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Economic Resilience in the Early Stage of the COVID-19 Pandemic: An Across-Economy Comparison

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Abstract: This paper evaluates the economic resilience of 52 economies based on 16 indicators in three dimensions (including the government, enterprises, and the public) and calculates their disaggregate output scores using the data envelopment analysis (DEA) method to measure and compare their economic resilience in the early stage of the COVID-19 pandemic. The evaluation results show that 23 of these economies had no room for further improvement in the overall economic resilience performance at that time. Germany's economic resilience performance, ranking 24th, is second only to these 23 economies, whereas Australia and Belgium are just behind Germany. These are the better performers among the 52 economies. Meanwhile, this paper also validates the notion that the construction of an economic resilience index is more suitable than the IMD World Competitiveness Index and the WEF Global Competitiveness Index in assessing the economic resilience of those economies during the COVID-19 pandemic. Therefore, it is more suitable for the sample countries to refer to the efficiency of each indicator in this article to formulate policy directions and goals, in order to strengthen their economic resilience under the epidemic. However, under the limitations of the COVID-19 epidemic at the time of writing this paper, the economic resilience scores measured in this paper still belong to resistance measures rather than recovery measures.

Keywords: economic resilience; COVID-19 pandemic; disaggregate output efficiency; aggregate output efficiency

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1. Introduction

The COVID-19 pandemic broke out in early 2020 and quickly spread to every corner of the world. With the exception of China, economies around the world have suffered from severe outbreaks of the pandemic in the United States, the European Union, Japan, South Korea, and the emerging economies, forcing them to take measures such as restricting commercial activities and restricting gatherings to combat the further spread of this pandemic. Such measures have undoubtedly dealt a major blow to the global economy. The pandemic has caused losses far exceeding those experienced during the 2003 SARS and the 2008–2009 financial tsunami. Although the global economy has gradually recovered from the bottom of the deep hole, most economies in the short term still have yet to return to the levels before the pandemic.

Although the pandemic still ravages and severely affects people's lives and livelihoods around the world, the people in Taiwan have been able to maintain a lifestyle not much worse than what they enjoyed before the pandemic, thanks to the advance planning and successful pandemic prevention of the government in Taiwan. Its economic performance has also exceeded expectations. From the perspective of overall economic performance, Taiwan's exports in 2020 in traditional manufacturing fell due to the sharp global economic recession and low demand in the first half of the year. However, as more economies

restart their economic activities, information and communication products have benefited from long-distance business opportunities and emerging technologies. The demand for applications has remained robust, and the export of information and electronic products is still showing double-digit growth. As for consumption, although the pandemic has severely hit international business and tourism and the Taiwanese have consumed sharply less in foreign economies, the domestic service industries have stopped their revenues from falling further, thanks to various revitalization programs. According to the International Monetary Fund (International Monetary Fund, IMF) data for July 2021, the global economy fell by an average of 3.3%, while 39 advanced economies showed a decline of 4.7% (Australia, Austria, Belgium, Canada, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, the Hong Kong Special Administrative Region, Iceland, Ireland, Israel, Italy, Japan, Korea, the Republic of Latvia, Lithuania, Luxembourg, the Macau Special Administrative Region, Malta, The Netherlands, New Zealand, Norway, Portugal, Puerto Rico, San Marino, Singapore, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Taiwan, the United Kingdom, and the United States), worse than the global average. Among them, the U.S. fell 3.5%, France fell 8.2%, Germany fell 4.9%, Japan fell 4.8%, the United Kingdom fell 9.9%, and Italy fell 8.9%. By comparison, Taiwan grew by 0.1 percentage point, showing that Taiwan's economic performance during the pandemic is better than that of the major advanced economies, which shows that Taiwan has been able to maintain the momentum of economic growth while successfully containing the pandemic.

Currently, only a simple narrative is available to analyze the above-mentioned expectation-shattering economic performance of Taiwan, but it is inadequate in explaining the key factors contributing to the economic growth under Taiwan's effective COVID-19 prevention measures. Economics Professor Charles I. Jones of Stanford University and Economics Professor Jesús Fernández-Villaverde of Penn State University pointed out in their official report published in October 2020 [1], in which they collected and cross-analyzed gross domestic product (GDP), unemployment rates, Google's COVID-19 Community Mobility Reports, and the COVID-19 mortality data, the impact of the pandemic on the economies of economies around the world. They showed that the confirmed mortality rate correlates positively to economic losses, indicating that the prevention of the pandemic is an important factor in controlling economic losses. Of the economies analyzed, Taiwan has extremely few deaths per million people, and it is the only country showing positive growth in GDP. This report concluded that the policies implemented by the government and the information provided by the government will affect the self-protection behavior of the general public. When a country effectively adopts a "non-drug intervention" policy, the pandemic can be controlled, and its overall economic loss will be reduced. Taiwan, South Korea, and Germany have adopted "non-drug intervention" policies to effectively control the pandemic, taking measures such as advanced deployment, active quarantine, and using big data to track contacts; their achievements have been internationally recognized.

However, from another point of view, many other economies other than Taiwan in that report also had low mortality rates during the pandemic, such as the Slovak Republic, New Zealand, Singapore, China, Japan, and South Korea, but they showed a 1% to 5% economic recession during the same period. This indicates that besides pandemic prevention performance, there may be other factors that helped Taiwan perform economically better than those economies. In terms of literature research, in related research in the past on regional resilience or economic resilience, the determining factors of regional or economic resilience were mainly discussed in theory or in empirical data studies in the explorations of the important factors that affect the performance of regional or economic resilience for a country or region in the face of economic or financial crises (such as the 2008 global financial tsunami). The main factor causing the current global economic recession is the spread of the COVID-19 virus, which is quite different from the economic or financial factors in the past.

In 2020, President Tsai Ing-wen was invited to write an article for *Time* magazine about Taiwan's experience in pandemic prevention. She emphasized that the success of

Taiwan's pandemic prevention efforts was due primarily to the unity and cooperation of the Taiwanese people, including the government, enterprises, and the public, working together to surmount difficulties.

In order to analyze the important factors that make the economic performances of different economies significantly different under the epidemic, this paper intends to construct an overall indicator containing multiple economic-related data to measure and compare the economic resilience of various economies in the face of the COVID-19 epidemic. Meanwhile, by analyzing and comparing the contents of the indicators, the paper provides an important reference for policy makers to formulate policies. The DEA method has been widely applied to generate an aggregate score from multiple performance indicators [2]. This paper then will demonstrate how to apply an output-oriented DEA model to measure and compare the economic resilience scores across economies in the world in the early stage of the COVID-19 pandemic.

Therefore, this paper will take into account the multiple aspects of enterprises, the public, and the governments. Through data indicators aggregated from statistics and survey data, we try to establish observational indicators in three dimensions about enterprises, the public, and the governments and use the DEA method to calculate the efficiency scores [2] in order to construct an indicator as a measure of the economic resilience of a country under the pandemic. We also explore how a country may demonstrate strong economic resilience during the pandemic. At the same time, because the main factors causing the current global economic recession are quite different from the economic or financial factors in the past, the selection of indicators for measuring economic resilience under the pandemic will be based on both past literature research and the opinions and insights put forth by current international appraisals or research institutions.

Moreover, by treating multiple performance indicators as outputs, an economy with an aggregate economic resilience score less than one must have some disaggregate output efficiency scores of less than one. We will then be able to tell the aspects in which this economy can improve and take as its priorities to enhance its economic resilience. Therefore, this paper can find concrete aspects for an economy to enhance its economic resilience.

At the time of writing this paper, the COVID-19 pandemic has not yet fully slowed down. Therefore, the statistics and survey data are available only for the periods before the pandemic and during the pandemic, and the data after the pandemic are necessarily not yet available. Under such constraints, this paper can only use the extent of the pandemic's impacts on the economy as the main indicator to measure economic resilience.

This paper found that of the 52 subject economies, 23 economies, including Taiwan, had no room for further improvement in the overall economic resilience performance at that time. Germany's economic resilience performance, ranked 24th, was second only to these 23 economies. Australia and Belgium immediately follow Germany. These 26 economies are in the top tier of the 52 economies. This paper also validates the notion that the construction of an economic resilience index is more suitable than the IMD World Competitiveness Index and the WEF Global Competitiveness Index in assessing the economic resilience of those economies during the COVID-19 pandemic. This paper takes economies as the decision-making units (DMUs) and then computes the economic resilience score of each economy under the epidemic in order to provide a reference for policymakers to plan future policies.

The structure of this paper is as follows. Section 2 reviews the related discussions and analyses of regional or economic resilience in the literature. Section 3 lays out the construction principles, the methods, and the data selection and sources of economic resilience indicators under the pandemic. Section 4 shows the results of the data aggregation, as well as the presentation and analysis of the construction indicators. Section 5 is the conclusion.

