Iranian Journal of Economic Studies, 13(1) 2024, 51-86

Shiraz University

Iranian Journal of Economic Studies

Journal homepage: ijes.shirazu.ac.ir

Pandemic and Progress: How COVID-19 Redefined the Economic Catch-Up Dynamics

Hassan Daliri*

Faculty of Humanities and Social Sciences, Golestan University, Gorgan, Iran.

Article History

Received date: 28 February 2025
Revised date: 03 April 2025
Accepted date: 03 April 2025
Available online: 15 May 2025

JEL Classification
O1
O4
D73

Keyword
Economic catch-up, convergence, COVID-19, external shocks, Governance, income groups.

Abstract

This study investigates how the COVID-19 pandemic affected economic catch-up dynamics across 194 countries, categorized by income groups, using a catch-up index relative to the United States (USA) and G7 economies. To assess shifts in economic convergence, the study compares each country's average catch-up index before and after the pandemic. Pre-pandemic periods (2001–2019, 2010–2019, 2014–2019) are contrasted with the post-pandemic phase (2020–2023), revealing varied trajectories shaped by income level, resilience, and benchmark selection. A clustering approach identifies six country groups with distinct recovery paths. Low-income countries experienced growing divergence from the USA, though less so from the G7. Lower-middle-income countries showed mixed results: nations like Vietnam and Bangladesh made significant gains, while structurally fragile economies such as Angola and Haiti lagged. Upper-middle-income countries remained relatively stable, while high-income countries diverged from the USA but converged with the G7. These outcomes highlight the uneven impact of global shocks on economic progress. Correlation analysis shows that governance factors like Control of Corruption and Regulatory Quality are key for convergence in low- and upper-middle-income economies. In contrast, COVID-19 mortality rates negatively influenced lower-middle-income countries. Despite strong institutions, high-income countries faced setbacks, with innovation emerging as crucial for maintaining convergence with advanced economies. The study culminates in policy recommendations that emphasize the enhancement of institutional quality, investment in digital infrastructure, and the promotion of global cooperation as key strategies to mitigate the asymmetric effects of future shocks.

Highlights

- Assesses economic catch-up dynamics across 194 countries relative to the USA and G7.
- Low-income countries diverged from the USA but remained closer to the G7, while high-income nations converged with the G7 but diverged from the USA.
- Identifies six distinct recovery patterns influenced by income levels and structural resilience.
- Strong institutions aid economic catch-up; corruption control and regulatory quality are crucial for lower-income nations

* H.daliri@gu.ac.ir
DOI: 10.22099/ijes.2025.52587.2013
© 2024, Shiraz University, All right reserved

1. Introduction

Economic Catch-Up refers to the process where less developed economies grow faster than more developed ones, thereby reducing the relative income or productivity gap over time. It emphasizes the relative improvement of one country's economic performance compared to a more advanced benchmark economy. Catch-up often involves specific growth-enhancing factors such as technology transfer, capital inflows, and policy reforms. Of course, a distinction must be made between this concept and the concept of convergence. Economic Convergence, is a broader concept, typically analyzed within the frameworks of absolute or conditional convergence theories. Absolute convergence suggests that all economies will eventually achieve the same level of per capita income if they share similar initial conditions. Conditional convergence, a refinement of this idea, posits that convergence depends on country-specific factors such as savings rates, population growth, human capital, and institutional quality (Barro & Sala-i-Martin, 1992). In general, the differences between these two concepts can be summarized as follows: Economic catch-up focuses on relative performance against a specific benchmark While, Economic convergence evaluates the general trend of income or productivity equality across a group of countries. Catch-up highlights factors like technology diffusion, foreign direct investment, and export-driven growth (Gerschenkron, 1962) but Convergence relies on diminishing returns to capital and the harmonization of structural and institutional factors (Solow, 1956).Catch-up explicitly compares a lagging economy to a leading one but Convergence may not involve a specific benchmark but rather examines trends within a peer group.

The COVID-19 pandemic, which began in late 2019, has emerged as one of the most significant global health crises in history, comparable to past pandemics such as the Spanish flu of 1918, the Black Death in the 14th century, and the HIV/AIDS epidemic. According to the World Health Organization (WHO), as of 2025, COVID-19 has infected over 770 million people and resulted in nearly 7 million deaths worldwide. The pandemic caused unprecedented disruptions to global economies, education, and healthcare systems, much like the Spanish flu, which infected one-third of the world’s population and caused an estimated 50 million deaths. However, unlike previous pandemics, the COVID-19 crisis unfolded in a time of advanced medical technology, including the rapid development of vaccines, yet it still overwhelmed health systems globally, highlighting the vulnerability of even the most advanced nations. Moreover, the COVID-19 pandemic's socioeconomic impact was profound, with the global economy shrinking by 3.5% in 2020, a contraction not seen since the Great Depression, further demonstrating its far-reaching consequences in comparison to earlier pandemics. While the Black Death killed an estimated 30-60% of Europe’s population, leading to long-term economic and social changes, COVID-19's impact on modern societies was characterized by rapid digital transformation, widespread lockdowns, and an increased focus on public health. External shocks, such as pandemics, financial crises, or geopolitical conflicts, can disrupt long-

term economic growth by altering key macroeconomic variables and structural dynamics. The mechanisms through which these shocks derail economies are multifaceted and depend on factors such as the nature of the shock, institutional resilience, and the pre-existing economic structure. For example, Shocks like the COVID-19 pandemic reduce aggregate demand due to income losses, unemployment, and reduced consumer and business confidence (Baldwin & Weder di Mauro, 2020). Declining demand can lead to persistent underutilization of resources, delaying recovery and long-term growth. In addition, shocks such as COVID-19 can cause disruptions in the supply chains and Supply-Side. Disruptions in global supply chains and production capabilities can lead to reduced output and productivity. Shocks can also impair human capital through health crises or prolonged unemployment, further limiting growth potential. Financial crises or political instability increase uncertainty, reducing both domestic and foreign investment. This hinders capital accumulation, a key driver of long-term growth (Ramey & Ramey, 1995). Weak institutions exacerbate the effects of shocks by limiting the capacity for effective policy responses, such as fiscal stimulus or monetary intervention (Rodrik, 1999).Also, Structural issues, such as corruption or inefficient governance, amplify the negative impacts. Countries heavily reliant on exports or foreign investment are particularly vulnerable to global economic shocks, as reduced trade flows or capital flight disrupt growth trajectories (Frankel & Romer, 1999). Past studies have shown that, Countries with limited fiscal or monetary capacity struggle to implement counter-cyclical policies, prolonging the recovery process. Effective governance, rule of law, and political stability mitigate the adverse effects of shocks. Economies dependent on a narrow set of industries (e.g., oil-exporting nations) are more vulnerable to external shocks. Highly integrated economies are more exposed to global crises but can also benefit from coordinated international recovery efforts.

Given the importance of identifying these dynamics, the present study attempts to answer the question of whether the path of economic catch-up in the world has changed after the COVID-19 pandemic. For this purpose, 194 countries in the world are examined in the period 2000-2023 and the change in their catch-up path is evaluated by estimating the economic catch-up index. This study employs a multi-phase analytical framework to assess shifts in global economic catch-up dynamics post-COVID-19. First, we construct an economic catch-up index relative to the USA and G7 benchmarks, analyzing pre-pandemic (2001–2019) and post-pandemic (2020–2023) periods across 194 countries. Using clustering techniques and ANOVA, we identify heterogeneous recovery patterns stratified by income groups. Governance and innovation metrics are then correlated with catch-up performance to isolate drivers of divergence or convergence. The analysis is structured as follows: Section 2 reviews theoretical foundations of convergence and pandemic impacts; Section 3 details methodology, including index construction and statistical tests; Section 4 presents empirical results across income groups and clusters; and Section 5 discusses

policy implications. By integrating quantitative and qualitative insights, this approach provides a comprehensive evaluation of how COVID-19 reshaped global economic hierarchies and informs strategies for equitable recovery.

2. Economic Catch-Up and COVID-19: Literature Review

The economic catch-up of countries, particularly in the context of exogenous shocks like the COVID-19 pandemic, can be analyzed through the lens of established growth and development theories. The Solow-Swan growth model (Solow, 1956) forms the cornerstone of convergence analysis, positing that countries with lower initial GDP per capita tend to grow faster than wealthier nations due to diminishing returns to capital. This process, known as absolute convergence, assumes homogeneity in savings rates, population growth, and technological progress. However, the findings of this study suggest that structural barriers—particularly in low-income countries—prevent absolute convergence, aligning more closely with the conditional convergence framework, where growth depends on country-specific factors such as governance, human capital, and institutional quality (Barro & Sala-i-Martin, 1992). Endogenous growth theories (Romer, 1990; Lucas, 1988) emphasize the importance of innovation, human capital accumulation, and technology transfer in sustaining long-term economic growth. Moreover, recent research by Lee (2019) shows that the persistence of structural barriers, especially in low-income countries, limits the speed of economic catch-up despite technological spillovers. Endogenous growth theories remain highly relevant in explaining the post-pandemic growth patterns, particularly emphasizing the importance of human capital, innovation, and technological diffusion. Aghion et al. (2021) underscore the role of innovation-led growth in narrowing income disparities, arguing that economies investing in research and development (R&D) and fostering technological adoption can achieve sustained economic growth. Similarly, Lee & Malin (2022) extend the Schumpeterian framework to demonstrate how digital transformation and the diffusion of artificial intelligence (AI) can accelerate convergence for countries that effectively integrate these technologies. The role of institutions has been reaffirmed in post-pandemic recovery studies. Acemoglu & Robinson (2012) argue that inclusive institutions—defined by secure property rights, rule of law, and equitable access to resources—are pivotal for long-term economic performance. The role of temporary external shocks in exacerbating long-term divergence has been well-documented (Barro & Sala-i-Martin, 1995). The COVID-19 pandemic serves as a unique case, disrupting global supply chains, labor markets, and fiscal stability, thereby amplifying pre-existing vulnerabilities in low- and middle-income countries. Sala-i-Martin (1996) provides extensive evidence supporting the theory of conditional convergence among OECD countries, where institutional and structural similarities facilitate faster economic alignment.

But what is economic catch-up? And how is it different from convergence? Economic catch-up refers to the process by which less developed economies grow

at a faster rate than more developed ones, thereby narrowing the income or productivity gap over time. This concept is rooted in the idea that lagging economies can leverage existing technologies, foreign investments, and policy reforms to accelerate growth, as highlighted by Gerschenkron's (1962) theory of the "advantages of backwardness." Economic catch-up is often juxtaposed with the broader concept of economic convergence. While both address income disparities, catch-up focuses on the relative performance of specific countries against advanced benchmarks, such as the United States or the G7, emphasizing short- to medium-term dynamics. Convergence, on the other hand, refers to the tendency of economies to achieve similar levels of per capita income over the long term, as theorized by the Solow-Swan growth model (Solow, 1956). The conditional version of this model stresses the importance of structural and policy-related factors, such as savings rates, population growth, and institutional quality, in determining growth trajectories (Barro & Sala-i-Martin, 1992).

External shocks, such as pandemics, financial crises, or geopolitical conflicts, pose significant challenges to both catch-up and convergence processes. These shocks can derail economies from their long-term growth paths by disrupting key macroeconomic variables, including investment, trade, and labor markets. For instance, the COVID-19 pandemic caused widespread economic disruptions, amplifying pre-existing vulnerabilities in low-income countries while imposing structural adjustments even in advanced economies. Theoretical frameworks, such as those proposed by Ramey & Ramey (1995) and Barro & Sala-i-Martin (1995), emphasize that such shocks can have persistent effects, particularly when they exacerbate institutional weaknesses or structural inefficiencies. The nature and magnitude of recovery from external shocks often vary, reflecting the interplay of policy responses, institutional resilience, and the characteristics of the shock itself. Recovery trajectories are typically categorized into three shapes: V-shaped, U-shaped, and L-shaped. A V-shaped recovery represents the most favorable scenario, where economies rebound quickly to pre-shock levels due to effective fiscal and monetary interventions, robust supply chains, and pent-up demand. For example, many advanced economies initially exhibited V-shaped recoveries post-COVID-19 due to large-scale stimulus measures and rapid vaccine rollouts (IMF, 2021). In contrast, U-shaped recoveries are characterized by prolonged periods of stagnation before eventual recovery, often resulting from delays in policy responses or structural adjustments. For instance, the slow recovery of some European economies after the 2008 Global Financial Crisis can be attributed to austerity measures and persistent financial fragility (Reinhart & Rogoff, 2009). Finally, L-shaped recoveries are the least desirable, involving long-term stagnation without a return to previous growth levels. Such outcomes are typically associated with severe structural damage, ineffective policy interventions, or prolonged institutional instability, as seen in Japan's "Lost Decade" following its 1991 asset price bubble collapse (Hayashi & Prescott, 2002). The recovery shape an economy experiences is influenced by several key factors. The quality and timeliness of policy responses play a critical

role; swift and effective interventions can prevent a U or L-shaped recovery, as emphasized by Keynesian economics.

