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Designing a CGE-based economic assessment mechanism from a tourism perspective: A case of post-COVID-19 recovery in Northeast Asia

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Abstract: This study aims to establish an economic assessment mechanism that evaluates the impacts of epidemic disasters from the perspective of the tourism industry. Using the Computable General Equilibrium (CGE) framework, we design a simulation mechanism to quantify losses caused by the COVID-19 pandemic. The Global Trade Analysis Project (GTAP) model incorporates tourism as a shock factor to simulate two scenarios: zero-COVID and coexistence, based on control measures implemented between 2020 and 2022 in the context of sustainable tourism development. Results indicate that economic indicators across all regions declined comprehensively under the assumption of rising unemployment. Specifically, (1) GDP losses are often underestimated but closer to observed outcomes; (2) accommodation and food service sectors exhibit greater output declines than transportation sectors; and (3) Northeast Asia experiences more severe output losses than the global average. Zero-COVID policies must be cautiously designed to prevent unemployment, particularly for smaller economies that are highly vulnerable to labor immobility. This study provides a tourism-oriented assessment mechanism for epidemic responses. It suggests that mitigating losses requires substituting cross-border consumption with trade in goods, restoring supply-side capacity, and avoiding excessive discriminatory restrictions on international travelers.
Keywords: *Economic assessment, Emergency management, GTAP, Tourism.*

1. Introduction

COVID-19 has been one of the most critical events in epidemic emergency management in recent years. The characteristics of COVID-19 include suddenness, uncertainty, destructiveness, derivativeness, and diffusiveness [1, 2]. Beyond its threat to human health, COVID-19 has also caused severe economic damage. With the widespread availability of vaccines and the declining fatality rate of mutated variants, governments in Europe and the United States have clearly shifted their strategies toward coexistence with the virus after the stages of mitigation and preparedness. The subsequent task is to formulate recovery policies aimed at restoring pre-pandemic productivity, with particular attention to the issue of sustainable development in the tourism industry.

The situation in Northeast Asia is unique, as it was the region most severely affected at the end of 2019. Although strict and effective policies have significantly reduced infection and mortality rates [3] the travel and leisure industry has not experienced a corresponding recovery [4-6]. As shown by travel export and import data [7] no significant rebound has occurred since the fourth quarter of 2019. Even though the World Health Organization (WHO) declared the end of the COVID-19 public health emergency in May 2023, the export and import values of the tourism industry in Northeast Asia have still not returned to pre-pandemic levels. By contrast, North America, Europe, and other regions have recovered and even exceeded their pre-pandemic figures (see Appendix 1). Among Northeast Asian countries, Japan has shown the fastest export recovery, whereas China's recovery remains below 50% of its 2019 levels.

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This shift can be attributed to changes in attitudes toward pandemic control in Northeast Asia following the emergence of the Omicron variant in 2022. At the beginning of that year, Japan and South Korea adopted coexistence strategies with the virus, while Hong Kong and Taiwan planned to lift restrictions gradually by mid-year. China, however, did not remove its border controls until early 2023. These divergent policy responses highlight the need to examine the economic impacts of both zero-COVID and coexistence policies, not only at the macroeconomic level but also with respect to regional trade. Accordingly, it is worthwhile to reassess whether the stringent zero-COVID measures implemented between 2020 and 2022 were a primary driver of the observed economic and trade downturn.

Since 2020, many countries have continued to incorporate lockdowns, isolation, and quarantine measures into their pandemic prevention policies to prevent the entry of COVID-19 [8, 9]. These measures have led to a sharp decline in cross-border travel [10-13]. Such policies directly affect tourism, particularly the accommodation and food service (AFS) industry [14, 15]. The AFS sector, which falls under consumption abroad and commercial presence modes of service trade, relies heavily on in-store consumption as the primary source of revenue for businesses [16, 17]. Consequently, AFS is highly vulnerable to border restrictions and domestic crowd-control measures. These constraints limit the scope of business operations, and the resulting liquidity risks have made business closures or market exits a frequent occurrence [18, 19].

However, pandemic control is not merely a binary choice between zero-COVID and coexistence policies; it involves complex trade-offs under conditions of uncertainty. This study, therefore, examines the variations in the degree of economic impacts associated with different policy intensities during the progression of the pandemic. For example, if the number of new cases in a region decreases substantially but does not fall to zero, the situation may be described as a partial achievement of zero-COVID, similar to China's dynamic zero-COVID strategy [20, 21]. Strict lockdown measures are generally required under zero-COVID approaches, resulting in different levels of economic disruption. Integrating mathematical models of emergency management with those for epidemic prevention has played a crucial role in shaping policy responses to public health emergencies such as COVID-19 [22].

Border controls have led to a continuous decline in tourism revenue. It is therefore important to evaluate the "cost" of maintaining prolonged border restrictions. The objective of this study is to analyze the economic changes associated with zero-COVID policies and, through a comparative analysis with coexistence strategies, to provide policy recommendations for the tourism sector during the recovery phase. In this context, our study establishes a mechanism for economic assessment. Using a computable general equilibrium (CGE) model from the perspective of the tourism industry, we examine the boundaries of economic impacts across various regions in Northeast Asia.

The main contributions of this study are as follows:

(1) By modifying the economic assumptions of the Global Trade Analysis Project (GTAP) model, we expand the application of the static GTAP framework to better reflect the economic impacts of COVID-19.

(2) We conduct an economic assessment using a multi-year comparative static approach, which captures the evolving nature of the pandemic and its implications for tourism.

This article is organized as follows: Section 2 is a literature review of the impact of the pandemic on the economy and tourism. Section 3 introduces the GTAP model and database. Section 4 provides simulation scenarios and shock designs, simulation results, and comparative statics. Section 5 is our discussion and summarizes the simulation results. The policy implications and conclusions are presented in the last two sections.

2. Literature Review

This section reviews the literature on the economic and tourism impacts of the COVID-19 pandemic, focusing on emergency management under pandemic policies, impact assessments using the GTAP model, and empirical studies of the tourism industry.

2.1. Emergency Management

In early 2020, to mitigate the widespread transmission of the coronavirus, many countries implemented mandatory large-scale quarantines, while border controls became the primary external policy under lockdown measures. The rationale for lockdowns was to shorten the duration of the crisis by reducing the number of COVID-19 cases and minimizing the economic disruption caused by the pandemic. Given the highly detrimental impact of the coronavirus, lockdowns were regarded as the only feasible policy option [8].

By 2021, as the transmissibility of new variants increased while their fatality rates declined, policymakers began to emphasize the "preparedness" phase. Each economy faced the challenge of balancing pandemic prevention with economic recovery, a trade-off that could not be fully resolved simultaneously [8, 23]. Under such circumstances, restoring normal lifestyles and production at the lowest possible cost of pandemic control became the primary goal, and vaccination was identified as the most viable solution to this challenge [24].

2022 marked a turning point in the "response" phase between Northeast Asia and Western countries. Although the full vaccination rate in Northeast Asian economies exceeded 70% in 2022[24, 25] [1], the region continued to prioritize vaccine development, research on the effectiveness of vaccine mixing, and the timely administration of booster shots to strengthen immunity. Nevertheless, most Northeast Asian economies maintained zero-COVID strategies and did not fully lift crowd-control measures.

Lockdowns and crowd-control policies increased social distancing, which in turn restricted the mobility of production factors and reduced real productivity. Prolonged low capacity ultimately resulted in labor unemployment [26, 27]. During the pandemic, workers unable to work remotely and those in low-wage occupations were particularly vulnerable to job loss [28]. The persistence of zero-COVID policies not only slowed domestic economic recovery but also affected foreign economies due to the interdependence of international supply chains [29, 30]. Consequently, before entering the recovery phase, policymakers must draw on three years of experience in pandemic prevention to conduct precise impact assessments and design effective revitalization strategies for the post-pandemic period.

2.2. Impact Assessments Using the GTAP Model

Numerous studies have employed the GTAP model to evaluate the economic impact of the COVID-19 pandemic across various countries, including those in Northeast Asia. Owing to differences in the shocks and scenarios designed, these studies have produced varying simulation results. McKibbin and Fernando [31] for instance, analyzed China under seven scenarios using assumptions on attack rates, case-fatality rates, and implied mortality rates. They applied shocks to labor supply and other variables to conduct simulation analyses. Their results showed GDP growth rates ranging from −6.2% to −0.4% for China, −9.9% to 0.3% for Japan, and −5.8% to 0.1% for South Korea [31].

