Transport and Telecommunication, 2026, volume 27, no. 2, 150-163
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia
DOI 10.2478/ttj-2026-0011

PASSENGER AND FREIGHT DEMAND UNDER MACROECONOMIC VOLATILITY: EVIDENCE FROM SOUTH KOREA AND THE UNITED STATES

Nari Jung

Department of Tourism Management, Kongju National University
Gongju-si, South Korea
nrjung43@kongju.ac.kr

This study investigates the asymmetric effects of economic growth and recession on airline demand by focusing on South Korea's and the United States' air passenger and freight sectors. Quarterly data from 1990 to 2023 are analyzed to identify the impact of economic fluctuations on air passenger and freight demand, incorporating macroeconomic variables such as the industrial production index, consumer price index, and oil prices. The results reveal a significant asymmetry in how airline demand responds to economic growth versus recessions. In South Korea and the United States, negative shocks lead to more pronounced declines in air passenger and freight demand versus the increases observed during periods of economic growth. Enhancing the aviation sector's resilience can help protect jobs and maintain crucial transport links. The nuanced understanding of short- and long-term dynamics from this study delivers new insights into the airline sector's response to macroeconomic shocks.

Keywords: Airline demand, economic growth, recession, asymmetric effects, tourism, NARDL, macroeconomic shocks

1. Introduction

The airline industry plays a crucial role in global trade, tourism, and economic activity, with air travel traffic playing a central role in international tourism demand (Albuquerque *et al*., 2022). The demand for air passenger and freight services is influenced by macroeconomic factors such as gross domestic product (GDP), inflation, industrial production, and oil prices (Button and Taylor, 2000; Bilotkach and Lakew, 2014; Liasidou, 2017; Zhang and Graham, 2020; Law *et al.*, 2022; Fu, 2023). An industry's response to these factors is nonlinear, in that they show greater sensitivity to negative economic shocks than to positive shocks (Goh and Law, 2011; Chi and Baek, 2013; Wadud, 2014; Chi, 2024). Airlines typically raise prices during cost increases faster than they lower prices during cost reductions, exemplifying this asymmetry (Escobari, 2013; Jiang and Que, 2022). This asymmetry can disrupt tourism by reducing arrivals and negatively impacting the tourism-dependent economies.

While prior research explores macroeconomic factors' effects on airline demand, several studies assume a linear relationship (Fernandes and Pacheco, 2010; Hu *et al*., 2015; Hakim and Merkert, 2016). Nonlinear models, such as the nonlinear autoregressive distributed lag (NARDL), challenge this assumption by capturing both short- and long-term asymmetries (Ahmad and Aworinde, 2019; Balsalobre-Lorente *et al.*, 2021). The NARDL model provides a refined framework for analyzing the airline industry's responses to positive and negative GDP changes.

This study compares the airline sectors in South Korea and the United States (U.S.), two economies with distinct structures. South Korea's export-driven economy is highly vulnerable to global shifts (Khan *et al.*, 2022), while the U.S. has shown resilience despite crises such as the 2008 downturn and COVID-19 pandemic (Zhang, 2023). Based on delineations of prior research regarding the usefulness of comparative analysis (Gómez López and Barrón Arreola, 2024), this study hopes to offer insights for policymakers and stakeholders for strengthening the airline industry's resilience during economic fluctuations. Specifically, this study investigates the effects of GDP changes on air passenger and freight demand by incorporating variables such as the industrial production index (IPI), consumer price index (CPI), and oil prices. The study's objectives are twofold:

1. Investigate the short- and long-term effects of GDP changes on air passenger and freight demand in South Korea and the U.S.
2. Assess how airline demand in South Korea and the U.S. responds to macroeconomic fluctuations and the implications for tourism.

Building on the fundamentals established by extant research, this study makes a novel contribution through its unique comparative and nonlinear perspective. Previous studies have primarily applied linear models or examined the relationship between air transport and economic growth within a single country

(Fernandes and Pacheco, 2010; Hu *et al.,* 2015; Hakim and Merkert, 2016). While these studies confirmed the positive causal link between GDP and air passenger traffic, they did not account for potential nonlinear or asymmetric responses of airline demand to macroeconomic fluctuations.

To address this gap, the present study employs a nonlinear autoregressive distributed lag (NARDL) framework to capture both short- and long-term asymmetries in the effects of economic expansions and recessions on airline demand. This study provides new empirical evidence on the aviation sector's resilience under macroeconomic volatility by comparing two economies with contrasting industrial and policy structures, South Korea and the United States. This paper extends existing research by using long-term quarterly data from 1990 to 2023 and incorporating key macroeconomic indicators, including the industrial production index, the consumer price index, and oil prices. This study presents an innovative analytical lens for understanding differential demand responses across distinct economic environments.