The COVID-19 pandemic has significantly influenced global economic convergence dynamics, prompting extensive research on its effects and recovery trajectories. Studies by the International Monetary Fund (Brussevich et al., 2022) highlight that while advanced economies benefited from increased public debt accumulation to support recovery, emerging and low-income nations faced severe setbacks. Analyzing data from 103 countries, the IMF emphasizes that the pandemic exacerbated income inequality due to disparities in fiscal capacity and recovery speed. Service-exporting economies, particularly those reliant on tourism, experienced the sharpest downturns, though projected recoveries remain optimistic.

Several studies further explore the short- and long-term consequences of the pandemic. Furceri et al. (2021) extend this analysis by assessing past pandemics' effects on inequality, providing a comparative framework for understanding COVID-19's economic impact. Their findings suggest that pandemics historically widen income gaps, particularly in developing nations. Martinho (2021) aims to evaluate the impact of COVID-19 on GDP per capita in OECD countries. Using convergence theory and data from the OECD database (Q4 2017 to Q3 2020), the research employs spatial autocorrelation methods for analysis. They conclude that, the pandemic, particularly in the first half of 2020, disrupted the convergence trends observed in GDP per capita from late 2017 to late 2019, presenting new challenges for future economic stability. Jawad & Naz (2023) examines the economic development of the USA, Pakistan, and the rest of the world by analyzing key macroeconomic variables such as interest rates, exchange rates, consumer price index (CPI), current account deficit, and stock prices from January 2016 to December 2022. They conclude that, Economic Growth Impact: The pandemic significantly impacted interest rates, initially increasing them before a gradual decline. They conclude that, all regions experienced significant devaluation of their exchange rates and rising unemployment, negatively affecting economic growth. High uncertainty led to a decrease in the CPI, which negatively influenced GDP. The decrease in imports resulted in a reduction of the current account deficit, significantly impacting the economy. Overall, the findings indicate that various macroeconomic factors, particularly during the pandemic, negatively impacted economic growth in the studied regions. Liu et al. (2023) analyze the effects of the pandemic on macroeconomic sectors, concentrating on both the severity and length of these impacts. Using the FAVAR model, their findings indicate that the pandemic had detrimental effects on the business index, consumption, industrial production, and financial markets. Notably, the negative effects on the macroeconomic business index persisted for more than 12 months. The study emphasizes the necessity for enhanced macroeconomic governance and strategies for risk prevention to ensure continued economic growth and social stability.

Trade and macroeconomic disruptions also played a crucial role in economic divergence during the pandemic. Baldwin et al. (2020) examine how supply chain shocks and uneven fiscal stimulus capacity contributed to growing disparities between advanced and developing economies. Using panel data from 72 countries, Cerra et al. (2022) investigate the long-term effects of pandemics, finding that COVID-19 significantly reduced growth potential, with developing economies experiencing more severe consequences. The OECD (2021) explores productivity trends across income groups, revealing that digital adoption improved productivity in high-income countries, whereas limited digital infrastructure exacerbated economic divergence in lower-income nations. Similarly, The World Bank (2022) assesses fiscal capacity, debt levels, and recovery dynamics, demonstrating that constrained fiscal space in developing nations delayed economic recovery and widened inequality.

Several studies analyze the policy responses and structural factors influencing post-pandemic recovery. Brodeur et al. (2021) provide a broad review of COVID-19's economic consequences, focusing on macroeconomic stability, social inequality, and public policy responses. They conclude that government interventions, such as fiscal stimulus and social distancing measures, significantly shaped economic outcomes, with recovery trajectories depending on institutional strength and pre-existing economic conditions. Maldonado et al. (2021) emphasize the long-term economic implications of pandemic-induced learning deficits, arguing that disruptions in education may deepen economic disparities, particularly in developing nations, unless substantial policy interventions are implemented. Liu & Cho (2024) analyze (193 countries, 2018–2021) finds FinTech significantly boosted economic growth during the COVID-19 pandemic, particularly in high-internet-usage countries, mitigating the crisis's economic severity by enabling resilient financial services.

Further studies explore sector-specific recovery strategies. Pichler et al. (2020) analyze the trade-off between economic reopening and epidemic control in the UK, using a production network model to simulate recovery scenarios. Their findings suggest that gradual reopening, supported by targeted lockdowns and sector-specific policies, minimizes both economic losses and public health risks. Mitze & Makkonen (2021) investigate the role of research and innovation (R&I) funding in post-crisis economic recovery, with a focus on Finland, concluding that strategic investments in innovation and technology accelerate economic catch-up by boosting productivity and competitiveness.

Historical analyses provide additional insights into COVID-19's long-term economic implications. Jordà et al. (2020) study past pandemics to project potential long-term economic stagnation, finding that pandemics typically lead to prolonged downturns due to labor market disruptions and lower investment rates. Gopinath (2020) presents an IMF perspective, describing the COVID-19 crisis as the worst recession since the Great Depression and advocating for strong fiscal and monetary policies to prevent long-term economic scarring.

Recent research highlights key factors influencing post-pandemic economic convergence. Furceri et al. (2021), analyzing data from 175 countries, argue that pandemics widen income gaps, especially in developing economies, and stress the need for targeted fiscal responses and structural reforms. Zheng (2023) assess the role of sovereign debt in post-COVID-19 recovery, concluding that high debt burdens reduce the effectiveness of fiscal stimulus and delay economic catch-up, necessitating debt restructuring and fiscal discipline.

Technological diffusion and institutional quality have also been identified as critical factors in economic recovery. A study by Liu et al. (2024) investigates the impact of COVID-19 on global innovation across 115 countries, categorizing the pandemic's spread into five phases. Key findings include: In the Entry and Takeoff phases, collectivist culture strengthened the link between COVID-19 spread and innovation. In the Proliferation phase, individualistic culture positively influenced this relationship, while in-group collectivist culture enhanced the connection between COVID-19 spread and national innovation input and output. Huang and Zhao explores how digital innovation (DI) bolstered firm resilience during the COVID-19 pandemic. It shows that companies with strong DI capabilities performed better, especially those facing higher exposure to COVID-19 and those with distant supply chains. DI mitigated negative impacts by reducing internal coordination costs and enhancing supply chain responsiveness. Lee & Trimi (2021) emphasizes the importance of sustainable innovation for organizational survival and success, particularly during the tumultuous period of the COVID-19 pandemic. It introduces convergence innovation (CI) as a new core competence for organizations, driven by the integration of various technologies, ideas, and strategies. Sunge et al., (2024) examines the impact of governance on post-COVID-19 economic recovery, analyzing data from 125 countries between 2020 and 2021 using structural equation modeling. While global findings show no mediation by governance in economic recovery, regional analysis indicates full mediation in Africa and among low-income countries, particularly in 2021. Key governance indicators in Africa, such as control of corruption, government effectiveness, regulatory quality, and rule of law, significantly contributed to recovery.

Collectively, these studies underscore the uneven effects of the COVID-19 pandemic on economic convergence. While advanced economies leveraged fiscal capacity and technological advancements for recovery, developing nations faced prolonged setbacks due to structural vulnerabilities. The trajectory of global economic convergence post-pandemic will largely depend on policy interventions, institutional resilience, and strategic investments in innovation and human capital.

3. Research Method

Figure 1 demonstrates the methodology for analyzing the Economic Catch-Up Index of various countries, focusing on their economic trajectories relative to the USA and G7 benchmarks. The study evaluates changes in economic catch-up

both before and after the COVID-19 pandemic, incorporating three distinct periods that represent the average performance of countries prior to the pandemic. The short-term analysis corresponds to the years 2014–2019, reflecting recent trends leading up to the crisis. The medium-term covers the years 2010–2019, offering a broader view of economic performance over the decade. Finally, the long-term analysis spans 2001–2019, capturing extensive structural trends over nearly two decades. These three periods will be compared to the post-COVID period, i.e. 2019-2023, in terms of the average economic catch-up index. The methodology involves calculating the index separately for the USA and G7 benchmarks and comparing the pre- and post-pandemic results to identify shifts in economic catch-up. By analyzing short-, medium-, and long-term periods, the study highlights how countries' economic trajectories were shaped by structural factors and policy decisions leading up to the pandemic. This enables an understanding of the pandemic's role in altering pre-existing trends. Finally, the results are disaggregated by country and income group, providing insights into disparities in economic performance across different development levels. This approach offers a comprehensive perspective on how the COVID-19 pandemic influenced global economic catch-up trends over varying time horizons. In addition, an attempt will be made to provide an initial analysis of the causes of differences in the response of countries and income groups by calculating the correlation between the estimated index of the amount of change in the path of catch-up after COVID-19 with other governance and structural variables.

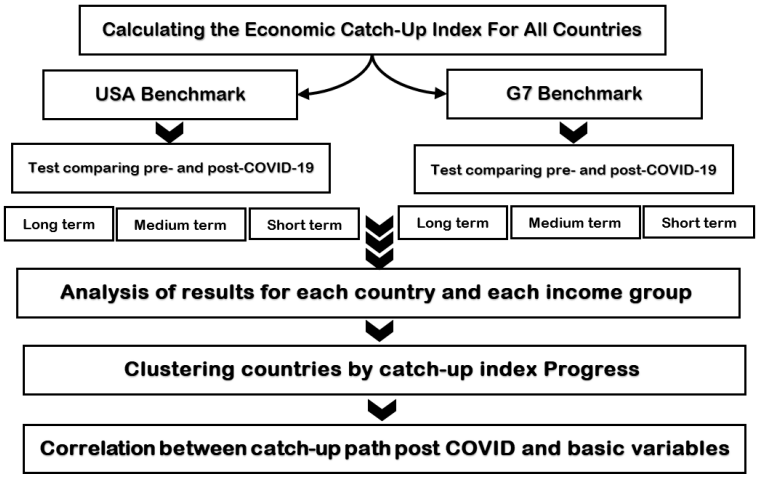

Figure1. The process of conducting the research method
***Source**: by the author*

We calculate the economic convergence index for 194 countries from 2000 to 2022 using the methodology introduced by Kant (2019), with the G7 economies serving as the benchmark. In this approach, the catch-up index is defined as follows: let y_{j0} and y_{B0} represent the per capita gross domestic product (GDP) for

country j and the benchmark country B in the base year, respectively (in this study, the benchmark is selected G7 economies – Canada, France, Germany, Italy, Japan, United Kingdom and United States- , and the base year is 2000). The ratio of per capita GDP between the two countries in year t is given by:

$$R_{jt} = \frac{y_{jt}}{y_{Bt}} \quad (1)$$

Consequently, the economic catch-up index for country j in year t can be defined as:

$$I_{jt} = \frac{R_{jt}}{R_{j0}} \quad (2)$$

Here, y_{jt} and y_{Bt} represent GDP per capita for country j and benchmark B in year t, respectively. A value greater than one indicates better catch-up (i.e., moving closer to the benchmark economy), while a value less than one signifies weaker catch-up (i.e., moving further away from the benchmark economy). All these steps will also be calculated once for the time when the United States is the benchmark.