Similarly, Song, et al. [3] evaluated the effectiveness of containment measures in China, reporting GDP growth rates ranging from −4.8% at the onset of the pandemic to 3.1% once full containment was achieved Song, et al. [3]. Verikios [32] employed a dynamic CGE model framework and found that

[1] With the novel coronavirus, the policy of vaccinating will become normal. According to the WHO, as of December 2023, the percentages of the total population vaccinated with a complete primary series of a COVID-19 vaccine in China, Japan, and South Korea were approximately 87%, 82%, and 87%, respectively. (https://covid19.who.int/); Hong Kong, Macao, and Taiwan are approximately 91%, 92%, and 87%, respectively. Please refer to Our World in Data. (https://ourworldindata.org/covid-vaccinations).

GDP growth turned positive for China and South Korea in the third quarter of 2020, and for Japan in the first quarter of 2021 Verikios [32]. Park, et al. [18] simulated scenarios based on the duration of containment, estimating China's GDP growth at −7.5% for short-term containment and −11.2% for long-term containment, while Japan's GDP growth was −5.9% and −8.9%, respectively [18].

The studies mentioned above primarily focused on commodity sectors, with variable shocks applied to real output and import tariffs. However, the literature using the GTAP model has not extensively examined the tourism industry. To address this gap, our analysis incorporates the tourism sector as a source of shock. Beyond GTAP-based studies, Škare, et al. [17] applied a panel structural vector autoregression analysis using data from 185 countries spanning 1995–2019 to estimate the pandemic's impact on tourism. Their findings indicated GDP declines of USD 853 billion in Europe, USD 895.6 billion in Northeast Asia, USD 1.5 trillion in the Americas, and USD 1.1 trillion in the Asia-Pacific region [17].

2.3. Empirical Estimations of the Tourism Industry

According to the World Travel and Tourism Council [33] large-scale pandemic prevention measures could cost the tourism sector approximately USD 2.1 trillion in GDP by 2020. In terms of GDP share, the contribution of tourism declined by 49.1%, resulting in the loss of around 62 million jobs. The United Nations World Tourism Organization (UNWTO) has also closely monitored the pandemic's impact on global tourism. On March 6, 2020, international travel was reported to be 2%–3% lower than in 2019. However, within just three weeks, by March 26, 2020, the reported reduction had widened to 20%–30% [34]. Many scholars argue that this estimate was highly conservative [17]. UNWTO data showed that by January 2021, international travel had declined by 86% compared with 2019, with the Asia-Pacific region experiencing an even steeper reduction of 96% [34].

The empirical findings of Škare, et al. [17] indicated that the global tourism industry's total contribution to GDP declined between 2.93% and 7.82%. Employment in the sector fell by 2.44% to 6.55%, while inbound tourism spending was estimated to drop by 25.0% to 35.0% Škare, et al. [17]. Fotiadis, et al. [35] further reported that international tourist flows decreased by 30.8% to 76.3% across regions, significantly disrupting the world's socio-economic and political landscape.

Taken together, these studies suggest that the COVID-19 pandemic had a severe negative impact on global tourism and the broader economy. For Northeast Asia, we are particularly concerned with the differences in the magnitude of these impacts across economies. The distinct contribution of this study is that it conducts a post-event analysis, aiming to explore the range of negative economic impacts of the pandemic and to establish a new mechanism for economic assessment specific to the tourism sector and epidemic management.

3. Method and Data

This section describes the GTAP standard model (version 10 database) and its indicators. Our research revised GTAP economic assumptions, shock coefficient, and scenario design based on zero-COVID characteristics.

3.1. The GTAP Model

The GTAP model is built on the neoclassical microeconomic theory of general equilibrium and incorporates data on bilateral trade, input, output, and factor allocation. The GTAP model is a CGE developed by Hertel [36] it can be a comparative statics analysis of multiregional and multisectoral. The components of the GTAP model, including the production structure, final demand structure, government, global transportation, global bank, and world regions, are presented. The advantage of the CGE model is that it can capture the linkage of events to various economies. Therefore, we use GTAP to simulate the impact of the COVID-19 pandemic in multiple regions, which is appropriate to observe the changes in its economic indicators and perform a comparative static analysis.

The production structure satisfies the cost minimization assumption, and the firms' output is determined using a three-stage optimization problem. The first stage is to decide the optimal value-added of land, capital, natural resources, and skilled and unskilled labor. This substitution elasticity of factors is the constant elasticity of the substitution (CES) function. The second stage is to determine the optimal proportion of intermediate input in domestic and imported inputs. This substitution elasticity of inputs is the Armington assumption [37]. Finally, firms' optimal outputs are determined by aggregating the value-added and the intermediate input using the Leontief function. The left side of Figure 1 depicts the nested production structure.

The final demand is composed of private consumption, government consumption, and savings. The regional household allocates total regional income over the three segments according to the Cobb–Douglas (C–D) function, implying that the proportions of expenditure of the three segments are fixed. The demand for private consumption is characterized by a nonhomothetic constant difference elasticity function, and a C–D function models the government expenditure. The final demands of private households and the government comprise domestic and imported goods. Following the Armington assumption, imports are first aggregated into composite imports using a CES function. Then, the composite imports and domestic goods are aggregated into the final consumption composite using a CES function. The nested picture of the consumption structure is shown on the right side of Figure 1.

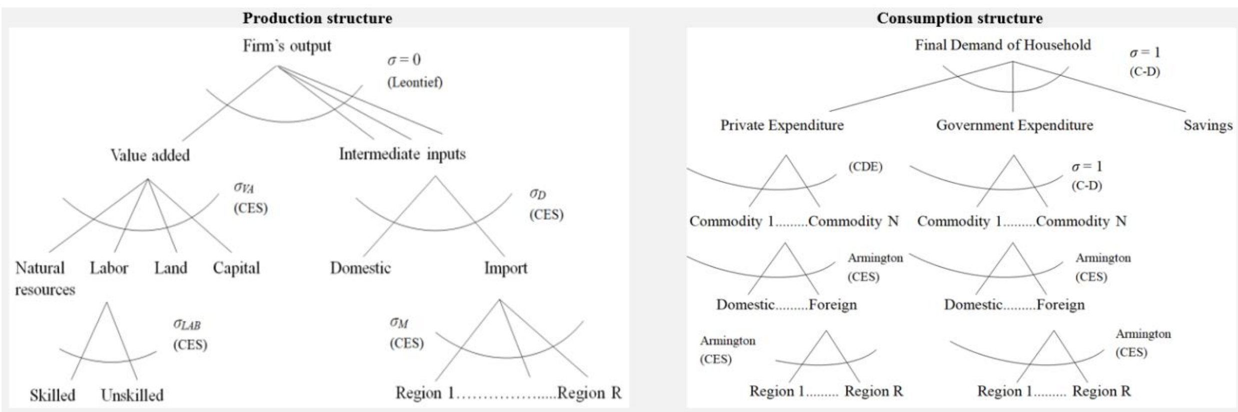

Figure 1.
Production and consumption structure nested picture.
Source: Armington [37]. *Global Trade Analysis: Modeling and Applications*. New York: Cambridge University Press.

The global transportation department calculates the transportation costs incurred by bilateral trade. Due to government intervention, prices in the two regions (A and B) change during the bilateral trade. When goods from A are exported to B, region A will impose tariffs or subsidies on the goods, but the price is free on board (FOB). Before the goods are exported to region B, the price comprises the cost, insurance, and freight (CIF) and is calculated as the transportation cost plus the FOB. Both FOB and CIF are the world prices. Finally, the government will intervene in goods entering region B, so the market price in region B is CIF plus tariffs or subsidies. GTAP calculates the import tariff based on the difference between the world and market prices. Therefore, the GTAP can provide complete bilateral tariff information.

The closure rules in the CGE models are the classifications of endogenous and exogenous variables. We can execute event simulations using shock exogenous variables. The GTAP model adopts a neoclassical macroeconomic closure at the global level. A fictitious global bank connects investment and savings in regions. In equilibrium, global savings are equal to global investment.

3.2. The GTAP Database

Our research adopts the GTAP version 10 database with 2017 as the base year. The database divides the world economy into 141 regions, each with 65 production sectors [38]. Our analysis focuses on the impacts of the COVID-19 pandemic in Northeast Asia, which is presented separately, including China (CHN), Japan (JPN), South Korea (KOR), Hong Kong (HKG), Taiwan (TWN), and the rest of Northeast Asia (RNA)[2]. Other regions are categorized based on their geographical location. We have grouped the 141 regions into 13 regions. Sectoral classification presents primary and secondary sectors. In the services, we presented separately by tourism sectors, including Accommodation, food, and service activities (AFS), Air transport (ATP), and other transport (ETP)[3]. And the others are highly aggregated. We aggregate the 65 sectors into 9 sectors.