2. Literature Review

The ability to respond and adapt to economic shocks varies by country. Rose [3] coined the term resilience in the research of the economic environment to study the economic

impact of earthquakes on local communities. In the study of regional economies, Christopherson et al. [4], Martin [5], and others discuss the so-called regional economic resilience. They believe that at least four dimensions are needed to capture the regional economic resilience associated with the shocks of a recession, namely resistance, recovery, renewal, and reorientation. Cooke [6] defines resilience as the technology that is constantly adapting to the economies of the region and the market's ability to withstand competitive pressure, emphasizing the interactions of knowledge horizontally and vertically, which requires a series of policy tools and the implementation of measures. Di Caro's [7] analysis of multiple regions in Italy concludes that several common factors affect resilience: infrastructure, innovation, skilled labor, and a robust financial system. Martin and Sunley [8] proposed that the resilience of a region depends on local characteristics, including connectivity with other regions. Martin et al. [9] use the structural adjustment index to reflect the application of changes in industrial structure to the study of regional economic resilience.

In 2008, the same financial crisis hit European countries, but they showed different economic resilience. Scholars are speeding up the discussion of the impact of resilience on regional economies. For example, Capello et al. [10] studied the role of European cities in regional resilience during the financial crisis; they found that the quality of the essential elements for production, the density of external cooperative networks, and the quality of urban infrastructure had all contributed to stronger economic resilience. Davies [11] studied the impact of the 2008–2010 economic recession on various regions in Europe and found that the correlation between the resilience, regional strength, and vulnerability of each country was different. Regions with more construction industries showed low resilience when they were hit by the asset bubbles. In addition, fiscal policies in response to economic recession have a significant regional impact, but the degree of which varied because political factors and institutional structures were different in various countries. Han and Goetz [12] used the ratio of the decline and rebound of employment rates to estimate the economic resilience of various regions in the United States during the financial tsunami.

In a more recent study, Bristow and Healy [13] conducted an empirical study on regional innovation capabilities and Europe's resilience in the 2007 economic crisis; they found that the regions with innovative leaders were more likely to resist or recover from crises. Rizzi et al. [14], in a principal component analysis, obtained three determinants of economic, social, and environmental resilience in 248 EU regions, and they used such data to measure the resilience performance of each region. Of them, the driving force for economic resilience mainly came from the average gross fixed capital per employee, the proportion of employees in technology industries, education level, and R&D expenditures. Fritzsch [15] studied the resilience after the crisis and explored the reasons for the different speeds and degrees of recovery in various countries, and he found that countries with a stricter rule of law and more complete rules and regulations had been more severely hurt in the financial crises, but they had also shown higher resilience. Han and Goetz [16] used data in input–output tables to calculate the centrality of industries in various parts of the United States and used the basic model of Goetz et al. [17] to find that the centrality of local industries had a significant positive impact on economic resilience. Bristow and Healy [18] explored the importance of agents for resilience, and creation and invention, as traits of humans, played an important role in it. Oprea et al. [19] used Quantiles Regression to analyze the economic resilience of seven Eastern European countries (Bulgaria, Hungary, Croatia, the Czech Republic, Romania, the Slovak Republic, and Slovenia). The determining factors of resilience mainly involved the scale of manufacturing, service, public administration, entrepreneurship, and human capital.

On the topic of Regions and Economic Resilience, Mayor and Ramos [20] presented a summary of several recent articles on regional and economic resilience, noting that the performance of the financial sector in the Italian region may mitigate the impact of the crisis. The economic impact, helping SMEs to enter the credit market, illustrates the importance of the financial environment for SMEs when a crisis occurs [21]. In China, it is different from the previous literature in that the economic resilience of an economy with a single industrial

structure may be lower [22], whereas the diversification of industries may not help buffer the systemic risks caused by the crisis [23]. In China, regional financial development has a positive impact on economic resilience. The variables, such as per capita GDP, fiscal revenue, actual use of foreign capital, residents at the end of the year, savings balance, education level, and the number of international internet users, are also suitable indexes for measuring urban resilience [24,25]. Wang and Li [26] studied data from the 2007–2008 financial crisis and found that there were five important determinants of economic resilience in each province: income inequality, innovation, government intervention, human capital, and financial development. Gong et al. [27] study the recent situation under the COVID-19 situation, arguing that past experience of coping with the disease pandemic, government support measures, and regional industrial structure will have an impact on the recovery and resilience rates in China. In addition, Di Pietro et al. [28] find that in the Europe, the proportion of regional capital-intensive industries, the degree of openness to foreign trade, and specialization are important driving factors for regional economic resilience. Martin and Gardiner [29] indicate that the difference in the economic resilience of the UK cities mainly comes from the degree of dependence on manufacturing. The greater the degree of dependence, the lower the resilience. However, skills, productivity, patents, and urban size and density are not empirically found to be the key determinants of urban economic resilience.

Regarding the survey reports of international rating agencies, the International Institute for Management Development (IMD) in Switzerland publishes the "World Competitiveness Annual Report" between May and June of each year. Regarding resilience performance, Arturo Bris, director of the IMD Global Competitiveness Center, said that the top five countries from the 2020 global ranking show that in the current global virus pandemic the small economies have demonstrated their competitiveness against the pandemic, which may be partly attributed to the fact that "It's easy to build social consensus" in these economies [30].

In response to the impact of the pandemic in 2020, the World Economic Forum (WEF) in Switzerland cancelled its World Competitiveness Report and instead issued a 'special report' [31], in which it stated that five traits had made a country more capable of showing economic resilience. The first trait is "the capabilities of a digital nation". An economy can maintain economic operations through remote work and the possession of good technological capabilities to monitor the spread of diseases, which will help demonstrate the resilience of the economy. The second trait is "a complete social safety net and financial systems." If an economy has a complete social safety net and financial systems, it can provide individuals and companies with timely access to financial resources to prevent large-scale unemployment and bankruptcy. The third trait is "the nation's ability to plan and deal with crises". Countries are faced with the pressure to keep a good balance between public health and economic activities, testing their ability to respond to the crisis. The fourth trait is a robust medical care system, to which the public have ready access. The final trait is that if an economy is experienced in pandemic prevention, it will be more capable of responding to the pandemic crisis.

In 2019, the Swiss Re Institute and the London School of Economics and Political Science jointly developed the Total Economic Resilience Index (E-RI), which weighted and averaged the annual data of 31 advanced and emerging economies from 2007 to 2018, including slack in fiscal budgets, slack in monetary policies, the banking environment, labor market efficiency, financial market development, economic complexity, depth of insurance, human capital, low-carbon economy, and other indicators, to develop the main indicator of global economic resilience. The indicator showed that the 2020 COVID-19 (Wuhan pandemic) has led to drastic changes in global economic resilience. Although large-scale stimulus plans have softened the global economic shock, they have also weakened the level of global resilience, leading to a 20% decline in global resilience in 2020 from 2019.

From the above review, it can be seen that when using a single indicator to measure economic resilience, GDP changes, GDP growth rate fluctuations, and labor market

fluctuations are mainly used to measure the ability to resist market, competition, and environmental shocks or the ability to return to its growth path. On the other hand, when using composite indicators to measure economic resilience, the formation of fixed capital per person, employment in the technology sector, the education level of the public, and R&D expenditure are the indicators often employed. To explore the determining factors of economic resilience, people often use infrastructure, land area, government fiscal conditions, the legal system, innovation capabilities, skilled labor, financial systems, industrial structure, industrial complexity, industrial centrality, entrepreneurship, and human capital.

However, in light of the reports of international organizations after the outbreak of the COVID-19 pandemic, it may be necessary to consider other aspects or indicators when discussing the economic resilience of an economy under the pandemic, possibly focusing on the financing environment, the digital capabilities of enterprises and the public, the ability of enterprises to respond to crises, the government's fiscal slack, and the planning and practical capabilities of government policy tools. Therefore, this paper hopes to build on the relevant literature and reports from international organizations in the past and construct indicators to measure economic resilience under the pandemic so as to explore how an economy may demonstrate strong economic resilience in the face of a pandemic.

The Materials and Methods should be described with sufficient details to allow others to replicate and build on the published results. Please note that the publication of your manuscript implicates that you must make all materials, data, computer code, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.

Research manuscripts reporting large datasets that are deposited in a publicly available database should specify where the data have been deposited and provide the relevant accession numbers. If the accession numbers have not yet been obtained at the time of submission, please state that they will be provided during review. They must be provided prior to publication.

Interventional studies involving animals or humans, and other studies that require ethical approval, must list the authority that provided approval and the corresponding ethical approval code.

3. Research Method and Data Source

3.1. Research Method

This paper summarizes the content of the referenced analyses and reports and tries to show the economic resilience via the three dimensions of the government, enterprises, and the public in the face of the pandemic. As for the selection of detailed indicators, this paper reviews relevant research literature, summarizes the data indicators used by major evaluation institutions, and classifies the data into three dimensions: the government, enterprises, and the public. The dimensional data are studied and calculated, and international comparisons are made.

Regarding the calculations of the dimensional indicators, this paper attempts to design and measure the three main quantitative indicators of resilience and establish an indicator system, the indicators of which are integrated into an indicator with economic implications. These indicators may help us understand the resilience of Taiwan and other economies. However, if the indicators in the measurement system are averaged and aggregated directly, partial errors will obviously occur because each condition indicator in the measurement process may play a different role and carry different significance. Additionally, reports from the IMD, WEF, and other international organizations and the current situation in various economies show that when an economy wants to show economic resilience in the face of the pandemic, the three dimensions—the government, enterprises, and the people—are not unrelated, but instead are mutually influencing each other.