2. Literature review

2.1. The impact of macroeconomic variables on tourism demand

Several studies have investigated how macroeconomic factors, including GDP, inflation, and oil prices, affect tourism demand. Bilotkach and Lakew (2014) and Button and Taylor (2000) showed a strong link between GDP growth and an increase in air passenger and freight demand, and a significant decline in discretionary travel during recessions. Hanson *et al*. (2022) emphasized the sensitivity of tourism demand to GDP fluctuations. Bustos *et al*. (2012) indicated that economic downturns cause sharper demand declines than the more moderate increases witnessed during economic expansions, highlighting tourism's vulnerability to negative economic shocks. Chen (2023) also concluded that macroeconomic factors significantly influence airline and tourism demand in China, reaffirming GDP's role in shaping tourism trends.

2.2. Nonlinear econometric approaches and asymmetric effects on tourism

To better capture the asymmetries shown above, nonlinear econometric models, such as the NARDL model, have increasingly been used in tourism research. Shin *et al*. (2014) demonstrated the NARDL model's effectiveness in uncovering short- and long-term asymmetries in how economic growth affects tourism demand. Allen and McAleer (2021) applied the NARDL model to show that negative economic shocks have more substantial and lasting effects on global financial indicators. These are particularly relevant for tourism because consumer confidence has a significant influence on travel behavior. Doğan *et al.* (2020) used the NARDL model to study the asymmetric relationship between renewable energy and economic growth, finding that they parallel tourism demand. Bahmani-Oskooee and Gelan (2019) also demonstrated that exchange rate fluctuations lead to asymmetric responses in tourism demand across various regions.

2.3. Comparative studies on tourism demand in South Korea and the U.S.

Comparative studies have revealed how distinct economic structures impact tourism demand. Khan *et al*. (2022) showed that South Korea's export-driven economy, which relies on air transport, is particularly vulnerable to global downturns, whereas the U.S., which has a more diverse economy, is more resilient. Specifically, the U.S. benefits from a large domestic tourism market that cushions the effects of global recessions. The Organization for Economic Co-operation and Development (2020) has highlighted how the COVID-19 pandemic exacerbated the vulnerabilities of export-dependent countries, leading to more significant declines in tourism in such countries (e.g., South Korea). By contrast, U.S. tourism was bolstered by the strong domestic market. Chen (2023) expanded on this by showing how the U.S. tourism and airline industries rebounded faster after the COVID-19 pandemic owing to stronger fiscal support and more flexible markets.

2.4. Implications of the COVID-19 pandemic on tourism demand

The COVID-19 pandemic drastically impacted global tourism demand, with global travel restrictions causing a sharp decline in air passenger volumes and international tourist arrivals (Suk and Kim, 2021; Jiang and Que, 2022). Tourism-dependent economies suffered substantially, as international tourism plays a crucial role in their revenue streams. While air passenger services were severely impacted, air freight remained relatively resilient during the pandemic owing to its role in maintaining supply chains. Kupfer *et al.* (2017) highlighted this structural strength of the air cargo sector, underscoring the divergent impacts of economic shocks on aviation and tourism. The pandemic showcased the need for tourism diversification, such as expanding cargo operations or promoting domestic tourism, to buffer against future shocks.

3. Model and data

3.1. Model specification

This study applies the NARDL model to examine how GDP fluctuations asymmetrically affect air passenger demand and freight demand in South Korea and the U.S. The NARDL model is ideal for capturing short- and long-term dynamics and identifying asymmetries in how airline demand reacts to positive and negative GDP changes (Shin *et al.*, 2014). Alongside GDP, other macroeconomic variables, such as the IPI, CPI, and West Texas Intermediate (WTI) oil prices, are included to ensure a thorough analysis.