3.3. The Indicators of Simulation in GTAP

The GTAP simulation indicator in this study mainly focuses on the change in the real GDP of the affected region (r) during the pandemic. The GDP is the quantity index in the GTAP model. After simulation, the percentage change in GDP is expressed as $qgdp(r)$, and the amount of change is calculated as $GDP(r) * qgdp(r)$. The second indicator is to observe the changes in total welfare. In the GTAP model, equivalent variation is adopted to measure welfare. The total welfare is the aggregate of four categories: allocative efficiency effects, terms of trade effects, investment–savings effects, and endowment effects [39]. The third indicator is to observe the change in sectoral output. We are concerned with the sum of all commodities/sectors (i) in each region (r). After simulation, $qo(i,r)$ is the percentage change and amount of change calculated as $VOM(i,r) * qo(i,r)$, where $VOM(i,r)$ is a value of the output of commodity (i) in the region (r) at the market price. Finally, we observe the changes in bilateral trade. The $qxs(i,r,s)$ is the percentage of change, which refers to export sales of the commodity (i) from the region (r) to the destination (s).

3.4. Shock Design

In this section, we describe scenarios and shocks before describing the simulation. The shock setting for international tourists comes from two components. The first one is the impact of the decline in international tourist receipts on AFS [5]. Because AFS is affected by international tourists, a suitable scenario design should exclude domestic consumption. We use the decline in the percentage of international tourist receipts as the simulated shock percentage [34] then multiply it by the percentage of international tourism receipts in total exports to exclude domestic consumption and thus derive the percentage of the decline in international tourists on AFS in Table 1 [34, 40, 41] [4]. Until the end of 2023, international tourists in Northeast Asia have not significantly recovered. Therefore, we employ a simulation analysis covering 2020 to 2023, utilizing updated data obtained after the 2020, 2021, and 2022 simulations as the base data for 2021, 2022, and 2023, respectively [42].

[2] RNA is aggregated by "Mongolia" and "the Rest of East Asia (Macao, SAR of China and Korea, DPR)". In addition to Northeast Asia, the rest of the regions are "Southeast Asia", "Southern Asia", "Western and Middle East Asia", "Oceania", "America", "Europe", and "Africa and the Rest of the World". Regional classification is organized according to the naming of the GTAP website. (http://www.gtap.org).

[3] ETP is aggregated by "Water transport" and "transport not elsewhere classified". In addition to AFS, ATP and ETP, the other sectors are "Primary industry", "Secondary industry", "Trade and Warehouse", "Financial", "Restricted services", and "Else services".

[4]"Decline in international tourist receipts" used in this study is updated to December 2022 from. "The percentage of International tourism receipts in total exports" uses 2019 data from the to reflect the tourism situation before the pandemic. Finally, we refer to mentioned that the aim of "import technology (ams)" is to handle bilateral service liberalization and other efficiency-enhancing measures to reduce the effective price of goods and service imports. As tourism is a service, imported technology can be a shock variable.

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Table 1.
The percentage of the decline in international tourists on AFS.

Year / Region	CHN	JPN	KOR	HKG	TWN	RNA
2020	-3.30	-4.19	-1.97	-4.56	-5.15	-41.70
2021	-3.21	-4.84	-1.85	-4.77	-5.55	-38.53
2022	-2.89	-4.13	-1.54	-4.51	-5.15	-30.73
2023	-1.33	0.44	-1.04	-1.42	-2.28	-3.90

Note: RNA figures are calculated based on the average of Mongolia and Macao.

The second one is to consider the spillover effect of production due to the decline in international tourists. The loss of international tourists will affect AFS and have negative spillover effects on production. For example, some crops will be left without buyers when restaurants and hotels are closed because of the COVID-19 pandemic [43]. Therefore, the production of crops will be affected. Moreover, the spillover effect will impact other economies through global supply chains and trade, especially the neighbors of Northeast Asia [3]. This study uses the Tokyo 2020 Olympic and Paralympic Games [44] as an example [45] [5]. The shock percentage of the spillover effect is measured by the decline in international air passengers, which is approximately 3.88% [40, 46] [6].

We modify the GTAP standard model and use output technology as the shock variable. According to Formula (1), the production function incorporates the technology spillover equation [44].

$$a_{irs} = E_{irs}^{1-\delta_{irs}} \cdot a_{ir}\ ,\ \delta_{irs} = \delta(H_{rs}, D_{irs}), \quad 0 \leq \delta_{irs} \leq 1, 0 \leq E_{irs} \leq 1 \qquad (1)$$

where i denotes the sector; s denotes the destination region; r denotes the region of origin of the productivity growth; a_{irs} denotes sector i's productivity growth rates from the origin to the destination region. a_{ir} denotes sector i's productivity growth rates of the origin regions. E_{irs} is an index of the amount of knowledge of sector i that is embodied in trade linkages between the two regions. δ_{irs} is a spillover delta calculated by an absorption capacity index (H_{rs}) multiplied by a structural similarity index (D_{irs}); the value is between 0 and 1[47] [7].

H_{rs} is determined by the relationship of human capital between the two regions, and it is measured by the average education level (h_s ans h_r), such as Formula (2). The complete transmission of knowledge occurs when the human capital in the destination region is higher than in the origin region. H_{rs} is equal to 1, it indicates that the destination region can fully convert knowledge into technology. Conversely, when H_{rs} is the approach 0, it means that the destination region lacks sufficient absorption capacity.

$$H_{rs} = min\ [1\ , \frac{h_s}{h_r}\ ] \qquad (2)$$

[5] Due to COVID-19, on July 8, 2021, the Japanese government announced that Tokyo had entered a fourth state of emergency, which will last until August 31, 2021. Thus, there would be no spectators at the venues of the Tokyo Olympic and Paralympic Games in 2020, and the expected revenue from ticket sales and merchandise being 90 billion yen would be down to a fraction of only several billion yen.

[6] The international passengers in the Asia Pacific fell by 77.6% (revenue passenger kilometers) in October 2020 from the International Air Transport Association. The percentage of tourism exports in Japan is about 5%. We use these data to calculate the percentage of the negative spillover effect, which is 3.88% in 2020. The production impact caused by international travelers of Tokyo 2020 gradually decreases over time. Therefore, the study assumes that the spillover effects will be reduced by half in 2021, 2022, and 2023. We conducted multi-stage simulations to test the convergence of economic indicators. This is to demonstrate the robustness of the GTAP modification mechanism. Meanwhile, it also predicts the recovery of the actual economic situation.

[7] The absorption capacity index (H_{rs}) data are from the study of. Database URL: http://barrolee.com/ the structural similarity index (D_{irs}) is from the value of purchases of endowment commodity at agents' price in the GTAP version 10 database.

D_{irs} is determined by the relationship of structural similarity in sectors between the two regions, such as Formula (3). When the sector is more similar between the two regions, the destination region can convert technology into production behavior through specific sectors. φ_{ir} and φ_{is} are structural characteristic indicators for sector i in region s and sector i in region r, and their difference represents the sectoral difference. d_i^{max} is the country where sector i has the most significant difference among all the regions. When φ_{ir} and φ_{is} are more similar, D_{irs} tends to approach 1. Conversely, when the difference is greater, D_{irs} tends to approach 0.

$$D_{irs} = exp\ [-\left|\frac{(\varphi_{ir} - \varphi_{is})}{d_i^{max}}\right|] \quad (3)$$

Combining 2 and 3, we can conclude that when the destination region has better absorption capacity ($H_{rs} \to 1$) but does not have structural similarity in domestic sectors, it cannot use new technology for production due to the industrial gap between the two regions. Similarly, when the destination region has structural similarity in sectors ($D_{irs} \to 1$) but without sufficient human capital, the knowledge cannot be absorbed, and new technologies cannot be available.