To examine whether countries have exhibited different responses to the economic shock induced by the COVID-19 pandemic, a clustering approach is employed. Specifically, after computing the economic catch-up index relative to the U.S. economy (as well as the G7 economies), countries are classified into distinct clusters based on their catch-up patterns.

The clustering process begins with determining the optimal number of clusters using statistical criteria such as the Calinski-Harabasz index (Calinski & Harabasz, 1974) and the Silhouette score (Rousseeuw, 1987), which assess the compactness and separation of clusters. Calinski-Harabasz Index (CH Index) is :

$$CH(k) = \frac{B_k/(k-1)}{W_k/(n-k)} \quad (3)$$

B_k is the between-cluster dispersion, W_k is the within-cluster dispersion, k is the number of clusters, n is the total number of observations. Once the optimal number of clusters is identified, countries are grouped accordingly using a clustering algorithm k-means clustering (MacQueen, 1967). The k-means algorithm minimizes intra-cluster variance using the following objective function: $\min \sum_{i=1}^{k} \sum_{x \in C_i} \|x - \mu_i\|^2$, where C_i is the set of points in cluster i and μ_i is the centroid of cluster i.

Following the clustering step, an analysis of variance (ANOVA) test is conducted to assess whether the identified clusters exhibit statistically significant differences in their economic catch-up trajectories. The ANOVA F-statistic is calculated as:

$$F = \frac{\sum_{j=1}^{k} n_j \left(\bar{X}_j - \bar{X}\right)^2/(k-1)}{\sum_{j=1}^{k} \sum_{i=1}^{n_j} \left(X_{ij} - \bar{X}_j\right)^2/(N-k)} \quad (4)$$

where: n_j is the number of observations in cluster j, $\bar{X}_j$ is the mean of cluster j, $\bar{X}$ is the overall mean, N is the total number of observations, k is the number of clusters.

Additionally, Bartlett's test for equal variances is performed to assess whether the variance within each cluster is homogeneous. The test statistic follows a chi-square (χ^2) distribution and is computed as:

$$\chi^2 = \frac{(N-k)\ln S^2 - \sum_{j=1}^{k}(n_j - 1)\ln S_j^2}{1 + \frac{1}{3(k-1)}\left(\sum_{j=1}^{k}\frac{1}{n_j - 1} - \frac{1}{N-k}\right)} \quad (5)$$

Where S^2 is the pooled variance and S_j^2 is the variance of cluster j. The F-statistic from ANOVA tests the null hypothesis that all clusters have the same mean catch-up index, while Bartlett's test for equal variances evaluates the homogeneity of variances across clusters. A statistically significant ANOVA result ($p < 0.05$) would indicate that the economic catch-up dynamics differ across clusters, thereby confirming heterogeneous responses to the COVID-19 shock.

3.1. Data and Description of the Variables

The data in Table 1 illustrates the differences in the economic catch-up index between the post-COVID-19 period and three different pre-COVID-19 benchmark periods (2001–2019, 2010–2019, and 2014–2019) across income groups. A higher mean value of the index indicates greater economic catch-up with the benchmark economy (USA or G7) in the post-COVID-19 period relative to the pre-COVID-19 period. Conversely, a negative value suggests a relative decline in economic catch-up. The table also reports standard deviations, as well as minimum and maximum values, providing insight into the variability and extremes within each income group and benchmark. For low-income countries, the results reveal limited or negative catch-up progress in most scenarios. For the USA benchmark, the mean differences across all three pre-COVID periods (B2001, B2010, B2014) are small or negative, with values such as -0.056 (B2010) and -0.048 (B2014). Similarly, with the G7 benchmark, the mean differences are slightly more favorable but still negative for B2010 (-0.001) and B2014 (-0.018). In the case of lower-middle-income countries, the results are more nuanced. For the USA benchmark, there is a slight positive mean difference of 0.111 in B2001, but this diminishes or turns negative for B2010 (-0.001) and B2014 (-0.027). For the G7 benchmark, however, the mean differences are consistently positive, particularly for B2001 (0.134) and B2010 (0.083). Descriptive statistics for other income groups can also be seen in Table 1. In summary, the table highlights varying degrees of economic catch-up across income groups and benchmark economies. Lower- and upper-middle-income countries exhibited some catch-up progress, especially with the G7, but this progress weakened in more recent pre-COVID benchmarks. High-income countries, while maintaining positive catch-up with the G7, struggled to maintain the same with the USA. These trends

underscore the uneven economic recovery trajectories across countries and income groups in the wake of the COVID-19 pandemic1.

Table 1. Difference in the economic catch-up index in the pre- and post-COVID-19 period

		Variable	n	Mean	Std.	Min	Max
Low income	USA Benchmark	B2001	21	0.001	0.300	-0.479	0.933
		B2010	21	-0.056	0.197	-0.392	0.524
		B2014	21	-0.048	0.139	-0.314	0.332
	G7 Benchmark	B2001	21	0.040	0.308	-0.454	0.998
		B2010	21	-0.001	0.206	-0.315	0.616
		B2014	21	-0.018	0.145	-0.275	0.391
Lower Middle income	USA Benchmark	B2001	50	0.111	0.287	-0.349	0.757
		B2010	50	-0.001	0.200	-0.414	0.467
		B2014	50	-0.027	0.162	-0.397	0.357
	G7 Benchmark	B2001	50	0.134	0.285	-0.306	0.773
		B2010	50	0.083	0.205	-0.311	0.570
		B2014	50	0.076	0.166	-0.222	0.500
Upper Middle income	USA Benchmark	B2001	53	0.119	0.400	-1.175	1.674
		B2010	53	0.002	0.274	-1.040	0.950
		B2014	53	-0.013	0.195	-0.653	0.664
	G7 Benchmark	B2001	53	0.075	0.365	-1.139	1.490
		B2010	53	0.036	0.253	-0.894	0.936
		B2014	53	0.040	0.186	-0.525	0.720
High income	USA Benchmark	B2001	71	-0.023	0.344	-0.822	1.926
		B2010	71	-0.052	0.323	-1.217	1.802
		B2014	71	-0.051	0.304	-1.062	1.781
	G7 Benchmark	B2001	71	0.215	0.430	-0.511	2.630
		B2010	71	0.204	0.400	-0.808	2.534
		B2014	71	0.186	0.380	-0.734	2.494

Note: *B2001: pre Covid-19 is 2001-2019; B2010: pre Covid-19 is 2010-2019; B2014: pre Covid-19 is 2014-2019.*
Source*: Calculated by the author*

The density plots (figure 1) provide a visual representation of the distribution of economic catch-up index differences for the pre- and post-COVID-19 periods across income groups, with comparisons made against the USA and G7 benchmarks the distributions for low-income countries are narrow and centered near zero for both the USA and G7 benchmarks, indicating minimal changes in the economic catch-up index. The peak of the distribution becomes sharper in more recent benchmarks (B2010 and B2014), suggesting reduced variability in the catch-up dynamics. The distributions for Lower-Middle-Income Countries are wider and slightly shifted to the right for the G7 benchmark compared to the USA

[1] Research data was obtained from the following sources: Economic Data (GDP per capita): World Bank and WDI. Governance Indicators: World Bank's Worldwide Governance Indicators (2022). COVID-19 Mortality Rates: Johns Hopkins University Coronavirus Resource Center (2023). Global Innovation Index: World Intellectual Property Organization (2022).

benchmark, especially in B2001 and B2010. This shift indicates relatively stronger catch-up progress with the G7 economies compared to the USA, though the distributions contract slightly for the more recent benchmark (B2014), reflecting less variability and diminishing progress. The density curves for upper-middle-income countries show greater variation in earlier benchmarks (B2001) and a shift closer to zero in later benchmarks (B2010 and B2014). For high-income countries, the distributions for the USA benchmark are consistently centered near zero or slightly negative, indicating limited or declining catch-up. In contrast, the distributions for the G7 benchmark are shifted to the right, particularly in B2001, showing stronger positive catch-up dynamics. Over time, the peaks narrow slightly, suggesting reduced variation in performance across countries within this group.

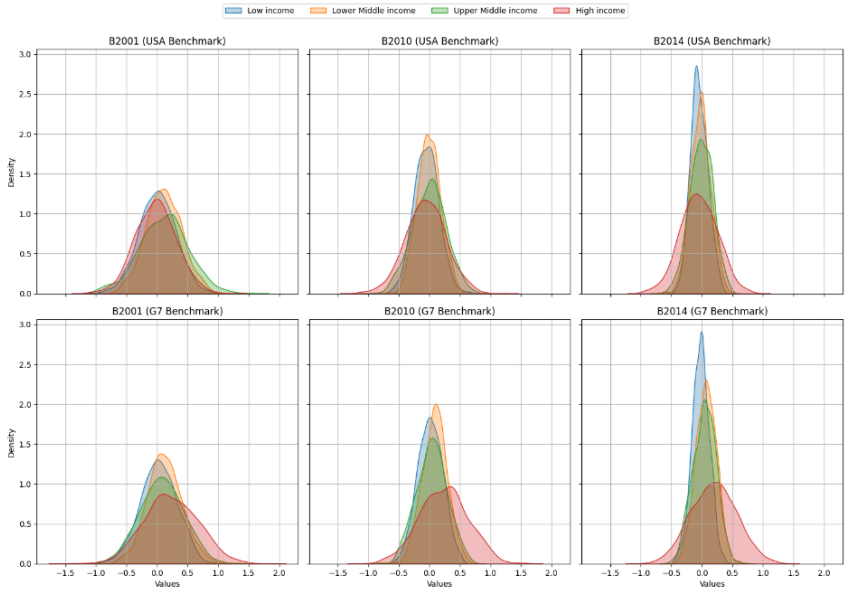

Figure 1. Density plots of Difference in the economic catch-up index in the pre- and post-COVID-19 period for income group-
***Source**: Calculated by the author*

4. Results

4.1. Economic Catch-Up Dynamics across countries: Pre- and Post-COVID-19 Analysis

Appendix 1 and figure 2 presents the results of differences in economic catch-up for low-income countries, using GDP per capita as the benchmark for comparison with two reference economies: the USA and the G7. The differences were calculated for three timeframes before COVID-19 (2001–2019, 2010–2019, and 2014–2019) and the post-COVID period. A positive and significant difference indicates improved economic catch-up after COVID-19 compared to the pre-COVID periods. According to the table, when the United States is the Benchmark

country: Countries like Burkina Faso (BFA), Ethiopia (ETH), Rwanda (RWA), and Togo (TGO) exhibit significant positive differences across all timeframes, indicating stronger catch-up toward the USA after the pandemic. Ethiopia demonstrates the most substantial improvement (e.g., 0.93 for 2001–2019).On the other hand, Countries like Burundi (BDI), Central African Republic (CAF), and Sudan (SDN) show significant negative values, suggesting divergence or slower catch-up after COVID-19. Results for countries like Mozambique (MOZ) and Yemen (YEM) reveal increased divergence in the short term (2014–2019), highlighting the uneven recovery paths post-COVID.

According to the Appendix 1 and figure 2, when the G7 is the Benchmark: Similar trends are observed with the G7 as the benchmark, though the magnitude of improvement or divergence often differs slightly. Ethiopia again shows the strongest positive results (e.g., 1.00 for 2001–2019), followed by Rwanda. These countries demonstrate robust growth trajectories in comparison to the G7 economies. The magnitude of negative values for some diverging countries, such as Sudan and Chad (TCD), is slightly reduced compared to the USA benchmark, suggesting varying catch-up patterns depending on the reference group. Long-term catch-up differences (2001–2019) are generally more pronounced compared to short-term (2014–2019) results, likely due to cumulative structural growth patterns over two decades. Shorter pre-COVID periods (2014–2019) yield mixed results, with several countries (e.g., Uganda and Somalia) showing non-significant or marginally negative values. This indicates that the global economic slowdown post-2014 may have impacted their catch-up trajectory. On average, total convergence differences are negative for the USA benchmark across all pre-COVID periods, indicating a net divergence post-COVID. However, for the G7 benchmark, the differences are mostly neutral (2001 and 2010) or slightly negative in the short term (2014–2019).

