parameter reveal a compelling narrative – the COVID-19 pandemic exercises a positive and substantial influence on vulnerability, transcending both linear and nonlinear regimes. This insight underscores the far-reaching and multifaceted impact of the pandemic on the economic vulnerability landscape. Transitioning to the economic resilience model, the slope parameter takes form at 6.546. In this domain, the COVID-19 pandemic unfolds as a potent force, exhibiting a negative and noteworthy effect on economic resilience in both the initial and subsequent regimes. Thus, this study articulates a discernible correlation: as the intensity of the COVID-19

pandemic escalates, vulnerability increases and economic resilience experiences a simultaneous decline across diverse nations. Crucially, the application of the PSTR model emerges as an invaluable tool, facilitating a nuanced and comprehensive understanding of the intricate dynamics in play. Through this analytical lens, the study not only unravels the multifaceted impacts of the COVID-19 pandemic on economic vulnerability and resilience but also sheds light on the temporal dimensions and distinct regimes that shape the global economic response to this unprecedented crisis. This investigation contributes significantly to the ongoing discourse, providing insights that can inform strategic decisions and policies aimed at navigating the economic aftermath of the pandemic on a global scale.

Based on the insights gleaned from the study on the economic impacts of the COVID-19 pandemic, several policy recommendations can be considered to enhance economic resilience and mitigate vulnerability on a global scale:

1. Economic Diversification Strategy: Advocate for the diversification of national economies to reduce reliance on specific sectors. By spreading economic activities across various industries, nations can mitigate the impact of external shocks, such as pandemics, and bolster resilience in times of crisis.
2. Healthcare Infrastructure Investment: Prioritize investments in healthcare infrastructure and systems to bolster a country's capacity to respond to health emergencies effectively. A well-developed healthcare system not only saves lives but also plays a crucial role in stabilizing the economy during a pandemic.
3. Enhanced International Collaboration: Foster international cooperation in monitoring and managing global health crises. Establish robust mechanisms for sharing vital information, resources, and best practices to ensure a coordinated and efficient response across borders.
4. Early Warning System Development: Invest in the creation of early warning systems capable of providing timely and accurate information

on emerging health threats. This enables swift implementation of preventive measures, thereby minimizing the economic impact of pandemics.

5. Strengthened Social Safety Nets: Bolster social safety nets to provide support to individuals and businesses during economic disruptions. Well-designed safety net programs can mitigate the socio-economic repercussions of crises, offering assistance to vulnerable populations.
6. Flexible Economic Policy Implementation: Implement flexible economic policies that can adapt to evolving circumstances. The ability to adjust fiscal and monetary policies in response to changing economic conditions is crucial for maintaining stability during and after a crisis.
7. Global Financial Support Mechanisms: Establish global financial support mechanisms to aid countries facing severe economic challenges during pandemics. These mechanisms could include debt relief initiatives, concessional financing, or coordinated international assistance aimed at stabilizing national economies.
8. Embrace Technology and Digital Transformation: Encourage the adoption of technology and digital transformation across various sectors. This not only facilitates economic activities during lockdowns but also enhances overall resilience by enabling remote work, online education, and e-commerce.
9. Capacity Building and Training Programs: Invest in capacity building and training programs for policymakers, healthcare professionals, and other stakeholders. Equipping countries with the necessary knowledge and skills ensures effective navigation of complex crises.
10. Research and Development Funding: Allocate resources for research and development in areas relevant to pandemic preparedness, such as vaccine development, antiviral drugs, and innovative healthcare solutions. This investment contributes to more effective responses to future health crises.

These policy recommendations aim to address the vulnerabilities highlighted in the study and build a foundation for greater economic resilience in the face of global challenges, particularly pandemics. Implementation of these measures requires collaborative efforts at national and international levels to create a more secure and sustainable global economic landscape.

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Conflicts of interest

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