3.5. Simulation Scenarios

Pandemic prevention policies can cause production factors immobility, especially labor factors. The long-term policy of zero-COVID will lead to unemployment in the labor market, making the economic assumption of perfect competition unreasonable. Some scholars have begun to break the perfect competitive assumption and use unemployment instead of full employment [48, 49]. According to the characteristics of the zero-COVID policy, we modify the economic assumption of the GTAP model, incorporating the unemployment situation of wage rigidity. Moreover, we adjust the labor mobility. After the COVID-19 pandemic, labor cannot be fully mobile worldwide, and the transformation between skilled and unskilled labor has become difficult [42]. Finally, under policy responses in different economic assumptions, we conduct four scenarios to simulate, as shown in Table 2.

Table 2.
The design of simulation scenarios.

Descriptions of shock	**Policy Responses**	**Economic assumptions**		**Scenarios**	**Comparative Static**
		Employment	**Labor mobility**		
(i). The impact of the decline in international tourists on AFS. (ii) Spillover effects of the decline in international air passengers.	Coexistence	Full employment	Mobile	F_M	baseline
	Zero-COVID	Full employment	Immobile	F_IM	CS_1
		Unemployment	Mobile	UN_M	CS_2
		Unemployment	Immobile	UN_IM	CS_3

Scenario F_M represents the coexistence policy and serves as a benchmark for the comparison. This study presents three scenarios for the zero-COVID policy. Scenario F_IM is a simulation of labor immobility caused by the zero-COVID policy, and its purpose is to reflect the phenomenon that labor factors (skilled labor and unskilled labor) cannot be normally converted during pandemic prevention. Scenario UN_M is a simulation of unemployment caused by the zero-COVID policy to reflect the economic environment that changed full employment under perfect competition to unemployment under imperfect competition during pandemic prevention. Scenario UN_IM considers both labor immobility and unemployment. Scenario F_IM and scenario UN_M are similar to the dynamic zero-COVID scenario design, while scenario UN_IM is a scenario design that strictly enforces zero-COVID.

CS1 is the comparison between scenario F_IM and F_M, which is the analysis of labor immobility during pandemic prevention; CS2 is the comparison between scenario UN_M and F_M, which is the analysis of unemployment during pandemic prevention; CS3 is the comparison between scenario

UN_IM and F_M, which considers the strict policy of zero-COVID. The design of the economic assessment mechanism is shown in Figure 2.

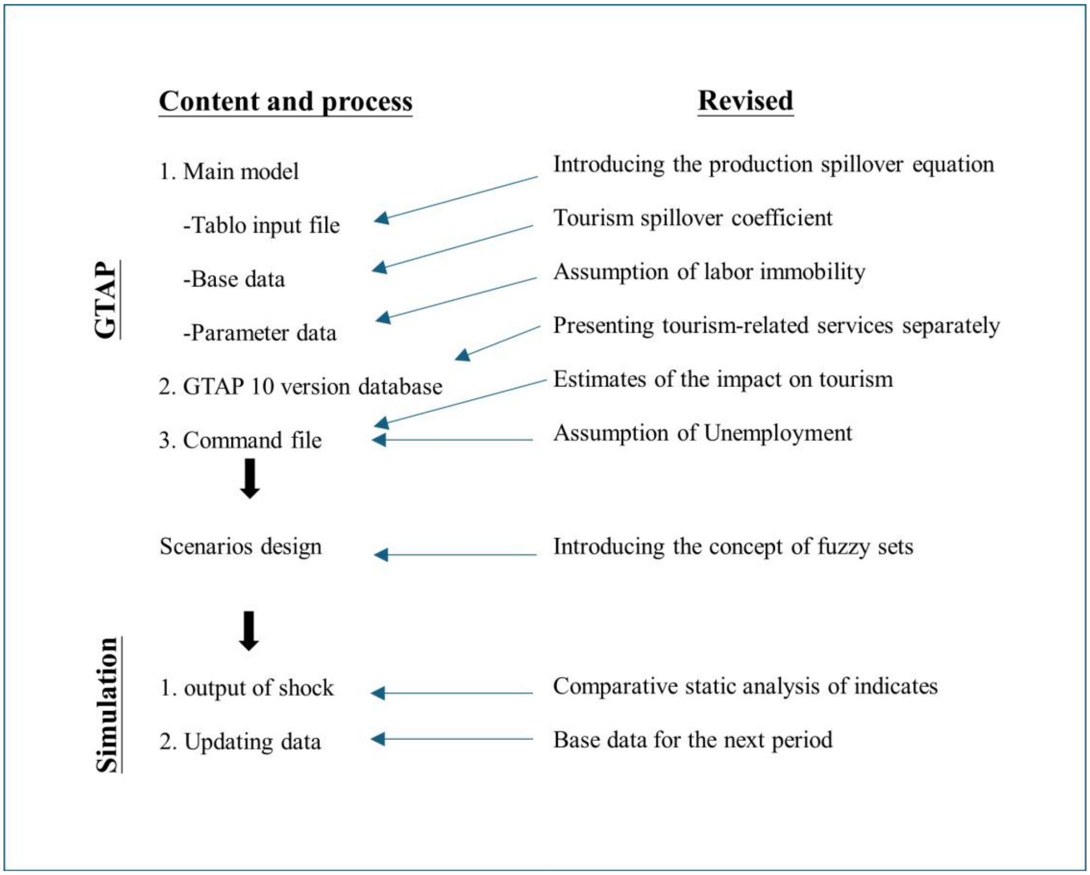

Figure 2.
Economic assessment mechanism.

4. Simulation Results

This section analyzes the simulation results of the decline in international tourism caused by the COVID-19 pandemic and its impact on Northeast Asian economies, holding other factors constant. We begin with the results for changes in macroeconomic indicators (real GDP, welfare effects, and sectoral output) and bilateral trade.

4.1. Changes in Macroeconomic Indicators

Table 3 presents the simulation results for 2020. In the baseline scenario (F_M), Northeast Asia's GDP declines across most economies. The percentage decreases are −0.43% in Hong Kong, −0.34% in RNA, −0.28% in South Korea, −0.25% in Japan, −0.17% in Taiwan, and −0.02% in China. In absolute terms (USD), Japan experienced the most severe loss of USD 11.26 billion, followed by South Korea (−USD 3.94 billion), China (−USD 1.76 billion), Hong Kong (−USD 1.26 billion), Taiwan (−USD 0.91 billion), and RNA (−USD 0.29 billion). The welfare effects mirror the GDP results, showing an overall welfare loss under the coexistence policy scenario.

Regarding sectoral output, the aggregate output of all sectors declined in every economy except China. China's total output value increased by 0.22% (USD 90.76 billion), whereas Japan, South Korea, Hong Kong, Taiwan, and RNA registered declines of −3.35% (−USD 459.30 billion), −2.45% (−USD 121.58 billion), −2.94% (−USD 31.68 billion), −2.58% (−USD 49.95 billion), and −0.36% (−USD 1.10 billion), respectively. These findings suggest that if China pursues a coexistence-oriented policy, it could emerge as a central driver of regional production.

Tourism was the sector most directly affected by the pandemic, particularly transportation (ATP and ETP). However, the results for the accommodation and food service (AFS) sector diverge. While Japan, South Korea, Hong Kong, and Taiwan experienced declines in AFS output, both China and RNA recorded growth. This pattern implies that under a coexistence policy, the aforementioned economies are more vulnerable to fluctuations in international tourist demand. By contrast, given China's vast potential outbound tourism market, both China and RNA shifted toward domestic tourism, allowing AFS to benefit despite the pandemic [50, 51].

When the zero-COVID policy is adopted and labor immobility occurs, GDP losses in Northeast Asia are reduced, as shown in scenario CS1. This suggests that, under conditions of labor immobility, the zero-COVID policy generates relatively better economic growth than coexistence. When an economy has sufficient labor resources, domestic production becomes more favorable, thereby mitigating the losses previously driven by declines in international tourism. The same conclusion applies to welfare, with the exception of China. However, sectoral output deteriorates further in most economies, except for Hong Kong and RNA, whose manufacturing industries account for only a small share of output.

When the zero-COVID policy is adopted and unemployment emerges, the losses in Northeast Asia's economic indicators intensify, as illustrated in scenario CS2. This implies that the negative impact on international tourism is compounded when the employment environment deteriorates due to pandemic prevention measures. Compared with the coexistence scenario, China, Japan, South Korea, Hong Kong, Taiwan, and RNA experience additional losses of 0.80%, 4.87%, 2.77%, 3.07%, 2.91%, and 2.78%, respectively.

When the zero-COVID policy simultaneously generates both labor immobility and unemployment, the results from scenario CS3 largely resemble those of CS2. However, a comparison of CS2 and CS3 reveals that the economic recession in China, Japan, and South Korea slows somewhat, while that in Hong Kong and Taiwan worsens. This outcome indicates that smaller economies are more vulnerable to the effects of labor immobility.