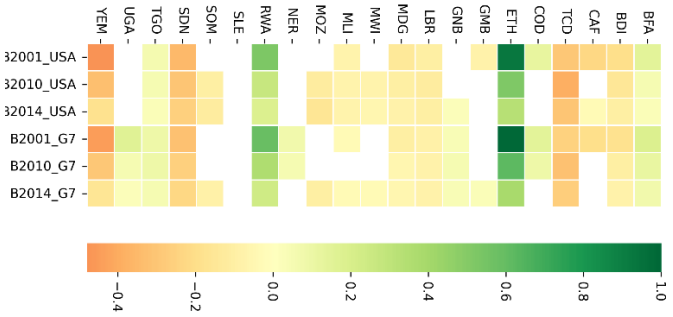

Figure 2. compare means difference test in the economic catch-up index of low-income countries in the pre- and post-covid-19 period

***Note**: Green box indicates improvement in catch-up index. Red box indicates decline in catch-up index. White Box: There is no significant difference in economic catch-up. B2001: pre Covid-19 is 2001-2019; B2010: pre Covid-19 is 2010-2019; B2014: pre Covid-19 is 2014-2019.*

***Source**: Calculated by the author*

The Figure 3 show the ranking of countries' performance in the catch-up index. According to the Figure, it can be seen that, in general, the performance of countries when the G7 is selected as the benchmark country is better than when the United States is the benchmark. This result could indicate that after COVID-19, the economic gap between low-income countries and the United States has increased. Of course, this gap with the G7 countries also shows an increase, but the performance in this case has been accompanied by less fluctuation.

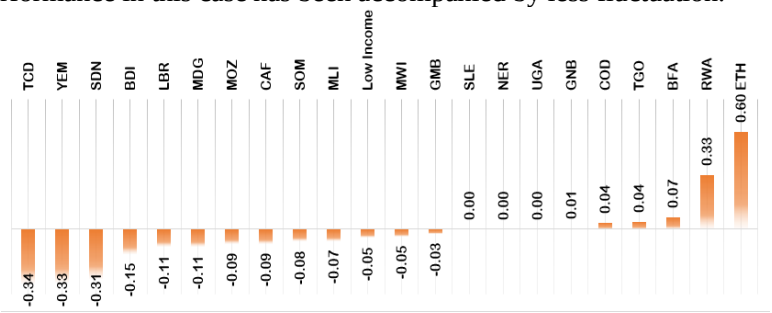

Figure 3. ranking of the Average difference in the economic catch-up index before and after COVID-19 compared to the United States in Low-Income Group
Source: *Calculated by the author*

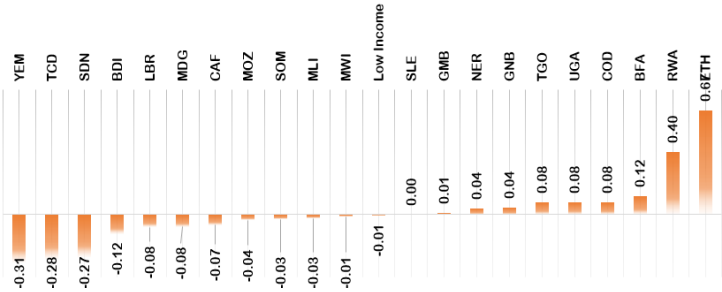

Figure 4.ranking of the Average difference in the economic catch-up index before and after COVID-19 compared to the G7 in Low-Income Group
Source: *Calculated by the author*

Appendix 1 and figure 5 shows a test comparing the economic catch-up after COVID-19 with the pre-COVID period for lower-middle-income countries. When the Benchmark economy is the United States, Countries such as Bangladesh (BGD), India (IND), and Vietnam (VNM) show consistently high positive values, indicating catch-up toward the USA benchmark. This result shows that after COVID-19, these countries have achieved greater catch-up with the US economy. On the other hand, Countries such as Angola (AGO), Haiti (HTI), and Lebanon (LBN) consistently display negative coefficients, implying divergence from the USA benchmark, potentially due to political instability, poor governance, or structural constraints. In other words, these countries have become further away from the US economy after the COVID-19 pandemic. This situation

could be due to the inability to maintain their own pace due to the COVID-19 pandemic. When the Benchmark economy is the G7, A similar pattern of convergence and divergence is observed, though G7 coefficients tend to be higher, reflecting broader economic trends shared among developed economies. An examination of the overall path of economic convergence of countries in this income group shows that, When the Benchmark economy is the United States, Difference of catch-up index is Negative in 2014 (-0.03), indicating a reversal of overall catch-up trends. When the Benchmark economy is the G7, Difference of catch-up index is Positive (0.08) suggesting the G7 provides a broader and more inclusive growth benchmark for developing countries. In other words, the COVID pandemic has caused countries in this income group to fall further behind the US economy, but compared to the economies of the G7 countries, lower-middle-income countries have been able to show greater catch-up.

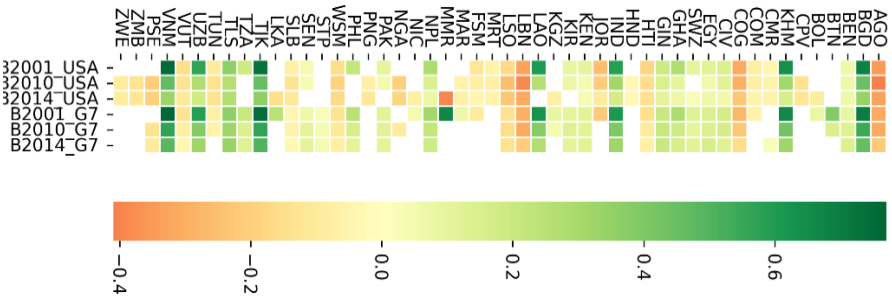

Figure 5- compare means difference test in the average economic catch-up index of lower-middle Income Group in the pre- and post-COVID-19 period

***Note**: Green box indicates improvement in catch-up index. Red box indicates decline in catch-up index. White Box: There is no significant difference in economic catch-up. B2001: pre Covid-19 is 2001-2019; B2010: pre Covid-19 is 2010-2019; B2014: pre Covid-19 is 2014-2019.*

***Source**: Calculated by the author*

The figure 6 shows the ranking of the size of the catch-up path change of countries in this income group after the COVID-19 pandemic. According to the figure, it can be seen that when the US economy is chosen as the Benchmark, a larger number of countries experience a negative catch-up path change after the COVID-19 pandemic. When the G7 countries are taken as the Benchmark, the catch-up path change of this income group with the G7 countries after the COVID-19 pandemic has been slightly smoother. In both cases, the best performance was in Vietnam and Tajikistan, and the worst performance was in Angola and Lebanon.

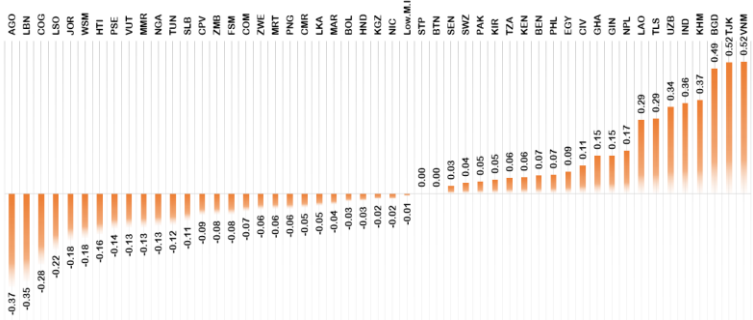

Figure 6. ranking of the Average difference in the economic catch-up index before and after COVID-19 compared to the United States in lower-middle Income Group
Source: *Calculated by the author*

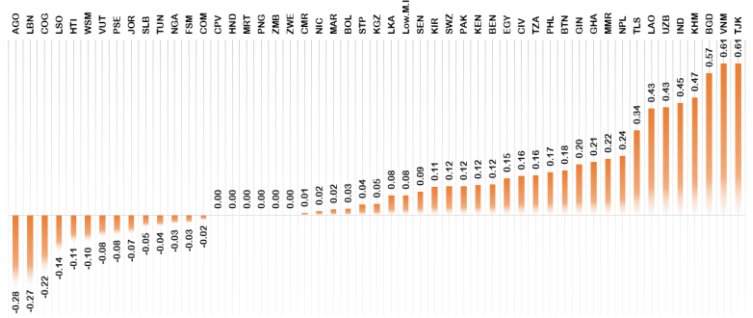

Figure 7. ranking of the Average difference in the economic catch-up index before and after COVID-19 compared to the G7 in lower-middle Income Group
Source: *Calculated by the author*

Examining the results of redirection among upper-middle-income countries reveals interesting results. China (CHN), Exhibits exceptionally high benchmarks in 2001 under both the USA (1.67) and G7 (1.49), maintaining positive but decreasing values by 2014 (USA: 0.66, G7: 0.72). The USA benchmark values are slightly higher than G7, indicating stronger alignment with the USA's economic trajectory. Therefore, it can be seen that the COVID-19 pandemic has caused China's economic alignment with the G7 countries and the United States to greatly improve. Turkmenistan is going through a similar situation. Starts with high positive benchmarks in 2001 (USA: 1.11, G7: 0.98), decreasing steadily by 2014 (USA: 0.40, G7: 0.45). Similar decline across both benchmarks suggests comparable trajectories relative to the USA and G7. On the other hand, countries Equatorial Guinea (GNQ), Suriname (SUR), Libya (LBY) show significant negative performance in the path of economic recovery after the Corona pandemic, in both measures. A regional based study of countries also reveals important results. In Europe and Central Asia (ECA), Countries like Armenia (ARM), Georgia (GEO), and Belarus (BLR) start with high positive, indicating

strong alignment with benchmarks. In Latin America and the Caribbean (LAC), mixed performance is observed, Dominican Republic (DOM) maintains modest positive catch-up across both benchmarks and Argentina (ARG) and Belize (BLZ) exhibit consistent negative values, highlighting divergence. In Sub-Saharan Africa (SSA), Botswana (BWA), Shows a stable but slightly negative trend, indicating slow divergence And South Africa (ZAF), consistently negative benchmarks, with improvement from -0.13 (USA, 2001) to -0.12 (2014).According to the results, Several countries, including China, Turkmenistan, and Albania, exhibit higher alignment with the USA benchmarks, reflecting stronger integration with the USA's economic structure. For most developing countries, particularly in Africa and Latin America, alignment with the G7 benchmark is slightly better, suggesting a more inclusive or diversified benchmark group. While many countries exhibit declining values, a few (e.g., China, Turkmenistan) maintain relatively strong performances. The G7 benchmarks appear slightly more favorable for developing countries, likely due to the broader economic integration it represents compared to the USA. Countries with persistently negative benchmarks (e.g., Libya, Equatorial Guinea) may require targeted interventions to enhance their convergence with global benchmarks, focusing on structural reforms and economic diversification. But in general, the test results for all upper-middle-income countries show that the outbreak of the COVID-19 has not caused a significant change in the path of catch-up these countries compared to the US economy, while compared to the G7 countries, it can be seen that the situation of this group of countries has improved.

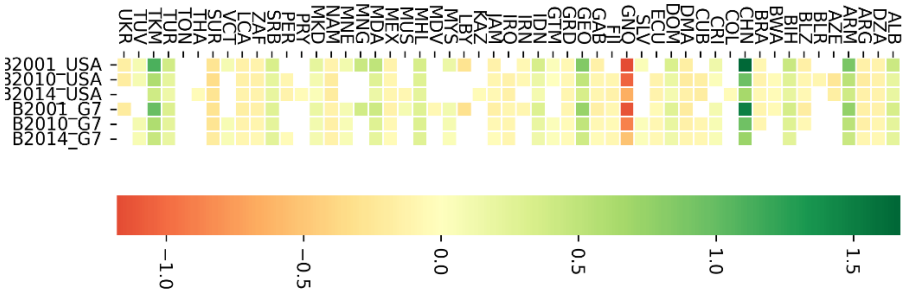

Figure 7- compare means difference test in the economic catch-up index of upper-middle Income Group in the pre- and post-COVID-19 period

Note: *Green box indicates improvement in catch-up index. Red box indicates decline in catch-up index. White Box: There is no significant difference in economic catch-up. B2001: pre Covid-19 is 2001-2019; B2010: pre Covid-19 is 2010-2019; B2014: pre Covid-19 is 2014-2019.*

Source*: Calculated by the author*

The results of the peer performance ranking of countries in this income group show that China and Turkmenistan have performed best on both measures, while the country Equatorial Guinea has experienced the highest divergence.