3.2. Model structure

The NARDL model used in this study is defined as follows:

$$\Delta \log(y_t) = \alpha^0 + \sum_{i=1}^{p} \alpha^1 \Delta log(x_{t-i}^{+}) + \sum_{i=1}^{q} \alpha_2 \Delta log(x_{t-i}^{-}) + \beta^1 \Delta \log(IPI)_t + \beta_2 \Delta log(CPI)_t + \beta_3 \Delta log(WTI)_t + \gamma log(y_{t-1}) + \theta D01 + \varepsilon_t. \quad (1)$$

Where y_t represents the log-transformed air passenger (AP) demand (log(AP)) or air freight (AF) demand (log(AF)) depending on the model. x_t^+ and x_t^- represent positive and negative changes in real GDP (log-transformed), respectively. $log(IPI)_t$, $log(CPI)_t$, and $log(WTI)_t$ represent the log-transformed IPI, CPI, and WTI oil prices, respectively. γ is the error correction term (ECT) that measures the speed of adjustment toward long-run equilibrium. $\theta D01$ is a dummy variable for the COVID-19 pandemic, set to 1 for Q1 2020 and 0 for earlier periods. ε_t is an error term representing any unexplained variability in the model.

The model for AP can be presented as follows:

$$\Delta log(AP_t) = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \Delta log(GDP_{t-i}^{+}) + \sum_{i=1}^{q} \alpha_2 \Delta log(GDP_{t-i}^{-}) + \beta^1 log(IPI)_t + \beta^2 log(CPI)_t + \beta^3 log(WTI)_t + \gamma log(AP)_t^{-1} + \theta D01_t + \varepsilon_t. \quad (2)$$

The model for AF can be presented as follows:

$$\Delta log(AF_t) = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \Delta log(GDP_{t-i}^{+}) + \sum_{i=1}^{q} \alpha_2 \Delta log(GDP_{t-i}^{-}) + \beta^1 \log(IPI)_t + \beta_2 log(CPI)_t + \beta_3 log(WTI)_t + \gamma log(AF)_{t-1} + \theta D01_t + \varepsilon_t. \quad (3)$$

The variables are:

AP: Air passenger demand at time $_t$ (log).

AF: Air freight demand at time $_t$ (log).

GDP^+ [illegible]: Positive and negative GDP changes (log-transformed).

IPI: IPI (log-transformed).

CPI: CPI (log-transformed).

WTI: WTI (log-transformed).

$D01$: Dummy variable for COVID-19 (1 from 2020Q1 onwards).

α [illegible]: Short- and long-run coefficients, and ECTs.

ε_t: Error term.

3.3. Data

This study used quarterly time series data from the first quarter of 1990 to the fourth quarter of 2023 to analyze the relationship between airline demand and key macroeconomic variables in South Korea and the U.S. The analysis included air passenger and freight demand, real GDP, IPI, CPI, and WTI oil prices. All the variables were log-transformed to facilitate the interpretation of elasticities and to stabilize variance, thereby addressing potential heteroscedasticity (Lütkepohl and Xu, 2012). A dummy variable was introduced to account for the structural impact of COVID-19, with a value of 1 assigned from the first quarter of 2020 onwards, and 0 for earlier periods. Table 1 lists the detailed data sources for each variable.

Table 1. Data sources for key variables

Variable	Description	Units	Source
Air passenger demand	Passenger-kilometers performed (PKM)	PKM	ICAO
Air freight demand	Ton-kilometers performed (TKP)	TKP	ICAO
GDP (South Korea)	South Korea's real GDP	Millions of Korean won	ECOS
GDP (U.S.)	U.S.'s real GDP	Billions of U.S. dollars	FRED
IPI (South Korea & U.S.)	Measures industrial output	Index	FRED
CPI (South Korea)	Tracks inflation (South Korea)	Index	ECOS
CPI (U.S.)	Tracks inflation (U.S.)	Index	FRED
WTI	West Texas Intermediate (WTI) crude oil prices	U.S. dollars per Barrel	EIV

Note: GDP = gross domestic product; IPI = industrial production index; CPI = consumer price index; WTI = West Texas Intermediate; ICAO = International Civil Aviation Organization; ECOS = Economic Statistics System; FRED =Federal Reserve economic Data; EIV = Energy Information Administration

3.4. Methodology

This study applied the NARDL model to explore the asymmetric effects of GDP fluctuations on air passenger and freight demand in South Korea and the U.S. The NARDL model is ideal for capturing short- and long-term dynamics along with asymmetries in responses to positive and negative GDP changes (Shin *et al.*, 2014). To ensure model validity, unit root tests (augmented Dickey-Fuller and Phillips-Perron) were conducted to confirm that the variables (air passenger demand, air freight demand, GDP, and other macroeconomic indicators) were integrated into order I(1), allowing their inclusion in the NARDL framework (Shahani and Singhal, 2023). The Akaike information criterion was used to select the optimal lag lengths and balanced model accuracy with parsimony.