For example, in an economy with a complete financial system, although corporate financing is quite easy in normal times, in the face of a global crisis such as COVID-19 if the government does not promote supportive financial policies in a timely manner, then even if there is good financing the environment may not be effective. Similarly, even when the government is facing a crisis caused by the pandemic, it plans to respond with the introduction of good fiscal and monetary policies; if there is no good policy execution, financial environment, public trust and cooperation, and rapid information dissemination, then the impact of the implementation of the policy will be much less than the efforts expended. Therefore, when constructing economic resilience indicators under the pandemic, the interaction effects between various detailed indicators must be considered.

Regarding the methods of establishing observational indicators, the DEA method used in this paper to calculate the efficiency scores was originally a research method used to measure energy efficiency [2] (Hu and Wang, 2006). The principle is to find efficient energy sources through the DEA method and compare it with the actual energy input to calculate the efficiency score as a measure of energy efficiency. From the viewpoint of output, the DEA method is used to find the most efficient output level given a fixed level of energy input and to compare it with the actual output level to calculate the efficiency score in order to measure its energy efficiency.

Along this line of reasoning, a large body of studies has also used DEA to construct an energy efficiency index [32–34]. DEA has developed rapidly over the past 30 years and has been applied in many research fields, such as banking and economics [32]. Zhou et al. [35] reviewed publications from 1983 to 2006 and found 100 such studies and discussed several related technical issues in the efficiency research of DEA, showing that the DEA method is a powerful tool in the study of efficiency-related issues. Based on this, this paper applies the method of DEA with disaggregate output efficiency scores to use the aforementioned three major data indicators of economic resilience, namely the government, enterprises, and the public, as the outputs to discuss how economies facing the onslaught of the COVID-19 pandemic show their economic resilience (efficiency scores) and to use this as a basis to analyze the situation among these economies.

The subject matter of economic resilience in these economies is discussed in this paper using this framework.

Suppose that each economy o has both desirable and undesirable outputs, denoted by y^g and y^b, respectively. The fractional programming problem solved by the CRS-SBM model with undesirable outputs but without inputs for economy o is expressed as follows [36]:

$$\min\rho = \frac{1}{1+\frac{1}{n_1+n_2}\left(\sum_{r=1}^{n_1}\frac{s_r^g}{y_{ro}^g}+\sum_{r=1}^{n_2}\frac{s_r^b}{y_{ro}^b}\right)},$$

$$\text{Subject to } y_o^g = Y^g\lambda - S^g,$$

$$y_o^b = Y^b\lambda + S^b,$$

$$\lambda \geq 0, s^g \geq 0, s^b \geq 0, \quad (1)$$

where each economy has m inputs, n_1 good outputs, and n_2 bad outputs; Y^g and Y^b are the matrices of the good outputs and bad outputs, respectively, where both Y^g and Y^b are bigger than zero; S^g and S^b are the matrices of the good output and bad output slacks, respectively; and λ is a constant vector of peer weights. The solved value of ρ will be the overall technical efficiency score for the oth economy with the inclusion of undesirable outputs.

As Hu and Chang [2] indicate, the efficiency score of a desirable output of economy o is:

$$\text{Actual Desirable Output/Target Desirable Output} \quad (2)$$

Because the actual desirable output is never greater than its target value, the disaggregate desirable output efficiency score is in the closed interval of [0, 1]. A zero value of efficiency means that this economy is extremely non-resilient in this item, whereas a

unitary value of efficiency implies that this economy is fully resilient in this item. Similarly, an efficiency score of an undesirable output of economy *o* is:

$$\text{Target Undesirable Output} / \text{Actual Undesirable Output} \quad (3)$$

Because the actual undesirable output is never less than its target value, the disaggregate undesirable output efficiency score is also in the closed interval of [0, 1].

Through Equations (2) and (3), the resilience scores of the economies on individual projects can be obtained as a measure of the economic resilience of those economies in the face of the COVID-19 pandemic. This approach has several traits. First, without further variable conversion, it allows the direct manipulation of the positive or negative relationship between the various indicators and economic resilience.

Second, incorporating all the indicators into the linear programming problem of the optimal production boundary can make the change of a single indicator affect the optimal production boundary, which may affect other indicators that need to be adjusted to achieve the optimal production boundary. In this paper, the economies are the DMUs in the DEA model. The efficiency frontier is constituted by efficient economies with respect to all of the outputs (items) taken into account. In addition to the overall resilience (efficiency) score, each economy also has its own disaggregate resilience (efficiency) scores with respect to all of the items taken into account.

3.2. Data Source

Different factors may need to be taken into account when discussing the economic resilience of an economy under the grip of the pandemic. It may also be necessary to focus on the financing environment, the digital capabilities of enterprises and the public, and the ability of enterprises to respond to crises, the government's fiscal slack, government policy tools, and planning and practical ability, which official statistics are less able to measure. At the same time, this paper also hopes to compare the situation of different economies through the design of the aforementioned indicators. Therefore, the data used in this paper came mainly from the national scores in the IMD World Competitiveness, IMD Digital Competitiveness, and WEF Global Competitiveness, which provided the data on the government, enterprises, and the public to calculate the indicators.

The IMD's World Competitiveness is the annual ranking of national competitiveness in the world that the "World Competitiveness Annual Report" publishes between May and June of each year, in which 63 economies were ranked based on more than 200 statistics and surveyed indicators that encompass the four major dimensions, namely economic performance, government effectiveness, enterprise effectiveness, and infrastructure. These are important reference materials for decision making in industry, government, and academia. In response to the rapid changes in emerging digital technology, a world digital competitiveness evaluation was created in 2017. The evaluation structure covers three indicators: knowledge, technology, and future readiness, which is further divided into 9 intermediate indicators and 51 detailed indicators.

The WEF Global Competitiveness is the "Global Competitiveness Report" published by the Swiss World Economic Forum in October of each year. It conducts global competitiveness evaluation rankings for about 140 economies based on more than 100 statistics and survey indicators. The evaluation covers four major categories: the environmental convenience, human capital, the market, and the innovation ecosystem. The WEF Global Competitiveness has been heavily referenced because it reflects the economic strength and prosperity of the economies.

Measuring the economic resilience of so many economies under this COVID-19 pandemic requires the use of survey data, and there is a need for consistency of data quality. These factors have guided this paper to choose the IMD World Competitiveness, IMD Digital Competitiveness, and WEF Global Competitiveness as its main sources of information. From the IMD World Competitiveness and IMD Digital Competitiveness, we will use the data in their 2020 reports. Because the WEF Global Competitiveness issued a special report

for 2020 due to the impact of the pandemic, this paper uses the data in its 2019 report. With regard to the indicators that require official statistics, and also considering the number and consistency of the economies covered in the data, this paper will use the data issued by the International Monetary Fund (IMF) and the IHS Markit.

3.3. Indicators Selection

This paper selects indicators from the three dimensions of the government, enterprises, and the public, as described below.

3.3.1. Government

In the literature, the government has always played an important role in the discussion of the factors that constitute regional or economic resilience. For example, Cooke [6] mentioned that regional resilience requires a series of policy tools and measures; the WEF [31] believes that the ability of a state to plan for and deal with crises includes how to balance public health and economic policies; Fritzsch [15] believes that economies with a strict rule of law and complete rules and regulations have higher resilience after a crisis; Oprea et al. [19] point out that the factors that determine resilience will involve public administration and such. Furthermore, in the face of the COVID-19 pandemic, the IMD [30] also pointed out that it is easier to consolidate social consensus in small economies, and this may be part of the reason why small economies have demonstrated their competitiveness in the face of the COVID-19. Government policy transparency, execution efficiency, and news media performance are interrelated. Practically speaking, all governments are committed to initiating supportive policies for the public and enterprises and stimulating fiscal policies. The Swiss Re Institute included fiscal slack in calculating the overall economic resilience index (E-RI). Accordingly, when constructing the government-level sub-indicators of economic resilience, this paper will focus on five major dimensions: fiscal policy, government transparency, government efficiency, news media, and public participation.

In line with the practice in the literature and international reports, the fiscal policy is measured by the percentage of national government debt to GDP, reflecting the scale of fiscal policy that the government can use in a crisis. Government transparency is measured in the IMD government transparency indicators, which have shown that the more transparent the government is during a crisis, the more it can achieve a balance between policies and promote them smoothly. Government efficiency is measured by the IMD's bribery and corruption indicator, which reflects the speed and thoroughness of the government's policy implementation during a crisis. The performance of the news media refers to the press freedom index of Reporters Without Borders, which measures the situation of the government transmission of information to the public during a pandemic. Public participation is measured with the overall democracy index. The higher the degree of democracy in the economy and the higher the degree of completeness of the economy's rule of law and system, the better the economy is able to achieve a policy balance. Of these four data points, the government transparency and efficiency indicators are taken from the IMD 2020 World Competitiveness Report; the percentage of government debt to GDP in various economies comes from IMF statistics, and the overall democracy index comes from the IMD, which quoted from the data from the Economist Intelligence Unit (EIU).