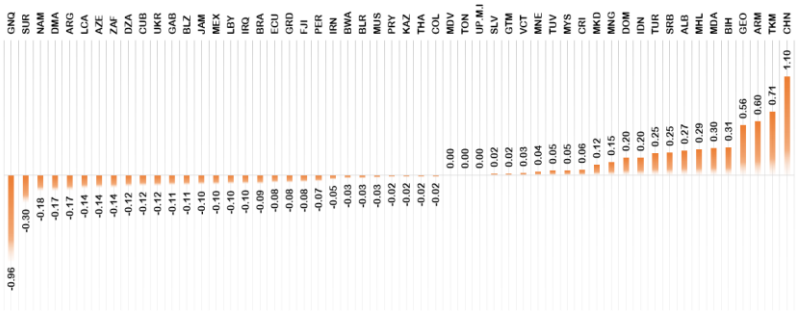

Figure 8. ranking of the Average difference in the economic catch-up index before and after COVID-19 compared to the United States in upper-middle Income Group
Source: *Calculated by the author*

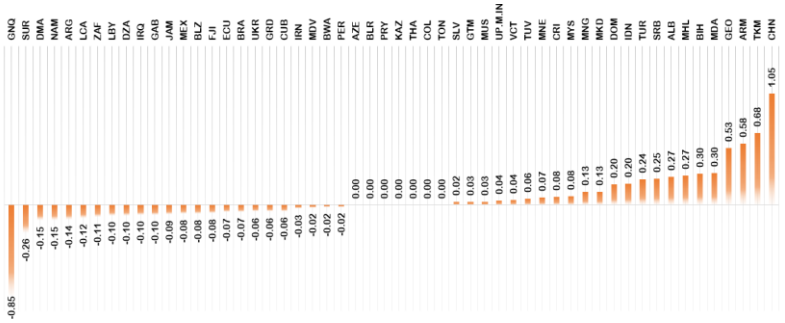

Figure 9. ranking of the Average difference in the economic catch-up index before and after COVID-19 compared to the G7 in upper-middle Income Group
Source: *Calculated by the author*

The results of the economic catch-up change trajectory for high-income countries are shown in Appendix 1 and figure 10. According to the results, when USA is Benchmark, Most countries display negative coefficients, indicating a lag behind the USA. Countries such as Guyana (GUY), Lithuania (LTU), and Romania (ROU) consistently show high positive coefficients, reflecting strong relative performance. When G7 is Benchmark, A higher number of countries exhibit positive coefficients compared to the USA Benchmark, suggesting better relative performance when measured against the G7. The coefficients remain relatively stable across the three periods, indicating consistency in relative positioning. Regional results can also be interesting. In North America, when USA is Benchmark, Canada shows stable negative coefficients, indicating sustained economic integration with the USA. When G7 is Benchmark, Positive coefficients for Canada across all periods indicate strong alignment with the G7, consistent with its membership and economic policies. In Europe (e.g., Germany, Bulgaria, Croatia), when USA is Benchmark, European countries exhibit diverse trends, with developed economies (e.g., Germany) showing moderate negative coefficients, while transition economies (e.g., Bulgaria, Croatia) demonstrate significant positive coefficients. When G7 is Benchmark, Most European

countries show positive coefficients, indicating convergence with the G7 economies. In Asia-Pacific (e.g., Japan, Singapore, Philippines), when USA is Benchmark, Advanced Asian economies (e.g., Japan, Singapore) have modest negative coefficients, reflecting divergence with the USA, while developing economies (e.g., the Philippines) exhibit high positive coefficients. When G7 is Benchmark, Advanced economies like Japan and Singapore show steady alignment with the G7, whereas developing countries like the Philippines demonstrate slower convergence. In Latin America (e.g., Chile, Uruguay), when USA is Benchmark, Latin American countries show mixed performance, with Chile demonstrating convergence over time while Uruguay exhibits divergence. When G7 is Benchmark, Relative to the G7, Latin American countries generally show positive coefficients, reflecting gradual alignment. In Africa and the Middle East (e.g., Saudi Arabia, Kuwait), when USA Benchmark, These regions show divergence, with countries like Saudi Arabia and Kuwait exhibiting negative coefficients. When G7 is Benchmark, There is a trend of modest convergence, particularly for resource-rich countries like Kuwait, due to integration with global markets In Advanced Economies (USA, G7 Members, and Peers), Countries such as Australia (AUS), Belgium (BEL), and Sweden (SWE) show consistent but modest positive coefficients relative to the G7. Against the USA, these countries generally exhibit negative coefficients, highlighting the USA's relative dominance. In Emerging and Transition Economies, Countries like Lithuania (LTU) and Romania (ROU) demonstrate significant positive performance relative to both benchmarks, particularly the G7. In Small and Developing Nations, Many smaller economies such as Antigua and Barbuda (ATG) and Barbados (BRB) show negative coefficients against the USA but achieve modest or neutral performance against the G7. Islands such as Bermuda (BMU) and Curacao (CUW) consistently lag behind both benchmarks, reflecting challenges in economic performance. It is also interesting to examine the results for the set of high-income countries. According to the results, high-income countries experience a worse situation after the pandemic compared to the United States in all three short-term, medium-term, and long-term catch-up paths. While compared to the G7 countries, the catch-up path of high-income countries has improved significantly after the pandemic. Therefore, it can be seen that the pandemic shock has caused high-income countries to become more convergent with the G7 and more divergent from the US economy.

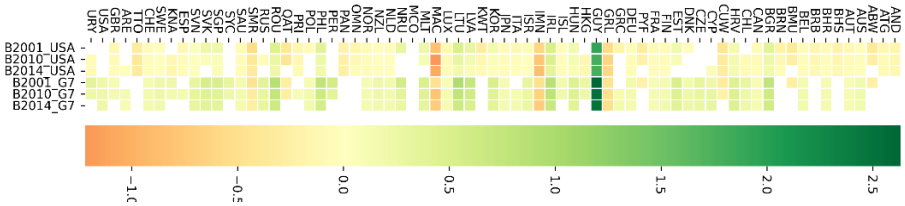

Figure 10- compare means difference test in the economic catch-up index of High Income Group in the pre- and post-COVID-19 period

***Note**: Green box indicates improvement in catch-up index. Red box indicates decline in catch-up index. White Box: There is no significant difference in economic catch-up. B2001: pre Covid-19 is 2001-2019; B2010: pre Covid-19 is 2010-2019; B2014: pre Covid-19 is 2014-2019.*
***Source**: Calculated by the author*

The ranking of the degree of change in the direction of this group of countries also shows that when the Benchmark of comparison is the US economy, many high-income countries have experienced a high divergence with the US after the outbreak of COVID-19. However, when the Benchmark of comparison is the G7 countries, many countries have had a significant convergence with the G7 after the outbreak of COVID-19.

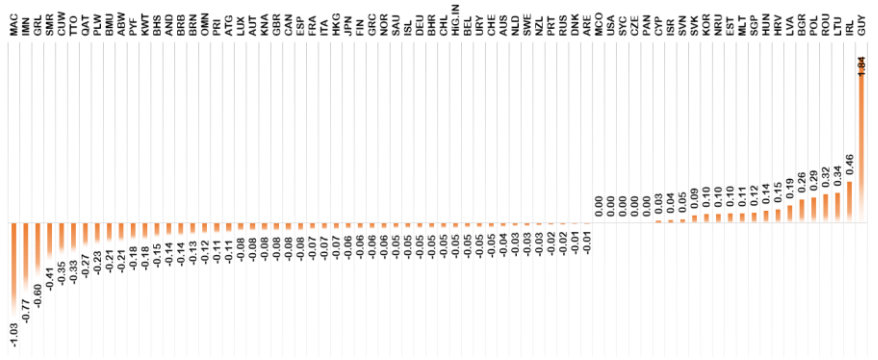

Figure 11- ranking of the Average difference in the economic catch-up index before and after COVID-19 compared to the United States in High Income Group
***Source:** Calculated by the author*

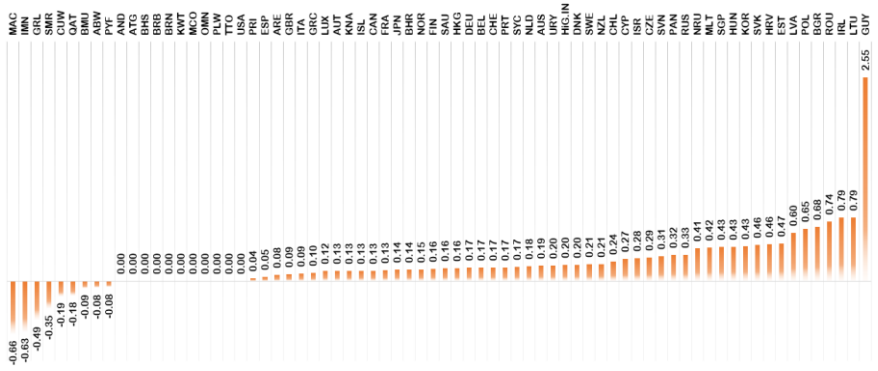

Figure 12- ranking of the Average difference in the economic catch-up index before and after COVID-19 compared to the G7s in High Income Group
***Source:** Calculated by the author*

4.2. Economic Catch-Up Dynamics across Income Groups: Pre- and Post-COVID-19 Analysis

In this section, by synthesizing the findings from the previous analysis, we aim to assess whether the trajectory of economic catch up among different income groups exhibited heterogeneous responses to the COVID-19 pandemic. Specifically, we investigate whether the pace and direction of economic catch-up varied systematically across income classifications, shedding light on potential asymmetries in resilience and recovery patterns. the provided charts compare economic catch-up trends before and after the COVID-19 pandemic across income groups (Low Income, Lower Middle Income, Upper Middle Income, and High Income) using two benchmarks: the USA and the G7. These trends are analyzed over three periods—2001, 2010, and 2014—with an average (AVREG) presented for comparison. The findings highlight key differences in catch-up dynamics among income groups and regions. For the USA benchmark, low-income countries exhibit consistently negative coefficients across all periods, indicating a strong and steady divergence towards the USA. From -0.056 in 2001 to -0.048. The theory of conditional convergence posits that convergence only occurs if countries share similar structural characteristics, including governance quality and human capital development. Since low-income nations often lack these preconditions, they remain trapped in a divergence path, aligning with the poverty trap theory (Kraay & McKenzie, 2014), which suggests that without substantial structural reforms, low-income nations fail to accelerate economic growth. Lower-middle-income countries also show signs of divergence. Of course, the results show that these countries have only deviated from their short-term catch-up path. Considering the results, their economic convergence with the United States has not changed significantly compared to the long-term and medium-term period before the COVID-19. Their inability to converge effectively with the USA aligns with findings by Rodrik (2013), who emphasizes that middle-income economies often face structural bottlenecks, including institutional rigidity and premature deindustrialization, limiting sustained growth. While COVID-19 caused temporary deviations in growth trajectories, the long-term and medium-term divergence patterns remain consistent, suggesting that these economies lacked the structural transformation needed to leverage technology diffusion and innovation for convergence (Diao et al., 2018). In contrast, upper-middle-income countries display no significant change in catch-up. Therefore, the outbreak of COVID-19 has not had a significant impact on changing the course of this group of countries compared to the US economy. This stability is consistent with the middle-income trap theory, where economies that achieve a certain income threshold often struggle to sustain high growth rates due to insufficient institutional capacity and innovation (Gill & Kharas, 2007). The resilience of upper-middle-income countries may also be attributed to diversified economies and moderate technological adoption, allowing them to maintain consistent growth trajectories despite external shocks like COVID-19. But, high-income countries, with stable coefficients at approximately -0.052, maintain

strong divergence with the USA. Interestingly, the coronavirus pandemic has caused the economic trajectory of high-income countries to be significantly different from that of the US economy, compared to the short, medium, and long-term periods before the pandemic. High-income nations experienced varying policy responses, fiscal stimuli, and sectoral disruptions that altered their economic paths relative to the USA. Studies by Furceri et al. (2021) suggest that external shocks such as pandemics exacerbate structural rigidities in advanced economies, leading to differentiated recovery trajectories. Moreover, Gopinath (2020) highlights that despite strong fiscal responses in high-income countries, the heterogeneity in pandemic responses influenced long-term convergence outcomes. The deviation in trajectory suggests that even within high-income groups, the extent of pandemic-induced disruptions varied based on institutional resilience and sectoral composition (OECD, 2021).