Table 3.
Simulation results of the decline in international tourists in 2020.

		GDP		Welfare	Sectoral output							
					sum		AFS		ATP		ETP	
	Regions	**%**	**USD**	**USD**	**%**	**USD**	**%**	**USD**	**%**	**USD**	**%**	**USD**
Baseline	CHN	-0.02	-1.76	-1.38	0.22	90.76	0.37	1.62	0.00	0.00	-0.02	-0.17
	JPN	-0.25	-11.26	-0.73	-3.35	-459.30	-3.17	-8.46	-0.01	0.00	-0.03	-0.11
	KOR	-0.28	-3.94	-1.04	-2.45	-121.58	-1.38	-1.21	-0.05	-0.01	-0.09	-0.08
	HKG	-0.43	-1.26	-0.14	-2.94	-31.68	-1.53	-0.67	-0.13	-0.03	-0.15	-0.13
	TWN	-0.17	-0.91	-0.13	-2.58	-49.95	-1.89	-0.47	-0.24	-0.02	-0.05	-0.01
	RNA	-0.34	-0.29	0.00	-0.36	-1.10	1.34	0.13	-0.36	-0.03	-0.18	-0.06
CS_1	CHN	0.00	-0.31	-0.24	-0.08	-33.52	-0.05	-0.20	0.00	0.00	0.00	-0.02
	JPN	0.01	0.23	0.28	-0.05	-6.85	-0.16	-0.42	0.02	0.00	0.01	0.04
	KOR	0.02	0.27	0.12	-0.03	-1.49	-0.14	-0.12	0.00	0.00	0.01	0.00
	HKG	0.01	0.04	0.02	0.16	1.72	0.05	0.02	0.02	0.00	0.01	0.01
	TWN	0.01	0.06	0.03	-0.11	-2.13	-0.26	-0.07	0.02	0.00	0.02	0.00
	RNA	0.04	0.03	0.03	0.43	1.31	-0.07	-0.01	0.04	0.00	0.01	0.01
CS_2	CHN	-0.80	-83.12	-81.59	-10.54	-4309.86	-0.90	-3.96	-0.96	-0.77	-0.85	-8.03
	JPN	-4.87	-224.06	-184.74	-62.99	-8636.15	-4.80	-12.80	-4.58	-1.42	-4.64	-17.18
	KOR	-2.77	-39.11	-31.47	-36.14	-1793.39	-2.72	-2.38	-3.01	-0.60	-2.81	-2.75
	HKG	-3.07	-8.93	-7.17	-40.17	-432.85	-3.02	-1.32	-3.24	-0.80	-3.06	-2.66
	TWN	-2.91	-15.41	-12.55	-37.43	-724.63	-3.01	-0.75	-2.94	-0.22	-2.94	-0.59
	RNA	-2.78	-2.37	-2.15	-37.97	-115.21	-3.42	-0.33	-3.19	-0.30	-3.07	-0.93
CS_3	CHN	-0.78	-81.05	-79.28	-10.20	-4170.86	-0.89	-3.92	-0.93	-0.75	-0.83	-7.84
	JPN	-4.73	-217.63	-179.67	-61.56	-8440.09	-4.83	-12.88	-4.48	-1.39	-4.54	-16.81
	KOR	-2.76	-38.96	-31.36	-36.18	-1795.38	-2.86	-2.50	-2.98	-0.60	-2.80	-2.74
	HKG	-3.11	-9.05	-7.25	-40.63	-437.81	-3.03	-1.32	-3.24	-0.80	-3.08	-2.68
	TWN	-2.96	-15.68	-12.73	-38.30	-741.47	-3.28	-0.82	-2.95	-0.22	-2.96	-0.59
	RNA	-2.68	-2.28	-2.09	-36.39	-110.42	-3.29	-0.32	-2.95	-0.28	-2.82	-0.86

Note: USD means a billion USD. The "sum" is a summation of all sectors.

Finally, we examine the robustness of the modified GTAP model and its shock design. It is assumed that the production impact of Tokyo 2020, driven by international travelers, diminishes over time. Under the assumption that the impact is halved each year, the economic losses in 2021, 2022, and 2023 decline proportionally compared with 2020 (as shown in Figure 3). This outcome suggests that the modified GTAP model is relatively robust. Moreover, it also simulates the tourism industry's transition into the recovery phase. As border controls are gradually lifted, although international tourism may not fully return to pre-2020 levels, the negative impacts on production and the economy are expected to ease progressively.

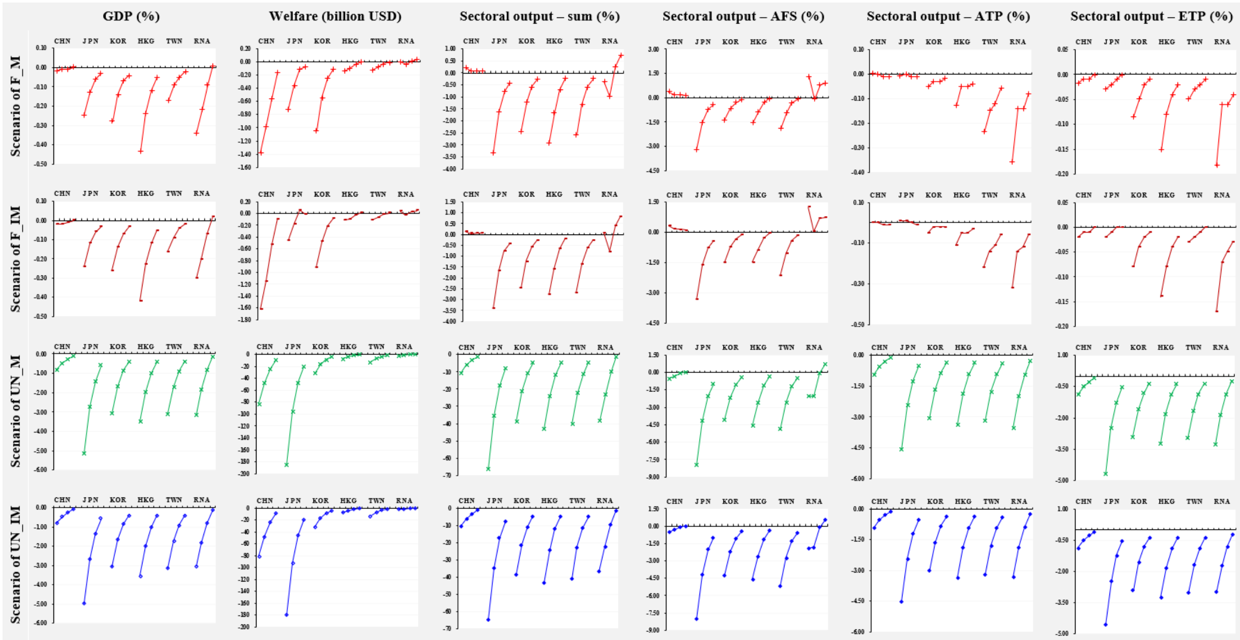

Figure 3.
Simulation results of the impact of COVID-19 in Northeast Asia.

Note: The points in the figure represent the predicted trends from 2020 to 2023. The "sum" is the sum of all sectors.