3.3.2. Enterprises

Facing a sudden external shock, it is a priority for an enterprise to address whether it has sufficient funds to tide it over until the difficult time has passed. Therefore, when facing the COVID-19 pandemic many governments have to initiate many supportive policies to infuse funds for small- and medium-sized enterprises that may be less well funded, in conjunction with a healthy financial and banking system to ensure that the economy can show economic resilience under the pandemic.

In the literature, Di Caro [7] believes that a sufficient financial system will affect regional resilience. The WEF [31] mentions that a sound financial system can provide

corporations with timely financing and prevent large-scale bankruptcies; the Swiss Re Institute also includes the banking system and the financial market development as indicators in measuring economic resilience. Therefore, when constructing the economic resilience sub-indicators of enterprises, this paper will consider an economy's performance in finance, financial stability, and financial services. The paper will use the WEF Global Competitiveness, the financing of SMEs, the non-performing loans percentage of gross total loans, and the IMD's Global Competitiveness of financial support business performance indicators (banking and financial services) as its corresponding measurement indicators of financing, financial stability, and financial services.

Besides the financial environment in which an enterprise operates, the ability of an enterprise to respond to a crisis also directly affects the economy's economic resilience, especially during the COVID-19 pandemic. Governments have adopted various measures to slow down the spread of the virus, such as lockdowns, border controls, and restrictions on gatherings and outside activities. Scaled-down private commercial activities and the rapid decline in demand have not only caused companies to sell less but at the same time have caused disrupted supply chains of the company's products. For these situations, companies need to have the ability and agility to respond quickly. Therefore, this paper will use IMD's Digital Competitiveness indicators (opportunities and threats) and corporate agility indicators (agility of companies) as the sub-indicators to measure the enterprises' reaction and flexibility.

Furthermore, because the impact pattern of the COVID-19 pandemic differs from that of the financial crisis of the past, the ability of digital applications has become an important factor in responding to the crisis. In the literature, the empirical IMF work report [30] found that the use of IT technology is one of the important factors in mitigating the effects of the pandemic. The report used data from nearly three million companies in the United States. During the pandemic, in areas where companies have adopted more IT technologies, the rise in unemployment rates is smaller. The WEF [31] believes that telecommuting to work can maintain economic activities without interruptions, helping demonstrate the resilience of the economy. The joint survey by the Leadercampus and the IMD in 2020 found that the more successful a business has been in achieving digital transformation, such as the digitization of the supply chain and the digitization of sales, the more it can minimize the impact of the pandemic and even further create positive benefits. Therefore, this paper will take the digital transformation in companies in the IMD World Competitiveness Index (digital transformation in companies) as its sub-indicator to measure the positive effect of digital transformation on economic resilience.

3.3.3. The Public

With the COVID-19 pandemic rapidly spreading, the public faces two most direct impacts in the threat to their physical and economic health. In particular, government-mandated control measures to slow the spread of the virus also slow commercial activities in large swaths of the economy; the supply chains are disrupted, leading to work stoppages; and outdoor movement controls make people's workplaces inaccessible to them. All this directly impacts the livelihoods of the public. When faced with economic impacts or a sharp recession, if they have savings their fear of an uncertain economic future will be lessened, giving more latitude to the government in its fiscal policies. Therefore, this paper will take the IMF's gross national savings as a percentage of the GDP as a measure of the resilience benefits of the people's saving habits, under the sub-indicator to measure the positive effect of saving on economic resilience.

Additionally, the education level of the public in the crisis caused by the pandemic also directly affects economic resilience. Regardless of the level of people's understanding and cooperation with the government's anti-pandemic policies and regardless of the level of their own anti-pandemic awareness, the education level of the public is an important factor that must be considered. In the literature, papers abound on the role of the education level of the public in regional or economic resilience. For example, when Rizzi et al. [14]

measure the resilience of various EU regions, they include the education level of the public in the drive for economic resilience. When Goetz et al. [17] and Han and Goetz [16] discuss the impact of economic resilience, they also use a basic model that includes the education level of the people. Based on this, this paper will use the proportion of people aged 25 to 34 who received higher education in the IMD World Competitiveness Report, under the sub-indicator to measure the effect of the education level of the public on economic resilience.

Finally, the digital application capabilities discussed in the section on economic resilience at the enterprise level are also one of the important factors for economic resilience at the public level under the COVID-19 pandemic crisis. For example, the pandemic has restricted people's activities and reduced in-store shopping, but it has also increased online shopping; it has reduced public transportation, but it has increased the use of shared bicycles, shared motorcycles, and shared automobiles; it has reduced sit-down dining at restaurants, but it has increased the opportunities to provide service under delivery platforms; it has reduced in-person schooling, but it has resulted in more online learning and increased content for online learning. All this can yield positive effects only when people possess adequate levels of proficiency in digital application capabilities. The more proficient the public is in its digital application capabilities, the higher the transparency and the speed with which the government is able to initiate and spread its support policies to counter the pandemic and the easier it is for enterprises to adopt remote work policies and for the employees to work and maintain the operation of the enterprises. Therefore, this paper includes mobile, communication, and the use of the internet as indicators of economic resilience at the population level and obtains data, respectively, from mobile broadband subscribers and communications technology in the IMD's World Competitiveness Report and the internet users as a percentage of the adult population in the WEF report.

4. Data Analysis

4.1. Data Sources, Narrative Statistics, and Correlation Analysis

In summary, after analyzing the selection of the detailed indicators under the aforementioned general indicators of the government, enterprises, and the public, this paper ultimately uses 16 detailed indicators to calculate the economic resilience indicators of the subject economies. The data sources are, respectively, the 2020 World Competitiveness Report and the 2020 Digital Competitiveness Report from the IMD, the 2020 Press Freedom Index, the 2019 WEF Global Competitiveness Report, and the January 2021 IMF Global Economic Outlook, as shown in Table 1. The data are summarized, and the incomplete data are excluded. The data in this study cover 52 economies. The 52 economies include Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Colombia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Israel, Eda Liberia, Japan, South Korea, Latvia, Lithuania, Luxembourg, Malaysia, Mexico, The Netherlands, New Zealand, Norway, Poland, Portugal, Qatar, Romania, Russia, Singapore, the Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, the United Kingdom, and the United States. After consolidating the data, the incomplete data were removed; the data in this paper cover 52 economies, and the basic statistics of each indicator of these 52 economies are shown in Table 2.

The fact that the indicators differ in concentration and the extent of dispersion shows that the indicators that this paper obtains from the literature and international reports to measure economic resilience may also contain different amounts of data. Therefore, it also points out that, when constructing the relevant indicator framework to measure an economy's economic resilience, this paper needs to use the DEA method to further show the difference in the information about each economy in the detailed indicator data. Furthermore, the indicators used in this paper to measure economic resilience are calculated through Equation (2), such that even if the original data have different units of measurement, it will not be a problem to use the original data directly. Therefore, this

paper will use the original data directly. Only in this way can the information contained in the collected data be presented more deeply and directly.

Table 1. Contents and sources of sub-indices and sub-indices.

Index Component	Sub-Index	Data	Source
Government	Fiscal policy	General government gross debt % of GDP	IMF
	Transparency	Transparency of government	IMD
	Efficiency	Bribery and corruption	IMD
	News media	Press freedom index	Reporters Sans Frontière
	Public participation	Democracy index	IMD
Enterprise	Finance	Financing of SMEs	WEF
	Financial services	Banking and financial services	IMD
	Financial stability	Non-performing loans % of gross total loans	WEF
	Digital transformation	Digital transformation in companies	IMD
	Reaction	Opportunities and threats	IMD
	Flexibility	Agility of companies	IMD
Populace	Saving	Gross national savings % of GDP	IMF
	Mobile	Mobile Broadband subscribers	IMD
	Communication	Communications technology	IMD
	Education	Higher education achievement	IMD
	Use of internet	Internet users % of adult population	WEF

Table 2. Basic descriptive statistics of detailed indicators.

Variable	Type	Mean	S.D.	Max	Min
Fiscal policy	Undesirable	63.82	41.12	234.90	8.40
Transparency	Desirable	5.07	1.67	7.97	1.52
Efficiency	Desirable	5.13	2.36	8.90	0.84
News media	Undesirable	26.20	14.33	78.48	7.84
Public participation	Desirable	7.46	1.60	9.87	2.26
Finance	Desirable	56.22	9.99	74.90	26.70
Financial stability	Desirable	91.48	15.45	100.00	8.90
Financial services	Desirable	6.30	0.99	7.95	4.33
Digital transformation	Desirable	5.85	0.91	7.39	4.33
Reaction	Desirable	6.24	0.78	7.75	4.00
Flexibility	Desirable	6.13	0.89	7.76	3.32
Saving	Desirable	24.85	6.91	42.09	12.42
Mobile	Desirable	81.96	17.16	100.00	37.70
Communication	Desirable	8.03	1.05	9.69	5.09
Education	Desirable	42.98	15.19	79.70	5.57
Use of internet	Desirable	80.32	14.39	99.70	34.50

Data source: calculated by the authors for this paper.