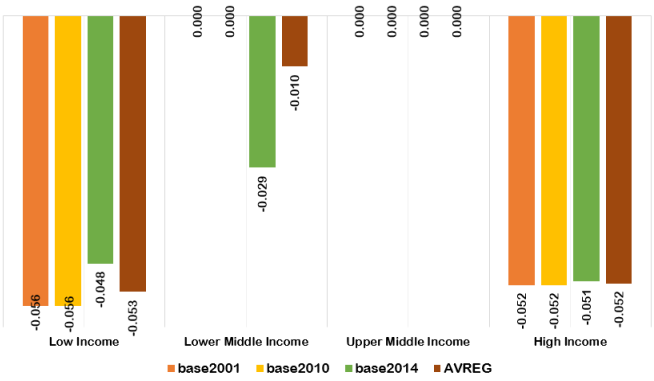

Figure 13. change in economic catch-up after the COVID-19 by income group: USA Benchmark

Source: *Calculated by the author*

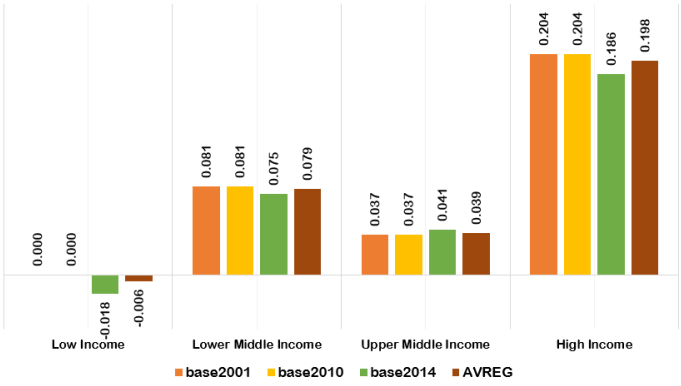

Figure 14. change in economic catch-up after the COVID-19 by income group: G7 Benchmark

***Source**: Calculated by the author*

For the G7 benchmark, the results reveal different dynamics. Low-income countries show slow divergence. Lower-middle-income countries demonstrate minor convergence, with coefficients decreasing slightly from 0.081 in 2001 to 0.075 in 2014, indicating structural improvements. The decline in coefficients indicates that these countries have made incremental progress in aligning with G7 benchmarks, reflecting ongoing institutional enhancements and policy reforms. Upper-middle-income countries show convergence, with coefficients steady at 0.037 across all periods. These countries, often characterized by diversified export bases and moderately strong institutional frameworks, exhibit resilience in maintaining growth momentum relative to the G7. High-income countries exhibit strong alignment, with coefficients slightly declining from 0.204 in 2001 to 0.198 in 2014, reflecting sustained economic and institutional ties within the G7. Studies by Cerra et al. (2022). The asymmetric impact of the pandemic on high-income and developing countries highlights the importance of policy resilience and adaptive institutional frameworks in mitigating long-term economic scarring.

The analysis reveals stark regional disparities in economic catch-up trajectories post-COVID-19. Asian economies, particularly Vietnam (+0.76 catch-up index vs. USA) and Bangladesh (+0.69), demonstrated resilience through export diversification, digital infrastructure investments, and robust manufacturing sectors. These nations aligned more closely with G7 benchmarks, reflecting their capacity to leverage global supply chain reconfigurations and innovation-driven growth. In contrast, African economies faced divergent outcomes: while Rwanda (+0.53) and Ethiopia (+0.93) achieved notable catch-up via agricultural modernization and FDI inflows, structurally weak economies like Angola (-0.35) and Sudan (-0.32) lagged due to governance deficits, commodity dependence, and political instability. Cluster analysis further underscored this divide, with Asian nations predominantly grouped in high-convergence clusters tied to technological adoption, whereas African countries clustered in groups marked by institutional fragility. These regional contrasts highlight the interplay of pre-existing structural conditions and pandemic-era policy agility, with Asia's recovery anchored in economic diversification and Africa's hindered by systemic.

4.3. Cluster Analysis of Economic Catch-Up: Assessing the Significance of Group Differences

To better understand the heterogeneity in economic catch-up across countries, this section employs cluster analysis to determine whether differences between groups are statistically significant. By grouping countries based on their economic catch up patterns before and after the COVID-19 pandemic, we assess whether these clusters exhibit distinct trajectories in their post-pandemic recovery. The optimal number of clusters is identified using statistical criteria, and analysis of variance (ANOVA) tests are conducted to evaluate whether the differences among clusters are significant. This approach allows for a more

systematic investigation into whether the pandemic had a uniform impact across countries or if structural and economic factors led to divergent recovery paths. The table 2 presents the Calinski/Harabasz pseudo-F values for the optimal number of clusters in two different benchmarks: USA and G7. For the USA benchmark, the pseudo-F value increases significantly from 146.84 for 2 clusters to 264.54 for 6 clusters, suggesting that 6 clusters might provide the best partition, as higher values indicate a better-defined cluster structure. For the G7 benchmark, the pseudo-F value shows a sharp increase at 5 clusters (351.88) and continues to be high for subsequent cluster counts, particularly 6 (379.79), suggesting that 6 clusters may also be the optimal choice for this benchmark. Therefore, based on these results, the optimal number of clusters for both benchmarks appears to be around 6.

Table 2. Calinski/Harabasz pseudo-F values for the optimal number of clusters

N. of clusters	2	3	4	5	6	7	8	9	10
USA Bench.	146.8	128.7	154.0	161.5	264.5	242.7	233	262.4	193.3
G7 Bench.	162.1	151.0	140.5	351.8	379.7	369.9	338.2	338	309.4

***Source**: Calculated by the author*

The table 3 (and Appendix 2 and 3) presents the distribution of clusters for both the USA and G7 benchmarks, showing frequency, percentage, and cumulative percentage for each cluster along with the mean values for three different years: 2001, 2010, and 2014.

USA Benchmark: The majority of the countries fall into Cluster 1 (47.69%) and Cluster 4 (28.21%), with significantly lower percentages in the other clusters. The mean values for the 2001, 2010, and 2014 bases in Cluster 1 are negative, indicating a lower level of the measured variable, while Cluster 5 shows much higher positive mean values, reflecting distinct economic performance in those clusters.

G7 Benchmark: The distribution for the G7 countries is more balanced across clusters, with Cluster 3 (32.31%) being the most frequent. Cluster 1 shows very high positive values for all three years, indicating the economic strength of countries in this cluster. Meanwhile, the mean values for the other clusters vary, with negative values in Clusters 4 and 5, reflecting lower economic performance for those countries in the benchmarks.

Table 3.cluster Distribution and Summary Statistics for USA and G7 Benchmarks

	Frequency			Summary statistics: mean		
clusters	Freq.	Percent	Cum.	Base2001	Base2010	Base2014
			USA Benchmark			
1	93	47.69	47.69	-0.07797	-0.09841	-0.0839
2	4	2.05	49.74	-0.79646	-0.92005	-0.79903
3	17	8.72	58.46	-0.33009	-0.32086	-0.27012
4	55	28.21	86.67	0.159516	0.045615	0.010793
5	2	1.03	87.69	1.799809	1.376194	1.222977
6	24	12.31	100	0.580825	0.342234	0.244813

total	195	100		0.052638	-0.02468	-0.03424
			G7 Benchmark			
1	1	1	0.51	2.630405	2.533567	2.493969
2	2	28	14.36	0.710787	0.530701	0.436152
3	3	63	32.31	0.21158	0.183835	0.164973
4	4	32	16.41	-0.22266	-0.17284	-0.12559
5	5	4	2.05	-0.64434	-0.71257	-0.61935
6	6	67	34.36	0.010092	-0.00173	0.001892
total	195	100		0.137619	0.105013	0.096051

***Source**: Calculated by the author*

The results of the statistical tests (F-statistic and Bartlett's Chi-squared) for both the USA and G7 benchmarks show significant differences between clusters across all time periods (2001, 2010, and 2014). The F-statistics are high and significant at the 1% level, indicating that there are notable differences between the clusters for both the USA and G7 data. Additionally, Bartlett's Chi-squared values suggest that the variances across clusters are unequal, further supporting the finding of significant variation within the groups. These results highlight the heterogeneity of the clusters and confirm that the differences between them are statistically significant.

Table 4. ANOVA Results and Bartlett's Test for Equal Variances

Variable	F-statistic	Bartlett's Chi-squared
	USA Benchmark	
b2001us	267.44***	39.44***
b2010us	327.20***	100.12***
b2014us	218.17***	133.36***
	G7 Benchmark	
b2001g7	281.01***	56.59***
b2010g7	483.18***	56.77***
b2014g7	431.99***	38.36***

***Note**: Significance Levels: *p < 0.10, **p < 0.05, ***p < 0.01.*
***Source**: Calculated by the author*

4-4. Governance Indicators and Economic Response to the COVID-19 Shock: A Correlation Analysis

This section examines the relationship between governance quality and the economic response of countries to the COVID-19 shock using correlation analysis. The table 5 provides a comprehensive analysis of the correlation between key economic governance indicators and the Economic Catch-Up Shift Index, which measures the difference in alignment between countries' economies with the USA and G7 benchmarks before and after the COVID-19 pandemic. This analysis explores these correlations across four income groups: low income, lower middle income, upper middle income, and high income, drawing insights from both the economic data and relevant theoretical frameworks.

For low-income countries, the correlations generally show a strong alignment with governance indicators such as Control of Corruption, Rule of Law,

and Government Effectiveness with both USA and G7 benchmarks, especially in earlier periods. The strongest positive correlations are observed with Control of Corruption and Government Effectiveness (with 0.65* and 0.68* correlations with the USA in 2001, respectively). These findings support the view in development economics that improvements in governance are crucial for economic catch-up. Corruption control and effective governance are typically seen as essential in enabling these countries to align more closely with high-income economies, as they foster a more stable and competitive environment conducive to growth. Interestingly, Regulatory Quality also shows significant positive correlations, suggesting that regulatory improvements—such as those that reduce bureaucratic inefficiencies—are associated with better alignment with the reference economies. This is in line with theoretical perspectives on market efficiency and institutional economics, which argue that sound regulatory frameworks are necessary for economic development and integration into global markets. However, governance dimensions like Political Stability No Violence and Voice and Accountability show weak correlations, implying that while governance factors are important, political stability and accountability might not have as immediate an effect on the post-pandemic economic catch-up in low-income countries. For lower middle-income countries, indicators of good governance were not significantly correlated with their rate of change in the economic catch-up index. In this group of countries, the mortality rate variable had the highest correlation. Countries with higher mortality rates moving further away from the reference economy.

Upper middle-income countries show somewhat stronger positive correlations with Regulatory Quality, Government Effectiveness, and Control of Corruption, similar to low-income countries, but with some variation in the magnitude of these correlations. This pattern suggests that these countries, while better positioned than lower-income countries, still face challenges in aligning with advanced economies in the aftermath of the pandemic. Interestingly, these countries show a slight negative correlation with Voice and Accountability, which could suggest that political accountability mechanisms, such as public participation in governance, may play a less direct role in economic alignment post-COVID.