Table 4.
Simulation results of bilateral trade under the impact of the COVID-19 pandemic in 2020.

		sum of all sectors						**AFS**					
	Regions	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Scenario of F_M	CHN	-	-	3.89	-11.50	4.27	-8.64	-	-	4.17	-11.90	4.97	-7.83
	JPN	-11.50	3.89	-	-	-10.10	-7.40	-11.90	4.17	-	-	-9.76	-6.30
	KOR	-8.64	4.27	-7.40	-10.10	-	-	-7.83	4.97	-6.30	-9.76	-	-
	HKG	-4.91	1.32	-3.63	-12.60	-3.31	-9.79	-4.94	2.29	-3.36	-12.10	-2.63	-7.99
	TWN	-8.05	3.86	-6.82	-10.40	-6.53	-7.44	-7.95	4.24	-6.43	-10.40	-5.71	-6.24
	RNA	-1.79	-30.90	-0.45	-40.20	-0.10	-38.70	-0.33	-30.90	1.33	-40.60	2.10	-37.80
Scenario of F_IM	CHN	-	-	3.87	-11.46	4.35	-9.06	-	-	4.22	-11.92	5.17	-8.28
	JPN	-11.46	3.87	-	-	-10.00	-7.87	-11.92	4.22	-	-	-9.73	-6.85
	KOR	-9.06	4.35	-7.87	-10.00	-	-	-8.28	5.17	-6.85	-9.73	-	-
	HKG	-4.42	1.31	-3.19	-12.62	-2.77	-10.24	-4.37	2.23	-2.88	-12.25	-1.99	-8.62
	TWN	-8.64	4.33	-7.48	-9.97	-7.11	-7.49	-8.71	4.8	-7.29	-10.04	-6.44	-6.32
	RNA	-1.80	-30.56	-0.52	-39.83	-0.07	-38.63	-0.55	-30.68	1	-40.49	1.93	-38.04
Scenario of UN_M	CHN	-	-	-22.86	-41.18	-8.32	-23.13	-	-	1.17	-14.49	3.45	-8.97
	JPN	-41.18	-22.86	-	-	-51.86	-48.27	-14.49	1.17	-	-	-13.77	-10.23
	KOR	-23.13	-8.32	-48.27	-51.86	-	-	-8.97	3.45	-10.23	-13.77	-	-
	HKG	-18.48	-13.48	-43.84	-56.34	-29.43	-38.58	-6.44	0.72	-7.73	-16.04	-5.65	-10.63
	TWN	-24.09	-9.28	-48.91	-52.73	-34.68	-34.88	-9.98	3.13	-11.22	-14.04	-9.22	-8.5
	RNA	-12.56	-44.75	-37.31	-82.21	-22.72	-66.12	-1.81	-32.07	-3.17	-43.37	-0.99	-39.72
Scenario of UN_IM	CHN	-	-	-20.98	-41.74	-7.53	-23.62	-	-	1.55	-14.63	3.86	-9.56
	JPN	-41.74	-20.98	-	-	-52.33	-47.61	-14.63	1.55	-	-	-13.8	-10.71
	KOR	-23.62	-7.53	-47.61	-52.33	-	-	-9.56	3.86	-10.71	-13.8	-	-
	HKG	-18.70	-13.16	-42.89	-57.20	-29.54	-39.36	-6.1	0.85	-7.29	-16.3	-5.18	-11.33
	TWN	-25.20	-8.55	-48.85	-53.29	-35.70	-35.36	-10.71	3.77	-11.84	-13.88	-9.84	-8.76
	RNA	-11.46	-43.84	-35.06	-82.41	-21.52	-66.09	-1.76	-31.83	-3.01	-43.43	-0.8	-40.07
		ATP						**ETP**					
	Regions	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**

Scenario of F_M	CHN	-	-	0.02	0.12	-0.07	0.05	-	-	-0.05	0.04	-0.14	0.03
	JPN	0.12	0.02	-	-	-0.03	-0.02	0.04	-0.05	-	-	-0.09	-0.02
	KOR	0.05	-0.07	-0.02	-0.03	-	-	0.03	-0.14	-0.02	-0.09	-	-
	HKG	-0.08	-0.04	-0.15	0.00	-0.23	-0.07	-0.13	-0.15	-0.17	-0.10	-0.27	-0.12
	TWN	-0.29	0.06	-0.36	0.10	-0.44	0.03	0.03	-0.13	-0.02	-0.08	-0.11	-0.09
	RNA	-0.39	0.02	-0.46	0.06	-0.54	-0.01	-0.19	-0.12	-0.23	-0.07	-0.33	-0.08
Scenario of F_IM	CHN	-	-	0.00	0.13	-0.08	0.02	-	-	-0.06	0.06	-0.14	0.03
	JPN	0.13	0.00	-	-	-0.01	-0.04	0.06	-0.06	-	-	-0.06	-0.01
	KOR	0.02	-0.08	-0.04	-0.01	-	-	0.03	-0.14	-0.01	-0.06	-	-
	HKG	-0.08	-0.05	-0.14	0.02	-0.22	-0.09	-0.14	-0.14	-0.18	-0.06	-0.27	-0.1
	TWN	-0.28	0.05	-0.33	0.12	-0.42	0.01	0.04	-0.13	0	-0.05	-0.09	-0.09
	RNA	-0.36	0.04	-0.42	0.10	-0.50	-0.01	-0.2	-0.07	-0.24	0.01	-0.33	-0.03
Scenario of UN_M	CHN	-	-	-3.06	-2.31	-1.36	-1.37	-	-	-2.57	-2.96	-1.05	-2.1
	JPN	-2.31	-3.06	-	-	-3.81	-4.56	-2.96	-2.57	-	-	-4.09	-4.72
	KOR	-1.37	-1.36	-4.56	-3.81	-	-	-2.1	-1.05	-4.72	-4.09	-	-
	HKG	-1.52	-1.62	-4.70	-4.06	-3.03	-3.14	-1.77	-1.53	-4.4	-4.55	-2.91	-3.7
	TWN	-1.70	-1.39	-4.87	-3.84	-3.21	-2.92	-2.1	-1.15	-4.72	-4.19	-3.24	-3.33
	RNA	-1.59	-1.45	-4.77	-3.90	-3.10	-2.98	-1.63	-1.3	-4.26	-4.33	-2.77	-3.48
Scenario of UN_IM	CHN	-	-	-2.88	-2.27	-1.32	-1.28	-	-	-2.5	-3	-1.29	-1.74
	JPN	-2.27	-2.88	-	-	-3.78	-4.34	-3	-2.5	-	-	-4.26	-4.21
	KOR	-1.28	-1.32	-4.34	-3.78	-	-	-1.74	-1.29	-4.21	-4.26	-	-
	HKG	-1.49	-1.61	-4.54	-4.07	-3.02	-3.09	-1.84	-1.68	-4.3	-4.64	-3.11	-3.41
	TWN	-1.67	-1.38	-4.71	-3.84	-3.19	-2.86	-1.82	-1.33	-4.29	-4.3	-3.1	-3.06
	RNA	-1.32	-1.38	-4.38	-3.84	-2.85	-2.86	-1.3	-1.32	-3.77	-4.29	-2.58	-3.05

Note: (i) and (ii) are trade routes of export to CHN and import from CHN. (iii) and (iv) are trade routes of export to JPN and import from JPN. (v) and (iv) are trade routes of export to KOR and import from KOR. % change from the baseline.

4.2. The Changes in Bilateral Trade

The simulation results for bilateral trade under the coexistence policy (scenario F_M) reveal that all trade routes for total commodities and AFS exhibit a declining trend, with the exception of imports from China. By contrast, the results for ATP and ETP do not show a consistent pattern (as reported in Table 4). These findings suggest that, during the pandemic, each economy maintained a rising demand for Chinese export goods and AFS. However, when unemployment arises as a consequence of the zero-COVID policy, all trade routes experience a comprehensive decline.

5. Discussion

Based on the simulation results of this study and their comparison with the existing literature, we summarize our observations into three points.

5.1. The Impact of the Tourism Industry as a Shock Factor on GDP Is Underestimated

For instance, China's GDP growth rate ranges from approximately −0.02% to −0.82%, corresponding to a loss of USD 2.07 to 84.88 billion in 2020. In comparison, prior GTAP-based studies reported larger impacts: −0.4% to −6.2% in McKibbin and Fernando [31] −4.8% in Song, et al. [3] and −7.5% in Park, et al. [18]. The primary reason is that our model uses the percentage decline in international tourist receipts as the shock rate, which may not be sufficiently strong. Moreover, international tourism may exert a relatively limited influence on China's economy. By contrast, our simulation results for Japan (−0.24% to −5.12%) and South Korea (−0.26% to −3.05%) also produce narrower ranges of change compared with those reported in the literature.

We further examine the relationship between actual GDP growth rates during the pandemic and the simulation results of this study. According to Figure 4, Japan and South Korea's GDP in 2020 falls within our estimated range. Although China and Taiwan still exhibited positive growth during the pandemic, the direction of our estimated range differs. Nevertheless, our results align more closely with observed realities than prior studies. This supports the reasonableness of designing scenarios under both perfect and imperfect competition. As shown in Figure 4, the recession rates of Japan and South Korea in 2020 approximate the assumed scenarios, while Hong Kong, Macau, and Mongolia fall below the unemployment threshold [52].

Overall, we find that the boundaries defined by coexistence policies and zero-COVID policies capture aspects of real-world outcomes. This indicates that the revised simulation mechanism proposed in this study is applicable to evaluating the pandemic's economic impacts.