It can be seen, based on the relationship between the selected indicator and economic resilience and the definition of the indicator data itself, that fiscal policy and news media are the inverse indicators, such that they are better if their scores are smaller. Therefore, in the DEA analysis framework, these indicators can be set to be undesirable outputs. All the other data of economic resilience belong in the indicators that are better if they are bigger, such that they are desirable outputs.

The correlation of indicator variables is shown in Table 3. On the whole, there is no high correlation with an absolute value higher than 0.6 between any two indicators. Therefore, no indicator in the DEA model can be replaced by another one. The DEA model is solvable because there is no serious linear inter-dependence between any two output variables.

Table 3. Correlation of indicator variables.

	Fiscal Policy	News Media	Transparency	Efficiency	Public Participation	Finance	Financial Stability	Financial Services	Digital Transformation	Reaction	Flexibility	Saving	Mobile	Communication	Education	Use of Internet
Fiscal policy	1															
News media	0.033	1														
Transparency	−0.063	−0.361	1													
Efficiency	0.051	−0.487	0.852	1												
Public participation	0.080	−0.867	0.398	0.455	1											
Finance	−0.107	−0.219	0.630	0.667	0.281	1										
Financial stability	−0.411	−0.024	0.176	0.267	0.062	0.607	1									
Financial services	−0.085	−0.257	0.724	0.704	0.297	0.812	0.403	1								
Digital transformation	−0.320	−0.089	0.630	0.458	0.116	0.430	0.240	0.485	1							
Reaction	−0.345	−0.095	0.560	0.478	0.099	0.375	0.207	0.547	0.802	1						
Flexibility	−0.438	−0.245	0.557	0.490	0.230	0.419	0.320	0.560	0.788	0.921	1					
Saving	−0.175	0.151	0.449	0.372	−0.186	0.429	0.314	0.368	0.493	0.369	0.382	1				
Mobile	−0.038	−0.057	0.303	0.376	0.024	0.318	0.356	0.352	0.307	0.274	0.283	0.346	1			
Communication	−0.047	−0.308	0.521	0.610	0.205	0.493	0.174	0.429	0.544	0.426	0.444	0.312	0.363	1		
Education	0.126	−0.192	0.382	0.544	0.233	0.303	0.043	0.271	0.337	0.258	0.305	0.210	0.373	0.557	1	
Use of internet	0.006	−0.606	0.531	0.730	0.457	0.440	0.195	0.402	0.312	0.289	0.391	0.158	0.364	0.554	0.642	1

Data source: calculated by the authors for this paper.

4.2. Empirical Analysis

The 16 detailed indicators are divided into three dimensions: the government, enterprises, and the public, and each of the dimensions is further divided into its detailed indicators. We then use Equations (1)–(3) to calculate the general indicator for economic resilience. Rizzi et al. [14] and Oprea et al. [19] use GDP-related changes as explanatory variables when they discuss the determining factors of regional economic resilience. For each of the 52 economies, this paper uses the GDP data in the IHS statistics and estimates for July 2021 to calculate the difference between the GDP growth rate in 2020 and the compound average GDP growth rate of the previous five years (2015–2019). We find that this difference and the total economic resilience indicator constructed in this paper show a correlation coefficient that is as high as 0.54, which is significantly higher than 0.37, which is the correlation coefficient between this difference and the 2020 IMD World Competitiveness Index score, and significantly higher than 0.32, which is the correlation coefficient between this difference and the 2019 the WEF Global Competitiveness Index score. It shows that the overall economic resilience index constructed in this paper may be more suitable for assessing the economic resilience of economies under the COVID-19 pandemic than the IMD World Competitiveness Index or the WEF Global Competitiveness Index (as in Appendix A).

Take the aforementioned government, enterprises, and the public and use Equation (1) to arrive at the best efficiency point, and use Equation (2) to find the indicator to measure economic resilience in the face of the COVID-19 pandemic. The ranking of economic resilience is shown in Table 4.

Table 4. Basic descriptive statistics of detailed indicators.

Economy	Rank	Economy	Rank	Economy	Rank	Economy	Rank
Australia	1	New Zealand	1	Czech Republic	27	Portugal	40
Canada	1	Norway	1	Malaysia	28	Cyprus	41
China	1	Qatar	1	Japan	29	Spain	42
Denmark	1	Russia	1	Latvia	30	Philippines	43
Estonia	1	Singapore	1	Israel	31	Romania	44
Finland	1	Sweden	1	Turkey	32	Brazil	45
Hong Kong	1	Switzerland	1	Slovenia	33	India	46
Iceland	1	Taiwan	1	Thailand	34	Mexico	47
Ireland	1	United Kingdom	1	France	35	Italy	48
Korea	1	USA	1	Bulgaria	36	Colombia	49
Lithuania	1	Germany	24	Indonesia	37	Slovak Republic	50
Luxembourg	1	Austria	25	Poland	38	South Africa	51
The Netherlands	1	Belgium	26	Hungary	39	Greece	52

Data source: calculated by the authors for this paper.

Of the subject economies, 23 of them are at the efficiency point, which indicates that currently they do not have room for improvement in economic resilience when compared with other economies. They are Australia, Canada, China, Denmark, Estonia, Finland, Hong Kong, Iceland, Ireland, South Korea, Lithuania, Luxembourg, The Netherlands, New Zealand, Norway, Qatar, Russia, Singapore, Sweden, Switzerland, Taiwan, the United Kingdom, and the United States.

Comparing the GDP growth rate of these 23 economies in 2020 with their average GDP growth rate from 2015 to 2019, it can be seen that the GDP growth rate of most of these economies during the COVID-19 pandemic is indeed better than that of the other 29 economies in the study. Taiwan's rapid response in the early stages of the pandemic, its strict border controls, mask mandate, and other public health measures have boosted its overall economic resilience. Its GDP growth rate in 2020 was higher, not lower, than the average GDP growth rate in 2015–2019. Some other economies also had superior economic resilience, but some economies suffered sharp declines in GDP growth in 2020 from their growth in 2015–2019, such as the United Kingdom, Iceland, Hong Kong, and Singapore.

All of them were affected by the pandemic during the same period, but they were also affected mainly by political events and industrial structure, such as the Brexit event, Hong Kong's legal disputes, Iceland's tourism-based industrial structure, and Singapore's oil industry, which accounted for a relatively high proportion of its economy.

Table 5 summarizes the disaggregate output scores of European economies which have room for improvement. Although being not among the above 23 economies that showed the best economic resilience, Germany, the largest economy in Europe, achieved the best efficiency in 4 of the 16 indicators, and 7 other indicators reached 80% of the target efficiency. Therefore, Germany's overall economic resilience is still quite good. The areas of weakness that caused Germany to fall behind the top 23 nations were in economic resilience and were found in three areas: its fiscal policy, communication, and education were lower than the efficiency target of 80%; its digital transformation fell below the efficiency target of 70%; and its mobile reached only about 50% of the target, hence the room for improvement. (The scores of the economic resilience index are shown in Appendix B; the index as a percentage of the efficiency target in the government dimension by subject economy is shown in Appendix C; the index as a percentage of the efficiency target in the enterprises dimension by subject economy is shown in Appendix D; the index as a percentage of the efficiency target in the public dimension by subject economy is shown in Appendix E.)

Table 5. The European economies whose resilience scores can be improved.

Economy	Germany	France	Portugal	Cyprus	Spain	Romania	Italy	Slovak Republic	Greece
Fiscal Policy	0.772	0.376	0.275	0.335	0.330	0.619	0.212	0.663	0.160
News Media	0.836	0.745	0.503	0.847	0.384	0.501	0.491	0.201	0.885
Transparency	1.000	0.941	0.444	0.624	0.471	0.345	0.406	0.096	0.705
Efficiency	0.951	0.881	0.894	1.000	0.950	0.813	0.945	0.798	1.000
Public Participation	0.823	0.378	0.670	0.864	0.393	0.335	0.296	0.349	0.309
Finance	1.000	0.886	0.805	0.760	0.930	0.834	0.730	0.898	0.515
Financial Stability	1.000	1.000	0.793	0.412	1.000	1.000	0.869	1.000	0.113
Financial Services	0.884	0.866	0.781	0.997	0.848	0.760	0.759	0.689	0.733
Digital Transformation	0.639	0.686	0.789	0.831	0.628	0.847	0.729	0.612	0.900
Reaction	0.810	0.773	0.784	0.850	0.832	0.839	1.000	0.644	1.000
Flexibility	0.823	0.717	0.714	0.780	0.807	0.793	0.843	0.683	0.839
Saving	1.000	0.755	0.721	0.473	0.811	0.738	0.890	0.673	0.515
Education	0.739	1.000	0.814	1.000	1.000	0.603	0.683	0.854	1.000
Mobile	0.508	0.827	0.453	0.413	0.877	0.759	0.782	0.757	0.997
Communication	0.715	1.000	1.000	1.000	0.940	1.000	0.874	0.822	0.988
Use of Internet	0.954	0.880	0.785	0.980	0.926	0.821	0.883	0.849	0.944

Data source: calculated by the authors for this paper.