Finally, high-income countries show relatively weak or negative correlations with most governance indicators, particularly Rule of Law, Control of Corruption, and Government Effectiveness, which are often seen as strong determinants of economic performance. However, in the context of post-pandemic recovery, the slight negative correlations (e.g., -0.25 for Rule of Law with the USA) may reflect the challenges even high-income countries face in adjusting their institutional frameworks in response to the pandemic's economic fallout. Political Stability No Violence shows strong negative correlations in these countries, which suggests that political instability, perhaps due to rising inequality or social unrest during the pandemic, might have been a more significant challenge to economic convergence than expected. Other studies have also confirmed that governance

indicators have had a very important effect on how the COVID shock affects countries' economies, for example, studies can be cited Liu et al. (2023), Sunge et al., (2024) and Gebka et al., (2024).

In terms of COVID-19 death per capita, the health crisis shows a varied impact across income groups. While the correlations are generally weak, they do indicate a significant negative impact in lower middle-income countries, which is consistent with the argument in health economics that pandemics disproportionately affect countries with weaker health systems, further hindering their economic alignment with advanced economies.

The Global Innovation Index reveals a strong positive correlation with high-income countries, particularly in the upper middle-income group, which is in line with theories that emphasize the importance of innovation as a driver of economic growth and convergence. For high-income countries, innovation serves as a key factor in maintaining competitive advantages and sustaining alignment with leading global economies, especially in the post-pandemic world where technological advancements have accelerated. On the other hand, lower middle-income and low-income countries show weaker correlations with the innovation index, underscoring the challenges these nations face in fostering innovation within their economies. Other studies also confirm this, for example, Daliri (2024) explores the catch-up effect, which suggests that incomes in emerging and developing countries will eventually converge with those of wealthier nations. It examines two key questions regarding the impact of COVID-19 on global economic catch-up and the role of innovation in this process. The results indicate that higher innovation levels significantly improve economic performance post-pandemic, with lower-middle-income countries benefiting the most. Specifically, increased innovation reduces the likelihood of diminished catch-up and enhances the chances of improved economic performance.

Table 5. Correlation test between catch-up path post COVID-19 and basic variables

		USA Benchmark			G7 Benchmark		
Income grope	Variable	B2001	B2010	B2014	B2001	B2010	B2014
Low income	RoL	0.56**	0.58**	0.56**	0.56**	0.58**	0.57**
	CoC	0.65***	0.66***	0.65***	0.65***	0.67***	0.66***
	RQ	0.49*	0.51**	0.50**	0.48*	0.51**	0.51**
	GE	0.68***	0.68***	0.64***	0.68***	0.69***	0.66***
	PSNV	0.33	0.32	0.29	0.32	0.32	0.30
	VaA	0.20	0.25	0.25	0.19	0.24	0.24
	CoD19	0.14	0.15	0.15	0.14	0.15	0.15
	GII	0.65**	0.58*	0.51	0.66**	0.60*	0.54
Lower Middle	RoL	-0.08	-0.06	-0.02	-0.08	-0.07	-0.04
	CoC	-0.08	-0.10	-0.09	-0.09	-0.10	-0.10
	RQ	-0.07	-0.05	-0.02	-0.07	-0.06	-0.04
	GE	-0.06	-0.04	-0.02	-0.07	-0.05	-0.03
	PSNV	-0.05	-0.03	-0.02	-0.06	-0.04	-0.03
	VaA	-0.06	-0.04	-0.02	-0.07	-0.05	-0.03

	CoD19	-0.25	-0.30*	-0.28	-0.25	-0.29*	-0.28
	GII	-0.07	-0.05	-0.03	-0.06	-0.05	-0.03
Upper Middle	RoL	0.10	0.16	0.11	0.11	0.15	0.10
	CoC	0.09	0.14	0.10	0.09	0.14	0.08
	RQ	0.24*	0.25*	0.21*	0.24*	0.25*	0.21*
	GE	0.27*	0.25*	0.20*	0.27*	0.25*	0.21*
	PSNV	0.01	0.02	-0.03	0.01	0.02	-0.02
	VaA	-0.14*	0.00	-0.03	-0.13*	-0.02	-0.08
	CoD19	0.09	0.10	0.11	0.09	0.09	0.10
	GII	0.59***	0.58***	0.57***	0.59***	0.58***	0.58***
	RoL	-0.25*	-0.21	-0.22	-0.28*	-0.26*	-0.26*
	CoC	-0.19	-0.14	-0.14	-0.23*	-0.20*	-0.21*
High income	RQ	-0.18	-0.19	-0.20	-0.18	-0.19	-0.20
	GE	-0.22*	-0.19	-0.19	-0.24*	-0.23	-0.23
	PSNV	-0.29*	-0.29*	-0.31*	-0.30*	-0.31*	-0.33***
	VaA	0.04	0.06	0.03	0.03	0.05	0.02
	CoD19	0.18	0.17	0.16	0.21	0.21	0.20
	GII	0.04	0.14	0.15	-0.01	0.05	0.04

***Note**: Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01. B2001: pre Covid-19 is 2001-2019; B2010: pre Covid-19 is 2010-2019; B2014: pre Covid-19 is 2014-2019. **RoL**: Rule of Law, **CoC**: Control of Corruption, **RQ**: Regulatory Quality, **GE**: Government Effectiveness, **PSNV**: Political Stability No Violence, **VaA**: Voice and Accountability // GII: Global Innovation Index// CoD19: COVID-19 death per capita.*
***Source**: Calculated by the author*

In summary, the analysis reveals that governance factors, particularly Control of Corruption, Government Effectiveness, and Regulatory Quality, are critical for economic convergence, particularly in low-income and upper middle-income countries. However, the impact of political factors and health crises on economic alignment is more complex, with varying effects across different income groups. High-income countries, despite having robust institutions, still face significant challenges in maintaining economic convergence post-pandemic, while lower-middle and low-income countries face institutional and governance-related hurdles that inhibit their alignment with advanced economies. These findings align with both institutional and development economics theories, which highlight the essential role of effective governance and innovation in shaping economic outcomes, especially in the context of global crises such as the COVID-19 pandemic.

5. Conclusion

This study provides a comprehensive analysis of the impact of the COVID-19 pandemic on economic catch-up dynamics across different income groups, using GDP per capita as a comparative benchmark against two reference economies: the United States (USA) and the G7. The results reveal distinct patterns of convergence and divergence, contingent on income level, region, and the chosen benchmark.

For low-income countries, the pandemic exacerbated divergence from the USA, with most countries experiencing slower economic catch-up. However, relative to the G7, some countries exhibited minor convergence, suggesting the inclusivity of the G7 as a benchmark for these economies. Among lower-middle-income countries, notable heterogeneity was observed. While some countries, like Bangladesh and Vietnam, achieved significant catch-up with both benchmarks, others, such as Angola and Haiti, demonstrated persistent divergence, largely attributable to structural constraints and governance challenges.

Upper-middle-income countries displayed relative stability, with limited changes in their catch-up dynamics. While countries like China and Turkmenistan maintained positive trajectories, others, such as Equatorial Guinea, faced setbacks. These findings underscore the critical role of structural resilience and diversified economic bases in mitigating pandemic shocks.

For high-income countries, a divergence from the USA's economic trajectory was evident across all periods. Conversely, these countries showed notable convergence with the G7, reflecting stronger institutional and economic integration within the G7 framework. This divergence-convergence duality highlights the varying nature of recovery pathways and the importance of regional and institutional alignments.

The clustering analysis revealed six distinct recovery trajectories among 194 countries, underscoring the asymmetric impact of the COVID-19 pandemic on economic catch-up dynamics. Low- and lower-middle-income countries, particularly in Sub-Saharan Africa and fragile states, formed clusters marked by persistent divergence from the USA benchmark, driven by structural vulnerabilities and governance deficits. In contrast, select emerging economies (e.g., Vietnam, Bangladesh) exhibited resilience, aligning more closely with the G7 benchmark due to policy adaptability and institutional reforms. High-income nations clustered into groups reflecting divergence from the USA but convergence within the G7, highlighting the role of regional economic integration. Upper-middle-income countries, such as China and Turkmenistan, demonstrated stability, leveraging diversified economies and innovation. These findings emphasize that post-pandemic recovery is not uniform but shaped by income levels, governance quality, and benchmark selection, reinforcing the need for tailored policy interventions to address divergent trajectories.

Examining the correlation between governance indicators and the degree to which countries change direction after COVID-19 shows that governance indicators like Control of Corruption, Government Effectiveness, and Regulatory Quality are crucial for economic convergence, particularly in low- and upper middle-income countries. However, political stability, Voice and Accountability, and health crises show varying impacts across income groups, with lower middle-income countries being disproportionately affected by COVID-19 mortality rates. High-income countries face challenges in maintaining convergence post-pandemic despite robust institutions, while innovation emerges as a key driver for

upper middle- and high-income economies, emphasizing the interplay of governance and innovation in shaping economic recovery and alignment.

In sum, the study underscores the pandemic's asymmetric impact on global economic dynamics, with significant policy implications. For developing countries, strengthening structural resilience, governance, and economic diversification is critical. For developed countries, fostering international cooperation and maintaining robust institutional ties within global economic blocs like the G7 remain essential.

Based on the research findings, the following policy recommendations can be made: 1-Institutional Strengthening: Low- and lower-middle-income countries must prioritize governance reforms, including anti-corruption measures and regulatory efficiency, to enhance resilience against external shocks. 2- Innovation and Digitalization: Upper-middle- and high-income economies should invest in R&D, digital infrastructure, and technology adoption to sustain growth and global competitiveness. 3- Regional and Global Collaboration: Policymakers should promote multilateral frameworks for debt relief, technology transfer, and coordinated fiscal responses to reduce disparities exacerbated by pandemics. 4-Health System Preparedness: Lower-income nations require international support to bolster healthcare capacity, mitigating the economic fallout from health crises. 5-Diversification Strategies: Structurally vulnerable economies, particularly those reliant on narrow sectors, must diversify production and export bases to reduce exposure to global shocks.

The study has several limitations. First, the post-COVID data (2020–2023) remains incomplete, constraining the ability to analyze long-term economic recovery trends with certainty. Second, governance and innovation indicators, such as the Worldwide Governance Indicators, may not fully capture the rapid institutional adaptations and policy shifts that occurred during the pandemic. These limitations suggest several avenues for future research. Incorporating post-2023 economic and health datasets would provide a more comprehensive assessment of long-term recovery trajectories. Additionally, utilizing composite indices, such as green economy metrics and digital resilience indicators, could offer deeper insights into emerging post-pandemic economic priorities. Furthermore, comparative analyses with concurrent global crises, such as climate change and geopolitical tensions, would help disentangle the effects of multidimensional external shocks on economic resilience and recovery.

Author Contributions

Conceptualization, methodology, validation, formal analysis, resources, supervision by H. Daliri.

Funding

This research was conducted with financial support from Golestan University under project number.

Conflicts of Interest
The authors declare no conflict of interest.

Data Availability Statement
The data supporting the findings of this study are available upon reasonable request from the corresponding author.

Acknowledgements
Not applicable

References
Acemoglu, D., & Robinson, J. A. (2012). *Why Nations Fail: The Origins of Power, Prosperity, and Poverty*. Crown Publishing Group.

Acemoglu, D., Johnson, S., & Robinson, J. A. (2003). Disease and development in historical perspective. *Journal of Economic History, 63*(3), 635-678.

Aghion, P., Antonin, C., & Bunel, S. (2021). *The power of creative destruction: Economic upheaval and the wealth of nations*. Harvard University Press.

Baldwin, R., & W. di Mauro, B. (2020). *Economics in the Time of COVID-19*. CEPR Press.

Baldwin, R., & W. di Mauro, B. (2020). Mitigating the COVID Economic Crisis: Act Fast and Do Whatever It Takes. *CEPR Press*.

Barro, R. J., & Sala-i-Martin, X. (1992). Convergence. *Journal of Political Economy*, *100*(2), 223–251.

Barro, R. J., & Sala-i-Martin, X. (1995). *Economic Growth*. McGraw-Hill.