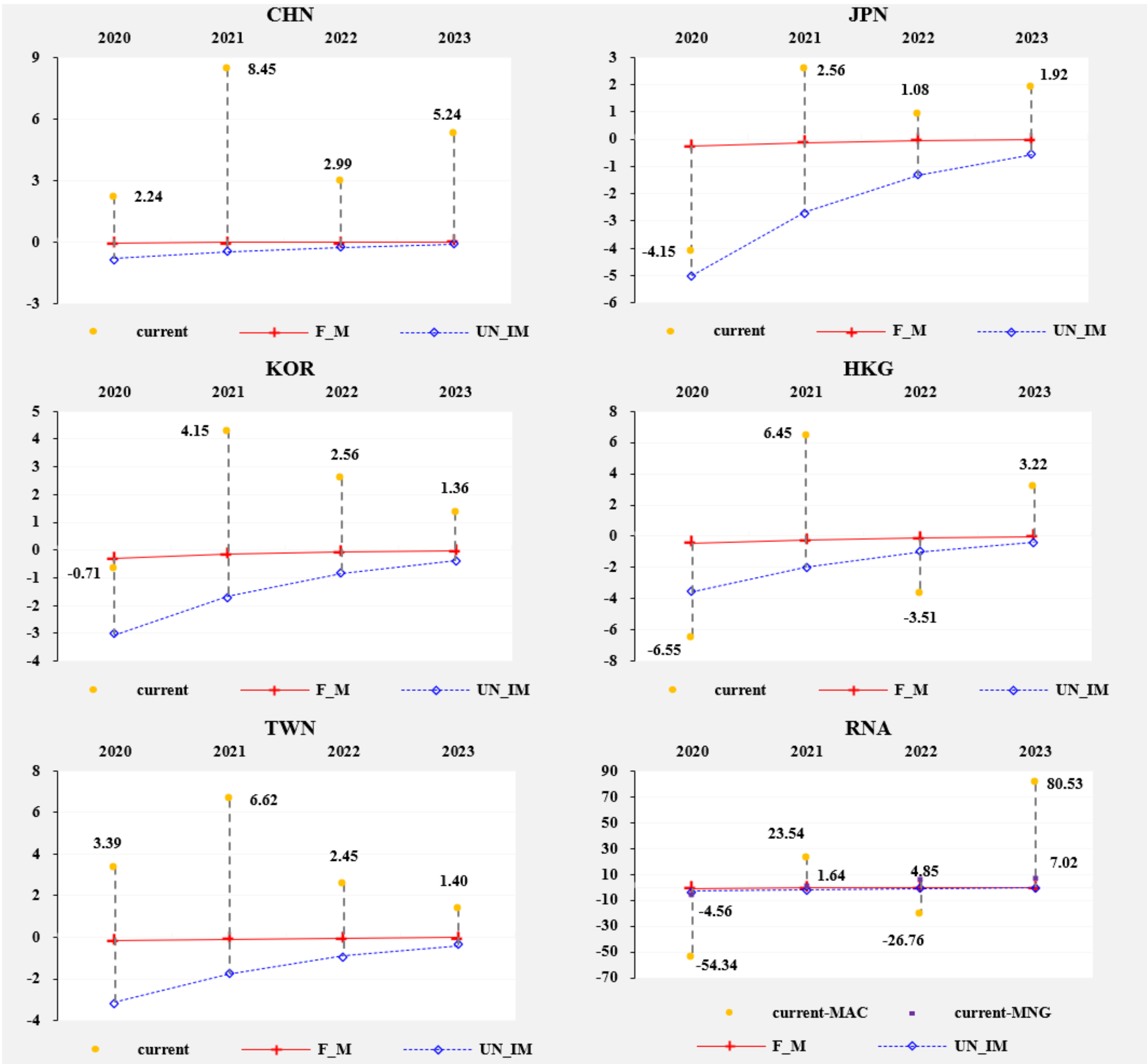

Figure 4.
The relationship between the current GDP and the simulation results.
Source: International Monetary Fund, World Economic Outlook Database, April 2024.
Note: Solid lines and dotted lines represent the simulations for the coexistence policy (scenario F_M) and zero-COVID policy (scenario UN_IM). The spot represents the current percentage of real GDP.

5.2. AFS Suffers More Severe Output Losses Than the Transportation Sector

Most scholars and international tourism organizations have analyzed the impact of the pandemic on tourism by focusing on the decline in international arrivals or the contribution of global tourism to

GDP. In this study, we simulate the output of the accommodation and food service (AFS) sector across Northeast Asian economies. Under the coexistence scenario, AFS output still increases in some regions. However, once the zero-COVID policy is adopted, AFS output ceases to grow in all Northeast Asian economies. The range of changes in AFS output is −0.53% to 0.32% for China, −8.00% to −3.33% for Japan, −4.24% to −1.52% for South Korea, −4.57% to −1.48% for Hong Kong, −5.17% to −2.15% for Taiwan, and −2.08% to 1.27% for the rest of Northeast Asia. Using Table 3, we calculate that total AFS losses in Northeast Asia range from 1.04% to 4.07% (USD 9.06 to 30.82 billion).

By comparison, the estimated losses in air transport of passengers (ATP) and other transport of passengers (ETP) are 0.12% to 3.12% (USD 0.09 to 4.20 billion) and 0.08% to 2.98% (USD 0.52 to 32.70 billion), respectively. Thus, the transportation sector's losses were not as severe as expected. One possible explanation is that certain business models shifted toward goods-related demand, thereby partially offsetting the negative impact of the decline in international tourists.

5.3. Northeast Asia Experienced More Severe Output Losses Than the Global Average

As shown in Table 3, the total output losses in Northeast Asia range from 1.86% to 39.45%. In comparison, Mandel and Veetil [53] estimated that the pandemic caused a 7% to 23% decline in global output. Therefore, our simulation results suggest that the pandemic's impact on Northeast Asia was more severe than the global average.

6. Policy Implications

By 2023, no economies in Northeast Asia continued to pursue a zero-COVID strategy. However, global challenges such as inflation and slowing consumption have hindered the pace of post-pandemic economic recovery [54]. Drawing on lessons from recent pandemic prevention experiences, this study proposes three sequential goals to support the revitalization of the tourism industry.

6.1. Establish a Mutually Recognized Public Health Mechanism Across the Region

During the pandemic, each economy should implement the WHO's case reporting standards and establish a mutually recognized vaccine certification system in Northeast Asia. We recommend that the region draw on the EU's "Digital Green Certificate" as a model for reopening borders in the tourism industry. For instance, China, Japan, South Korea, and Chinese territories could develop a joint health certification framework, enabling foreign travelers to be treated in line with the health protocols of the host country. Such a mechanism would also facilitate the smooth cross-border movement of labor within the region, ensuring their ability to participate in daily production activities.

6.2. Avoid Excessive Interventionist and Discriminatory Policies

Before 2022, to prevent the risk of coronavirus importation, the tourism industry in some economies developed implicit discriminatory practices while implementing pandemic prevention measures. For instance, foreign travelers were sometimes refused hotel reservations, denied entry to specific venues, or compelled to accept unreasonable prices for quarantine accommodations upon arrival.

By the end of 2022, China abandoned its zero-COVID policy, and quarantine requirements for inbound travelers across Northeast Asia were lifted, leading to a surge in expected cross-border travel. However, China's abrupt policy shift triggered a rapid increase in confirmed cases, coupled with the suspension of official case reporting. This development led other regions to impose targeted restrictions—such as entry visa barriers and renewed quarantine requirements—on Chinese tourists, which substantially reduced their willingness to travel abroad. During this period, additional cases were reported where Chinese residents faced obstacles in applying for or renewing passports.

Although Northeast Asian economies are geographically proximate, pandemic-era cooperation was constrained by geopolitical tensions, limiting the effectiveness of regional travel recovery [55]. To mitigate the negative consequences of the COVID-19 crisis, including higher costs, the global tourism industry requires cooperation rather than competition [17]. This is particularly crucial in Northeast Asia, which remains one of the world's largest tourism markets, with Chinese tourists representing significant latent demand [50, 51, 56, 57][8].