In France, its performance in fiscal policy and public participation indicators was short by 40% of the efficiency target. Moreover, 10 indicators fell between 60% and 90% of their efficiency targets, giving the economy a ranking of 35th, in the lower middle of the population.

Spain's performance in enterprises and the public indicators is not far behind that of France, but its fiscal policy, news media, public participation, and transparency in the government's dimension only reached between 30% and 50% of their respective efficiency targets, giving the economy a position of 42nd in the ranking of the overall economy economic resilience.

In Italy, its fiscal policy and public participation indicators did not reach 30% of their respective efficiency target. Thirteen indicators fell between 40% and 90% of their efficiency targets. Therefore, its overall economic resilience ranking fell to 45th.

Among the subject economies, the European economies ranking in the bottom quarter of economic resilience are Portugal, Cyprus, Romania, the Slovak Republic, and Greece. Portugal and the Slovak Republic have only one indicator each reaching the efficiency

target, and the remaining indicators all fell below 90% of the efficiency target, meaning that there is room for improvement at all levels. Furthermore, the room for improvement in some indicators is significantly greater than that of other economies, such as Portugal in fiscal policy and transparency, and the Slovak Republic in news media, transparency, and public participation. Therefore, their overall economic resilience ranks 40 and 50, respectively.

Romania is similar to the above two economies in that it is also in a situation where there is room for improvement at all levels, giving it a ranking of 44th.

For Cyprus and Greece though, three indicators reached the target efficiency level. For Cyprus, there is significantly more room for improvement in fiscal policy, financial stability, saving, and mobile than other economies. Therefore, the overall economic resilience for Cyprus is 41. For Greece, the room for improvement in fiscal policy, financial stability, and public participation is significantly greater than those in other economies. Greece is the only economy in Europe that has reached less than 50% of the target value for efficiency and is ranked 52nd in the study.

Table 6 summarizes the disaggregate output scores of the Asian economies which have room for improvement. Japan is a major advanced economy in Asia. Even though Japan's transparency and mobile indicators both reached the efficiency targets, and seven other indicators reached more than 90% of their respective efficiency target, its fiscal policy indicator is only 16% of the efficiency target, while news media, digital transformation, reaction, and flexibility fell short of 70% of the efficiency target, showing considerable room for improvement in both the government and enterprises. Therefore, Japan ranked 29th in the overall economic resilience indicator.

Table 6. The Asian economies whose resilience scores can be improved.

Economy	India	Indonesia	Israel	Japan	Malaysia	Philippines	Thailand
Fiscal Policy	0.447	0.652	0.554	0.161	0.781	0.514	0.902
News Media	0.940	0.803	0.640	0.665	0.747	0.652	0.513
Transparency	0.494	0.428	0.610	1.000	0.523	0.245	0.300
Efficiency	0.943	0.806	0.847	0.973	0.742	0.786	0.684
Public Participation	0.353	0.398	0.302	0.780	0.235	0.244	0.182
Finance	1.000	0.981	1.000	0.987	1.000	0.850	0.936
Financial Stability	0.924	0.978	1.000	0.989	1.000	1.000	0.984
Financial Services	0.987	1.000	0.738	0.836	0.925	1.000	1.000
Digital Transformation	0.954	0.966	0.945	0.679	0.866	0.799	0.822
Reaction	0.960	0.953	0.933	0.575	0.926	0.930	0.839
Flexibility	0.897	0.822	0.876	0.479	0.857	0.831	0.798
Saving	1.000	1.000	0.805	0.901	0.792	0.634	0.975
Education	0.253	0.315	0.983	0.945	0.770	0.467	0.690
Mobile	0.483	1.000	0.744	1.000	0.885	0.723	1.000
Communication	1.000	0.799	0.778	0.984	0.833	0.571	0.871
Use of Internet	0.419	0.437	0.881	0.934	0.864	0.648	0.592

Data source: calculated by the authors for this paper.

For Southeast Asian economies, aside from Singapore having reached the efficiency target of its economic resilience indicator, Malaysia, Thailand, Indonesia, and the Philippines also reached their efficiency target in two to three indicators, but Malaysia's public participation; Thailand's transparency and public participation; Indonesia's transparency, public participation, education, and use of internet; and the Philippines' transparency, public participation, and education all reached less than 50% of their respective efficiency target, giving them economic resilience indicator rankings of 28th, 34th, 37th, and 43rd, respectively.

For India, in South Asia, its financial stability, savings, and communication reached the efficiency target, but three indicators in both the government dimension and the

public dimension fell below 50% of the efficiency target (fiscal policy, transparency, public participation, mobile, education, and use of internet), ranking it 46th.

After the outbreak of the pandemic, Israel, in West Asia, vaccinated its people faster than any other nation in the world, giving it the best pandemic prevention results among the subject economies. The drop in GDP growth rate in 2020 from the average GDP growth rate from 2015 to 2019 was less than many other economies that reached their efficiency targets in economic resilience, but Israel's economic resilience index ranked 31st, which may indicate that their relatively better performance in GDP growth may have come mainly from their pandemic prevention results.

Table 7 summarizes the disaggregate output scores of American economies which have room for improvement. As Table 7 shows, Brazil, Mexico, and Colombia, in Central and South America, rank in the lower quarter of the economic resilience index vs. their efficiency target, mainly because there is much room for improvement in the indicators in the government dimension. Brazil's fiscal policy only reached 33% of its efficiency target and its transparency and public participation reached about 23% of its efficiency target.

Table 7. The American economies whose resilience scores can be improved.

Economy	Brazil	Mexico	Colombia
Fiscal Policy	0.331	0.609	0.631
News Media	0.494	0.368	0.247
Transparency	0.228	0.155	0.165
Efficiency	0.761	0.802	0.657
Public Participation	0.233	0.184	0.186
Finance	0.707	0.823	0.744
Financial Stability	1.000	1.000	1.000
Financial Services	0.756	0.629	0.720
Digital Transformation	0.681	0.742	0.666
Reaction	0.811	0.765	0.769
Flexibility	0.789	0.796	0.716
Saving	0.548	0.641	0.652
Education	0.463	0.658	0.497
Mobile	0.933	0.427	0.775
Communication	0.621	0.699	0.671
Use of Internet	0.708	0.662	0.686

Data source: calculated by the authors for this paper.

Mexico's news media is 25% of the efficiency target, and its transparency and public participation are less than 20% of the efficiency target.

Colombia's news media is 37% of the efficiency target, and its transparency and public participation are also less than 20% of the efficiency target. In addition, in these three economies, of the 16 indicators only financial stability reached the efficiency target, such that their economic resilience indexes are 45, 47, and 49, respectively.

5. Conclusions

The number of cases has continued to rise, and variant virus strains have been found in some economies and regions since COVID-19 spread from Wuhan, China and ravaged the world. Even though many economies have begun vaccination, the pandemic seems to go on unabated in the world. This pandemic has hit the global economy hard, affecting the economic performance of economies to varying degrees, which also reflects the economic resilience of those economies while under the pandemic. The shock of this pandemic is significantly different from that of past economic crises that were caused by global financial and fiscal issues. When assessing the economic resilience of economies, it is impossible to just completely follow the standards used in the past. It is then necessary to discuss economic resilience through the actual conditions under the pandemic. Therefore, by applying the output-oriented DEA model, this paper measures and compares the economic

resilience of different aspects that affect the economic growth of economies from the three main bodies: the government, enterprises, and the public.

There are 23 economies, including Taiwan, whose economic resilience indicators are at the efficiency point, which means that there is no more room for improvement in economic resilience relative to other economies. They are Australia, Canada, China, Denmark, Estonia, Finland, Hong Kong, Iceland, Ireland, South Korea, Lithuania, Luxembourg, The Netherlands, New Zealand, Norway, Qatar, Russia, Singapore, Sweden, Switzerland, Taiwan, the United Kingdom, and the United States. Taiwan's speedy response in the early stages of the pandemic, strict border controls, mask mandate, and other public health measures have boosted its overall economic resilience. Its GDP growth rate in 2020 is higher, rather than lower, than the average GDP growth rate in 2015–2019. Some other economies also showed excellent economic resilience, but their GDP growth rate in 2020 fell more sharply than their respective average GDP growth rate from 2015 to 2019, due to certain political events or industrial structure issues.

As for the performance of other major economies, Germany achieved the best efficiency performance in 4 out of 16 indicators. Overall, it is still quite good in terms of economic resilience, which is second only to those of the top 23 economies. France's performance in fiscal policy and public participation indicators did not reach 40% of its efficiency target, dragging its overall economic resilience to rank 35th, in the lower middle pack of the 52 subject economies. The three indicators (fiscal policy, news media, public participation, and transparency) in Spain's government dimension only reached between 30% and 50% of their efficiency target; so, Spain's overall economic resilience ranked 42nd. In Italy, its fiscal policy and public participation indicators did not reach 30% of the efficiency target, so its overall economic resilience ranking fell to 45th. In Japan, a major advanced economy in Asia, although the transparency and mobile indicators reached the efficiency target, and another seven indicators reached more than 90% of their efficiency target, its fiscal policy indicator only reached 16% of its efficiency target and its news media, digital transformation, reaction, and flexibility did not reach 70% of the efficiency target, indicating that there is still considerable room for improvement in both the government and enterprises dimensions. Therefore, its overall economic resilience indicator ranks 29.