Bitler, M. P., Hoynes, H. W., & Schanzenbach, D. W. (2020). *The social safety net in the wake of COVID-19*. *Brookings Papers on Economic Activity*, 2020(2), 119-145.

Brodeur, A., Gray, D., Islam, A., & Bhuiyan, S. (2021). *A literature review of the economics of COVID-19*. *Journal of Economic Surveys*, 35(4), 1007-1044.

Brussevich M. and Liu S. and, Papageorgiou C. (2022). Income Convergence or Divergence in the Aftermath of the COVID-19 Shock?, *Working Paper* No. 2022/121

Caliński, T., & Harabasz, J. (1974). A dendrite method for cluster analysis. *Communications in Statistics*, 3(1), 1–27. https://doi.org/10.1080/03610927408827101.

Cerra, V., & Saxena, S. C. (2008). Growth dynamics: The myth of economic recovery. *American Economic Review*, *98*(1), 439-457.

Cerra, V., Fatás, A., & Saxena, S. C. (2022). Hysteresis and Business Cycles. Journal of Economic Perspectives, 36(1), 3-28.

Chetty, R., Friedman, J. N., Hendren, N., Stepner, M., & The Opportunity Insights Team. (2024). *The economic impacts of COVID-19: Evidence from a new public database built using private sector data*. *The Quarterly Journal of Economics*, 139, Issue 2, 829–889, https://doi.org/10.1093/qje/qjad048.

Daliri, H. (2024). The Role of Innovation in Changing the Path of Economic Catch-Up after the COVID 19 Pandemic. *Innovation Economic Ecosystem Studies*, 4(3), 1-18. doi: 10.22111/innoeco.2025.50062.1126

Diao, X., McMillan, M., & Rodrik, D. (2018). The recent growth boom in developing economies: A structural-change perspective. In G. Fields & G. Pfeffermann (Eds.), The role of global firms in global development (pp. 17-55). Oxford University Press.

Easterly, W., & Levine, R. (2003). Tropics, germs, and crops: How endowments influence economic development. *Journal of Monetary Economics*, *50*(1), 3-39.

Fernandes, N. (2020). *Economic effects of coronavirus outbreak (COVID-19) on the world economy*. *IESE Business School Working Paper No. WP-1240-E*.

Frankel, J. A., & Romer, D. (1999). Does trade cause growth? *American Economic Review*, *89*(3), 379-399.

Furceri, D., Loungani, P., Ostry, J. D., & Pizzuto, P. (2021). Will COVID-19 Have Long-Lasting Effects on Inequality? IMF Working Paper Series.

Gebka B. and R. P. Kanungo and J. Wildman (2024), The transition from COVID-19 infections to deaths: Do governance quality and corruption affect it?, *Journal of Policy Modeling*, 46, 2, 2024, 235-253.

Gerschenkron, A. (1962). *Economic Backwardness in Historical Perspective*. Belknap Press.

Gill, I. S., & Kharas, H. (2007). *An East Asian renaissance: Ideas for economic growth*. World Bank Publications.

Gopinath, G. (2020). The great lockdown: Worst economic downturn since the Great Depression. *IMF Blog*.

Hayashi, F., & Prescott, E. C. (2002). The 1990s in Japan: A lost decade. *Review of Economic Dynamics*, *5*(1), 206-235.

Huang H., L. Zhao, (2024). Does digital innovation help firms navigate the COVID-19 pandemic? Evidence from China, *Emerging Markets Review*, 62, 101171, https://doi.org/10.1016/j.ememar.2024.101171

International Monetary Fund (IMF). (2021). World Economic Outlook: Managing Divergent Recoveries.

Jawad M., and M. Naz (2023), Impact of Covid-19 pandemic on macroeconomic aspects, *Journal of Open Innovation: Technology, Market, and Complexity*, 9, 3, 100126, https://doi.org/10.1016/j.joitmc.2023.100126

Jordà, Ò., Singh, S. R., & Taylor, A. M. (2020). Longer-run economic consequences of pandemics. *NBER Working Paper No. 26934*.

Kant C. (2019). Income convergence and the catch-up index, *The North American Journal of Economics and Finance*, 48, 613-627.

Kraay, A., & McKenzie, D. (2014). Do poverty traps exist? Assessing the evidence. *Journal of Economic Perspectives*, 28(3), 127-148.

Lee, K. (2019). Economics, Economic Development and Growth, International Business, Management, *Cambridge University Press*

Lee S. M. and S. Trimi (2021). Convergence innovation in the digital age and in the COVID-19 pandemic crisis, *Journal of Business Research*, 123, 14-22, https://doi.org/10.1016/j.jbusres.2020.09.041

Liu L. and H. Zheng and Y. Peng and F. Zhu and T. Xue (2024). Different patterns of national innovation under COVID-19: The moderating role of culture, *International Journal of Intercultural Relations*, 103, 102058, https://doi.org/10.1016/j.ijintrel.2024.102058

Liu C., X. Sun, Q. Feng, X. Yao (2023). How did the macroeconomic sectors respond under the pandemic in China? Evidence from FAVAR model, *Procedia Computer Science*, 221, 488-492, https://doi.org/10.1016/j.procs.2023.08.005

Liu, W. and Y. Chu (2024). FinTech, economic growth, and COVID-19: International evidence, *Asia Pacific Management Review*, 29, 3, 362-367

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics, 22*(1), 3–42.

MacQueen, J. B. (1967). Some methods for classification and analysis of multivariate observations. In L. M. Le Cam & J. Neyman (Eds.), Proceedings of the fifth Berkeley symposium on mathematical statistics and probability (Vol. 1, pp. 281–297). California: University of California Press.

Maldonado, J. E., Vandeplas, A., & Vogel, L. (2021). *The economic impact of COVID-19 learning deficits: A survey of the literature*. *European Commission Directorate-General for Economic and Financial Affairs*.

Martinho V. J. P. D. (2021). Impact of Covid-19 on the convergence of GDP per capita in OECD countries, *Regional Science Policy & Practice*, 13, 55-72, https://doi.org/10.1111/rsp3.12435

Mitze, T., & Makkonen, T. (2021). *Can large-scale R&I funding stimulate post-crisis recovery growth? Evidence for Finland during COVID-19*. *arXiv preprint arXiv:2112.11562*.

OECD. (2021). The Economic Impacts of COVID-19: Lessons Learned from the Pandemic. *OECD Publishing*.

Pichler, A., Pangallo, M., del Rio-Chanona, R. M., Lafond, F., & Farmer, J. D. (2020). Production networks and epidemic spreading: How to restart the UK economy?. *arXiv preprint arXiv:2005.10585*.

Pritchett, L. (1997). Divergence, big time. *Journal of Economic Perspectives*, 11(3), 3–17.

Ramey, G., & Ramey, V. A. (1995). Cross-country evidence on the link between volatility and growth. *American Economic Review*, *85*(5), 1138-1151.

Reinhart, C. M., & Rogoff, K. S. (2009). *This Time is Different: Eight Centuries of Financial Folly*. Princeton University Press.

Rodrik, D. (1999). Institutions for high-quality growth: What they are and how to acquire them. *Studies in Comparative International Development, 35*(3), 3-31.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5, Part 2), S71–S102.

Rousseeuw P. (1987). Silhouettes: A graphical aid to the interpretation and validation of cluster analysis, *Journal of Computational and Applied Mathematics*, 20, 53-65

Sala-i-Martin, X. (1996). The classical approach to convergence analysis. *Economic Journal*, *106*(437), 1019–1036.

Solow, R. M. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, *70*(1), 65–94.

Sunge R., C. Mudzingiri, N. Mkhize (2024), The COVID-19 pandemic and economic recovery: The mediating role of governance, a global perspective, Heliyon, 10, 22, e39869, https://doi.org/10.1016/j.heliyon.2024.e39869

World Bank. (2022). World Development Report 2022: Finance for an Equitable Recovery.

Zheng H. (2023).Sovereign debt responses to the COVID-19 pandemic, *Journal of International Economics*, *143*, *103766*, https://doi.org/10.1016/j.jinteco.2023.103766.

Appendix 1: Country clustering results when the US is the benchmark

Cluster 1: BDI, CAF, GMB, LBR, MDG, MWI, MLI, MOZ, SLE, SOM, BOL, CPV, CMR, COM, HTI, HND, JOR, KGZ, MRT, FSM, MAR, NIC, NGA, PNG, WSM, STP, SLB, TUN, VUT, PSE, ZMB, ZWE, DZA, ARG, AZE, BLZ, BWA, BRA, CUB, DMA, ECU, FJI, GAB, GRD, IRN, IRQ, JAM, LBY, MDV, MEX, NAM, PER, ZAF, LCA, TON, UKR, AND, ATG, AUS, AUT, BHS, BHR, BRB, BEL, BRN, CAN, CHL, DNK, FIN, FRA, DEU, GRC, HKG, ISL, ITA, JPN, KWT, LUX, NLD, NZL, NOR, OMN, PRT, PRI, SAU, SYC, ESP, KNA, SWE, CHE, ARE, GBR, URY.

Cluster 2: GNQ, GRL, IMN, MAC.

Cluster 3: TCD, SDN, YEM, AGO, COG, LBN, LSO, SUR, ABW, BMU, CUW, PYF, MCO, PLW, QAT, SMR, TTO.

Cluster 4: BFA, COD, GNB, NER, TGO, UGA, BEN, BTN, CIV, EGY, SWZ, GHA, GIN, KEN, KIR, MMR, NPL, PAK, PHL, SEN, LKA, TZA, BLR, COL, CRI, DOM, SLV, GTM, IDN, KAZ, MYS, MUS, MNG, MNE, MKD, PRY, VCT, THA, TUV, HRV, CYP, CZE, EST, HUN, ISR, KOR, LVA, MLT, NRU, PAN, RUS, SGP, SVK, SVN.

Cluster 5: CHN, GUY.

Cluster 6: ETH, RWA, BGD, KHM, IND, LAO, TJK, TLS, UZB, VNM, ALB, ARM, BIH, GEO, MHL, MDA, SRB, TUR, TKM, BGR, IRL, LTU, POL, ROU.

Appendix 2: Country clustering results when the G7 is the benchmark

Cluster 1: GUY

Cluster 2: ETH, RWA, BGD, KHM, IND, LAO, TJK, UZB, VNM, ARM, CHN, GEO, TKM, BGR, HRV, EST, HUN, IRL, KOR, LVA, LTU, MLT, NRU, PAN, POL, ROU, SGP, SVK.

Cluster 3: BFA, BEN, BTN, CIV, EGY, SWZ, GHA, GIN, KEN, KIR, MMR, NPL, PAK, PHL, SEN, TZA, TLS, ALB, BIH, DOM, IDN, MHL, MDA, MNG, MKD, SRB, TUR, ATG, AUS, AUT, BHR, BEL, CAN, CHL, CYP, CZE, DNK, FIN, FRA, DEU, GRC, HKG, ISL, ISR, ITA, JPN, LUX, NLD, NZL, NOR, PRT, PRI, RUS, SAU, SYC, SVN, ESP, KNA, SWE, CHE, GBR, USA, URY.

Cluster 4: BDI, CAF, TCD, SDN, YEM, AGO, COG, HTI, JOR, LBN, LSO, WSM, PSE, DZA, ARG, BLZ, DMA, GAB, IRQ, JAM, LBY, NAM, ZAF, LCA, SUR, UKR, ABW, BMU, CUW, PYF, QAT, SMR.

Cluster 5: GNQ, GRL, IMN, MAC.

Cluster 6: COD, GMB, GNB, LBR, MDG, MWI, MLI, MOZ, NER, SLE, SOM, TGO, UGA, BOL, CPV, CMR, COM, HND, KGZ, MRT, FSM, MAR, NIC, NGA, PNG, STP, SLB, LKA, TUN, VUT, ZMB, ZWE, AZE, BLR, BWA, BRA, COL, CRI, CUB, ECU, SLV, FJI, GRD, GTM, IRN, KAZ, MYS, MDV, MUS, MEX, MNE, PRY, PER, VCT, THA, TON, TUV, AND, BHS, BRB, BRN, KWT, MCO, OMN, PLW, TTO, ARE.