6.3. Develop Recovery Policies Targeted at the Supply Side of the Tourism Industry.

During the pandemic, many tourism-related firms and employees experienced business closures and unemployment. To prevent irreversible structural damage under prolonged prevention policies, policymakers should encourage innovative business models. One potential approach is to substitute cross-border consumption with goods trade. Owing to their geographical proximity, Northeast Asian economies already benefit from well-developed shipping and logistics networks, which could be leveraged to facilitate such substitution. Government tourism agencies could cooperate in exporting domestic souvenirs, cultural products, and specialty food items (e.g., seafood) through cold-chain technologies and air transportation. At the same time, private tourism associations and enterprises could participate in merchandise trade and travel exhibitions to mitigate the decline in international tourist arrivals. However, such substitution does not compensate for all subsectors, particularly the accommodation industry. Therefore, beyond goods-trade substitution, restoring international flight capacity and ensuring an adequate workforce remain essential priorities for tourism recovery. Considering that COVID-19 may eventually be managed like seasonal influenza, insufficient service quality due to capacity constraints could undermine the long-term competitiveness of the sector once international tourism rebounds.

7. Conclusion

This study conducted a comparative analysis of the economy-wide impacts of the COVID-19 pandemic in Northeast Asia. The simulation results highlight that the design of economic assumptions plays a decisive role in shaping the estimated impacts of COVID-19. Specifically, when governments adopt a zero-COVID policy, they should minimize the risk of unemployment while simultaneously resuming economic activities under controlled conditions [58]. If unemployment emerges, smaller economies are particularly vulnerable to labor immobility.

Relative to existing studies, our findings contribute several novel insights. First, the simulation framework suggests that GDP losses are often underestimated. Second, within the tourism sector, accommodation, food, and services (AFS) experienced more severe declines compared to the transportation sector. Third, Northeast Asia suffered larger output losses, in percentage terms, than the global average during the pandemic. Collectively, these results indicate that the simulation mechanism employed in this study offers outcomes that align more closely with real-world developments.

The evolution of emergent public health crises substantially influences tourism stakeholders' behavior [59]. After reopening, achieving pre-pandemic profit levels has proven challenging, as both travel costs and travel time are expected to remain higher than in the pre-COVID-19 era [60, 61]. Accordingly, the question of how to stimulate tourism demand and restore travelers' confidence will be a central topic for future research [62, 63]. While our results confirm China's significant potential for outbound tourism, the broader post-pandemic economic shifts have produced ripple effects on consumer choices, with preferences gradually moving away from globalization toward regionalization [61, 64]. Moreover, the industry may increasingly transform toward environmentally sustainable forms of tourism, such as low-carbon, small-scale, and regional domestic travel [6, 15, 51].

[8] Taking Japan as an example, according to the Japan Tourism Statistics data, the total number of inbound tourists to Japan reached approximately 25 million people in 2023. Among them, visitors from Northeast Asia accounted for about 62.6% of the total. Specifically, visitors from South Korea, Taiwan, China, and Hong Kong constituted 27.8%, 16.8%, 9.7%, and 8.4%, respectively.

Finally, this study is limited in scope. Although it approaches the issue from the perspective of tourism, it is difficult to capture the pandemic's heterogeneous impacts across all industries. For instance, while the number of international air passengers decreased due to border restrictions, the demand for freight transportation increased. To approximate tourism activity, we employed AFS as a proxy, which represents a limitation of our analysis.

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Institutional Review Board Statement:
This study did not involve human participants and thus did not require Institutional Review Board approval.

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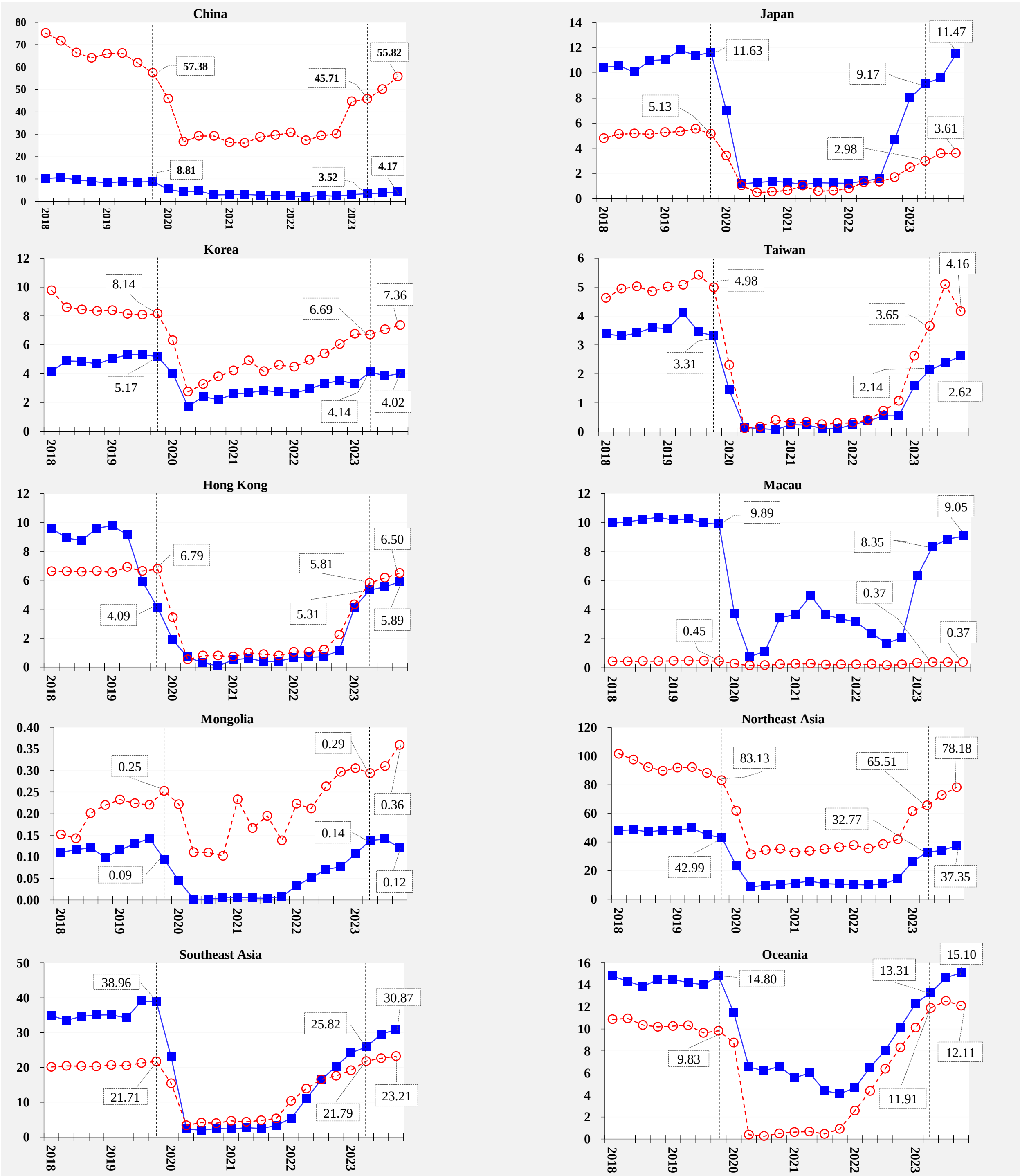
Appendix 1. Tourism import and export trends after the pandemic



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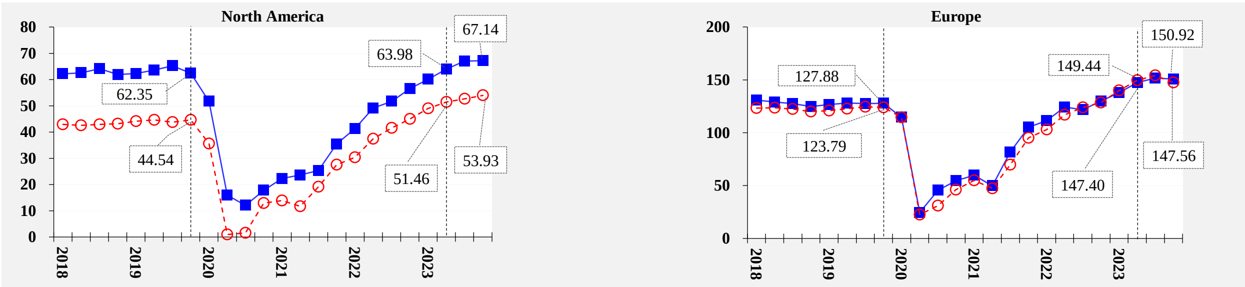

Note: The data source is UNCTAD [7]. The vertical axis is a billion USD, and the horizontal axis is time. The dotted line in the figure represents the imports, and the solid line represents the exports, indicating the outbound tourism of locals and foreigners, respectively.