Generally speaking, the world is still in the grip of the COVID-19 pandemic at the time of this writing; so, the statistics and survey data are only for the periods before and during the pandemic. The overall economic resilience indicator constructed via Equations (1)–(3) and the difference between the GDP growth rate in 2020 and the compound average GDP growth rate of the previous five years (2015–2019) show a correlation coefficient of 0.54, which is higher than 0.37, which is the correlation coefficient between this difference and the 2020 IMD World Competitiveness Index score, and higher than 0.32, which is the correlation coefficient between this difference and the 2019 the WEF Global Competitiveness Index score, showing that this paper is more suitable than the IMD World Competitiveness Index to assess the economic resilience of economies under the COVID-19 pandemic. Therefore, the evaluation results of the sub-indicators of each dimension presented in this paper could be used as an important factor for governments to strengthen their economic resilience in order to face similar crises in the future.

This article takes economies as the decision-making units and then calculates 16 indicators through aggregated calculation to measure the economic resilience scores of each economy under the COVID-19 epidemic, in order to provide policy makers with a reference for future policy planning. Being different from previous literature, which mostly compares different regions within an economy or tries to find out what factors affect regional economic resilience, this paper is a relatively new attempt to propose a model for measuring economic resilience scores. Compared with the results of Oprea et al. [19], among the seven Eastern European economies, Bulgaria, Slovenia, Romania, and the Slovak Republic are more economically resilient. In the results of this paper, the economic resilience of the Czech Republic is better than Bulgaria, Slovenia, Romania, and the Slovak Republic, which is slightly different from the findings of Oprea et al. [19].

It is worth noting that in terms of research methods, the DEA method in this paper measures economic resilience, such that the economies located on the efficiency frontier are only the best among the sample economies. At the time of writing this article, the world is still under the COVID-19 epidemic. Due to the data limitations, the economic resilience scores measured in this article should belong to the concept of resilience rather than the recovery. These are the circumstances that must be considered in interpreting the results in this paper. After the COVID-19 epidemic, the recovery of each economy can be measured, and the economic resilience performance of each economy can be more completely presented, which should be an important direction for future research.

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Appendix A

Table A1. List of WEF indexes, IMD indexes, economic resilience scores, and changes in GDP growth rate by subject economy.

Economy	WEF	IMD	Resilience Score	GDP Difference
Australia	79	85.03	1.000	−4.84
Austria	77	86.27	0.763	−8.50
Belgium	76	77.78	0.735	−7.90
Brazil	61	49.63	0.575	−4.63
Bulgaria	65	59.43	0.685	−7.37
Canada	80	93.51	1.000	−7.39
China	74	82.04	1.000	−4.28
Colombia	63	52.15	0.552	−9.12
Cyprus	66	75.35	0.652	−10.08
Czech Republic	71	71.24	0.731	−9.29
Denmark	81	99.50	1.000	−4.60
Estonia	71	76.23	1.000	−6.99
Finland	80	88.63	1.000	−4.81
France	79	71.69	0.686	−9.78
Germany	82	85.88	0.824	−6.86
Greece	63	57.87	0.453	−8.78
Hong Kong	83	97.06	1.000	−7.96
Hungary	65	59.95	0.664	−9.25
Iceland	75	81.46	1.000	−11.09
India	61	62.09	0.573	−13.78
Indonesia	65	66.75	0.684	−7.10

Table A1. *Cont.*

Economy	WEF	IMD	Resilience Score	GDP Difference
Ireland	75	90.73	1.000	−4.01
Israel	77	77.71	0.717	−5.99
Italy	72	61.97	0.555	−10.01
Japan	82	69.85	0.723	−5.49
Korea	80	79.22	1.000	−3.67
Latvia	67	65.36	0.723	−6.52
Lithuania	68	73.60	1.000	−4.57
Luxembourg	77	87.70	1.000	−4.26
Malaysia	75	76.39	0.731	−10.60
Mexico	65	54.80	0.564	−10.20
The Netherlands	82	98.35	1.000	−6.15
New Zealand	77	80.27	1.000	−5.09
Norway	78	94.60	1.000	−2.69
Philippines	62	60.42	0.625	−16.02
Poland	69	66.97	0.675	−7.19
Portugal	70	68.22	0.657	−10.28
Qatar	73	87.86	1.000	−4.41
Romania	64	55.56	0.617	−8.78
Russia	67	56.47	1.000	−4.60
Singapore	85	100.00	1.000	−8.56
Slovak Republic	67	49.54	0.523	−7.57
Slovenia	70	68.62	0.705	−10.06
South Africa	62	45.16	0.491	−7.67
Spain	75	68.23	0.645	−13.43
Sweden	81	95.87	1.000	−5.09
Switzerland	82	98.37	1.000	−4.67
Taiwan	80	91.27	1.000	0.32
Thailand	68	75.39	0.696	−9.71
Turkey	62	60.00	0.707	−2.08
United Kingdom	81	84.36	1.000	−11.38
USA	84	92.36	1.000	−5.79

Data source: calculated by the authors for this paper.

Appendix B

Table A2. Ranking of economic resilience indexes.

Economy	Score	Rank	Economy	Score	Rank
Australia	1.000	1	Czech Republic	0.731	27
Canada	1.000	1	Malaysia	0.731	28
China	1.000	1	Japan	0.723	29
Denmark	1.000	1	Latvia	0.723	30
Estonia	1.000	1	Israel	0.717	31
Finland	1.000	1	Turkey	0.707	32
Hong Kong	1.000	1	Slovenia	0.705	33
Iceland	1.000	1	Thailand	0.696	34
Ireland	1.000	1	France	0.686	35
Korea	1.000	1	Bulgaria	0.685	36
Lithuania	1.000	1	Indonesia	0.684	37
Luxembourg	1.000	1	Poland	0.675	38
The Netherlands	1.000	1	Hungary	0.664	39
New Zealand	1.000	1	Portugal	0.657	40
Norway	1.000	1	Cyprus	0.652	41
Qatar	1.000	1	Spain	0.645	42
Russia	1.000	1	Philippines	0.625	43
Singapore	1.000	1	Romania	0.617	44

Table A2. *Cont.*

Economy	Score	Rank	Economy	Score	Rank
Sweden	1.000	1	Brazil	0.575	45
Switzerland	1.000	1	India	0.573	46
Taiwan	1.000	1	Mexico	0.564	47
United Kingdom	1.000	1	Italy	0.555	48
USA	1.000	1	Colombia	0.552	49
Germany	0.824	24	Slovak Republic	0.523	50
Austria	0.763	25	South Africa	0.491	51
Belgium	0.735	26	Greece	0.453	52

Data source: calculated by the authors for this paper.

Appendix C

Table A3. Output efficiency in the government dimension.

Economy	Fiscal Policy	Transparency	Efficiency	News Media	Public Participation
Australia	1.000	1.000	1.000	1.000	1.000
Austria	0.535	0.847	0.951	0.874	0.493
Belgium	0.371	0.562	1.000	0.823	0.648
Brazil	0.331	0.494	0.228	0.761	0.233
Bulgaria	1.000	0.597	0.369	0.896	0.276
Canada	1.000	1.000	1.000	1.000	1.000
China	1.000	1.000	1.000	1.000	1.000
Colombia	0.609	0.368	0.155	0.802	0.184
Cyprus	0.335	0.847	0.624	1.000	0.864
Czech Republic	0.920	0.551	0.376	0.884	0.366
Denmark	1.000	1.000	1.000	1.000	1.000
Estonia	1.000	1.000	1.000	1.000	1.000
Finland	1.000	1.000	1.000	1.000	1.000
France	0.376	0.745	0.941	0.881	0.378
Germany	0.772	0.836	1.000	0.951	0.823
Greece	0.160	0.885	0.705	1.000	0.309
Hong Kong	1.000	1.000	1.000	1.000	1.000
Hungary	0.604	0.531	0.357	0.699	0.348
Iceland	1.000	1.000	1.000	1.000	1.000
India	0.447	0.940	0.494	0.943	0.353
Indonesia	0.652	0.803	0.428	0.806	0.398
Ireland	1.000	1.000	1.000	1.000	1.000
Israel	0.554	0.640	0.610	0.847	0.302
Italy	0.212	0.491	0.406	0.945	0.296
Japan	0.161	0.665	1.000	0.973	0.780
Korea	1.000	1.000	1.000	1.000	1.000
Latvia	0.819	0.705	0.499	0.871	0.415
Lithuania	1.000	1.000	1.000	1.000	1.000
Luxembourg	1.000	1.000	1.000	1.000	1.000
Malaysia	0.781	0.747	0.523	0.742	0.235
Mexico	0.631	0.247	0.165	0.657	0.186
The Netherlands	1.000	1.000	1.000	1.000	1.000
New Zealand	1.000	1.000	1.000	1.000	1.000
Norway	1.000	1.000	1.000	1.000	1.000
Philippines	0.514	0.652	0.245	0.786	0.244
Poland	0.370	0.568	0.716	0.843	0.392
Portugal	0.275	0.503	0.444	0.894	0.670
Qatar	1.000	1.000	1.000	1.000	1.000
Romania	0.619	0.501	0.345	0.813	0.335
Russia	1.000	1.000	1.000	1.000	1.000

Table A3. *Cont.*

Economy	Fiscal Policy	Transparency	Efficiency	News Media	Public Participation
Singapore	1.000	1.000	1.000	1.000	1.000
Slovak Republic	0.663	0.201	0.096	0.798	0.349
Slovenia	0.503	0.552	0.479	0.814	0.359
South Africa	0.527	0.505	0.130	0.791	0.360
Spain	0.330	0.384	0.471	0.950	0.393
Sweden	1.000	1.000	1.000	1.000	1.000
Switzerland	1.000	1.000	1.000	1.000	1.000
Taiwan	1.000	1.000	1.000	1.000	1.000
Thailand	0.902	0.513	0.300	0.684	0.182
Turkey	1	0.444	0.456	0.445	0.163
United Kingdom	1.000	1.000	1.000	1.000	1.000
USA	1.000	1.000	1.000	1.000	1.000

Data source: calculated by the authors for this paper.

Appendix D

Table A4. Output efficiency in the enterprises dimension.

Economy	Finance	Financial Stability	Financial Services	Digital Transform-ation	Reaction	Flexibility
Australia	1.000	1.000	1.000	1.000	1.000	1.000
Austria	1.000	1.000	0.961	0.788	0.963	0.955
Belgium	0.949	1.000	0.941	0.767	0.845	0.840
Brazil	0.707	1.000	0.756	0.681	0.811	0.789
Bulgaria	0.982	0.887	0.804	0.891	0.893	0.758
Canada	1.000	1.000	1.000	1.000	1.000	1.000
China	1.000	1.000	1.000	1.000	1.000	1.000
Colombia	0.823	1.000	1.000	0.742	0.765	0.796
Cyprus	0.760	0.412	1.000	0.831	0.850	0.780
Czech Republic	0.982	1.000	0.881	0.856	0.895	0.823
Denmark	1.000	1.000	1.000	1.000	1.000	1.000
Estonia	1.000	1.000	1.000	1.000	1.000	1.000
Finland	1.000	1.000	1.000	1.000	1.000	1.000
France	0.886	1.000	0.866	0.686	0.773	0.717
Germany	1.000	1.000	0.884	0.639	0.810	0.823
Greece	0.515	0.113	0.733	0.900	1	0.839
Hong Kong	1.000	1.000	1.000	1.000	1.000	1.000
Hungary	0.762	0.934	0.728	0.661	0.645	0.656
Iceland	1.000	1.000	1.000	1.000	1.000	1.000
India	1.000	0.924	0.987	0.954	0.960	0.897
Indonesia	0.981	0.978	1.000	0.966	0.953	0.822
Ireland	1.000	1.000	1.000	1.000	1.000	1.000
Israel	1.000	1.000	0.738	0.945	0.933	0.876
Italy	0.730	0.869	0.759	0.729	1.000	0.843
Japan	0.987	0.989	0.836	0.679	0.575	0.479
Korea	1.000	1.000	1.000	1.000	1.000	1.000
Latvia	0.893	1.000	0.712	0.904	0.874	0.813
Lithuania	1.000	1.000	1.000	1.000	1.000	1.000
Luxembourg	1.000	1.000	1.000	1.000	1.000	1.000
Malaysia	1.000	1.000	0.925	0.866	0.926	0.857
Mexico	0.744	1.000	0.720	0.666	0.769	0.716
The Netherlands	1.000	1.000	1.000	1.000	1.000	1.000
New Zealand	1.000	1.000	1.000	1.000	1.000	1.000
Norway	1.000	1.000	1.000	1.000	1.000	1.000

Table A4. *Cont.*

Economy	Finance	Financial Stability	Financial Services	Digital Transform-ation	Reaction	Flexibility
Philippines	0.850	1.000	1.000	0.799	0.930	0.831
Poland	0.894	1.000	1.000	0.921	0.937	0.912
Portugal	0.805	0.793	0.781	0.789	0.784	0.714
Qatar	1.000	1.000	1.000	1.000	1.000	1.000
Romania	0.834	1.000	0.760	0.847	0.839	0.793
Russia	1.000	1.000	1.000	1.000	1.000	1.000
Singapore	1.000	1.000	1.000	1.000	1.000	1.000
Slovak Republic	0.898	1.000	0.689	0.612	0.644	0.683
Slovenia	0.893	0.985	0.834	0.778	0.838	0.853
South Africa	0.729	1.000	0.708	0.659	0.711	0.641
Spain	0.930	1.000	0.848	0.628	0.832	0.807
Sweden	1.000	1.000	1.000	1.000	1.000	1.000
Switzerland	1.000	1.000	1.000	1.000	1.000	1.000
Taiwan	1.000	1.000	1.000	1.000	1.000	1.000
Thailand	0.936	0.984	1.000	0.822	0.839	0.798
Turkey	0.823	0.994	0.856	0.767	0.953	0.901
United Kingdom	1.000	1.000	1.000	1.000	1.000	1.000
USA	1.000	1.000	1.000	1.000	1.000	1.000

Appendix E

Table A5. Output efficiency in the populace dimension by subject economy.

Economy	Savings	Education	Mobile	Communication	Use of Internet
Australia	1.000	1.000	1.000	1.000	1.000
Austria	0.891	0.965	0.940	0.881	0.923
Belgium	0.820	0.983	0.923	1.000	0.942
Brazil	0.548	0.934	0.621	0.463	0.708
Bulgaria	0.664	1.000	0.936	0.817	0.755
Canada	1.000	1.000	1.000	1.000	1.000
China	1.000	1.000	1.000	1.000	1.000
Colombia	0.641	0.427	0.699	0.658	0.662
Cyprus	0.473	0.413	1.000	1.000	0.980
Czech Republic	0.952	1.000	0.825	0.727	0.867
Denmark	1.000	1.000	1.000	1.000	1.000
Estonia	1.000	1.000	1.000	1.000	1.000
Finland	1.000	1.000	1.000	1.000	1.000
France	0.755	0.827	1.000	1.000	0.880
Germany	1.000	0.508	0.715	0.739	0.954
Greece	0.515	0.997	0.988	1.000	0.944
Hong Kong	1.000	1.000	1.000	1.000	1.000
Hungary	0.804	1.000	0.866	0.578	0.794
Iceland	1.000	1.000	1.000	1.000	1.000
India	1.000	0.484	1.000	0.253	0.419
Indonesia	1.000	1.000	0.799	0.315	0.437
Ireland	1.000	1.000	1.000	1.000	1.000
Israel	0.805	0.744	0.778	0.983	0.881
Italy	0.890	0.782	0.874	0.683	0.883
Japan	0.901	1.000	0.984	0.945	0.934
Korea	1.000	1.000	1.000	1.000	1.000
Latvia	0.888	1.000	0.929	0.997	0.917
Lithuania	1.000	1.000	1.000	1.000	1.000

Table A5. *Cont.*

Economy	Savings	Education	Mobile	Communication	Use of Internet
Luxembourg	1.000	1.000	1.000	1.000	1.000
Malaysia	0.792	0.885	0.833	0.770	0.864
Mexico	0.652	0.775	0.671	0.497	0.686
The Netherlands	1.000	1.000	1.000	1.000	1.000
New Zealand	1.000	1.000	1.000	1.000	1.000
Norway	1.000	1.000	1.000	1.000	1.000
Philippines	0.634	0.723	0.571	0.467	0.648
Poland	0.662	0.975	0.895	1.000	0.889
Portugal	0.721	0.453	1.000	0.814	0.785
Qatar	1.000	1.000	1.000	1.000	1.000
Romania	0.738	0.760	1.000	0.603	0.821
Russia	1.000	1.000	1.000	1.000	1.000
Singapore	1.000	1.000	1.000	1.000	1.000
Slovak Republic	0.673	0.757	0.822	0.854	0.849
Slovenia	0.887	1.000	0.865	0.937	0.817
South Africa	0.425	0.686	0.599	0.119	0.580
Spain	0.811	0.877	0.940	1.000	0.926
Sweden	1.000	1.000	1.000	1.000	1.000
Switzerland	1.000	1.000	1.000	1.000	1.000
Taiwan	1.000	1.000	1.000	1.000	1.000
Thailand	0.975	1.000	0.871	0.690	0.592
Turkey	0.875	1.000	0.799	0.753	0.730
United Kingdom	1.000	1.000	1.000	1.000	1.000
USA	1.000	1.000	1.000	1.000	1.000

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