Following the lag selection, a bounds test for cointegration was used to verify the presence of a long-run equilibrium relationship between GDP and airline demand variables, accounting for both the I(0) and I(1) variables (Pesaran *et al.*, 2001). Estimating the short- and long-run coefficients allowed for the separation of positive and negative GDP effects, with the ECT indicating the speed at which deviations from equilibrium were corrected. Asymmetric effects were formally tested using the Wald test, confirming that the airline industry responds differently to economic expansions and recessions (Ampofo *et al.*, 2021). Log transformations of variables were employed to interpret coefficients as elasticities and stabilize variance (Lütkepohl and Xu, 2012).

4. Results

4.1. Unit root tests

To verify the stationarity of key variables (AP, AF, real GDP, IPI, and WTI oil prices) in South Korea and the U.S., augmented Dickey-Fuller and Phillips-Perron tests were employed. Table 2 summarizes the results. All variables are nonstationary at all levels but become stationary after first-differencing, thereby rejecting the null hypothesis of a unit root at the 1% significance level. This confirms that the variables are integrated of order one, I(1), supporting their suitability for subsequent long-run and short-run analyses.

Table 2. Unit root test results

Panel A: Unit root testing with structural break by ADF and PP at level I(0).			
		ADF	PP
	ln AP	-2.751*	-2.873*
	ln AF	-2.727*	-2.848*
i = South Korea	ln GDP	-3.350**	-4.609***
	ln IPI	-2.197	-2.703*
	ln CPI	-6.011***	-5.400***
	ln AP	-4.853***	-4.824***
	ln AF	-4.853***	-4.824***
i = U.S.	ln GDP	-0.984	-1.058
	ln IPI	-2.240	-2.130
	ln CPI	-0.132	-0.243
ln WTI		-1.756	-1.496
Panel B: Unit root testing with structural break by ADF and PP at first difference.			
		ADF	PP
	ln AP	-9.703***	-9.840***
	ln AF	-9.673***	-9.813***
i = South Korea	ln GDP	-7.560***	-7.494***
	ln IPI	-8.214***	-7.267***
	ln CPI	-9.293***	-9.882***
	ln AP	-10.959***	-15.554***
	ln AF	-10.959***	-15.554***
i = U.S.	ln GDP	-13.161***	-13.184***
	ln IPI	-10.292***	-10.417***
	ln CPI	-7.451***	-7.451***
ln WTI		-10.109***	-10.049***

Note: *i* denotes the country index (*i* = South Korea and U.S.). The critical values for the significance levels are -3.48 at 1%, -2.88 at 5%, and -2.58 at 10%. AP = air passenger demand; AF = air freight demand; GDP = gross domestic product; IPI = industrial production index; CPI = consumer price index; WTI =West Texas Intermediate

4.2. Long-run relationship

This study used a NARDL model to assess the long-term equilibrium between air passenger demand, air freight demand, and economic growth variables in South Korea and the U.S. The results summarized in Table 3 highlight the asymmetric effects of positive and negative changes in real GDP on both air passenger and air freight demand. Additional key macroeconomic factors, such as the IPI, CPI, and WTI, were also examined. The bounds test confirms a co-integrating long-term relationship between these variables, indicating that the airline industry in both countries responds asymmetrically to economic expansions and recessions.

4.2.1. South Korea versus the U. S.: Long-term impact

In South Korea, positive and negative GDP changes showed no statistically significant impact on long-term airline demand; however, IPI had a significant negative effect, while CPI and WTI prices positively influenced demand in the long run. By contrast, in the U.S., neither GDP changes nor IPI and

WTI had significant long-term effects; however, CPI emerged as a significant factor affecting both air passenger and freight demand in the long run, underscoring its critical role in shaping U.S. airline market dynamics.

Table 3. Long-run relationship and bounds test results for air passenger (AP) and air freight (AF) demand in South Korea and the U.S.

	i = South Korea		*i* =U.S.	
	AP	AF	AP	AF
F-statistic	13.81***	14.11***	5.88***	5.88***
Pos	3.23(3.14)	3.28(3.12)	-3.44(2.12)	-3.44(2.12)
Neg	-2.93(4.05)	-2.74(4.03)	3.76(3.69)	3.76(3.69)
ln IPI	-11.34(2.33)***	-11.43(2.31)***	0.79(0.85)	0.79(0.85)
ln CPI	18.11(3.52)***	18.29(3.49)***	5.09(2.65)*	5.09(2.65)*
ln WTI	0.70(0.30)**	0.70(0.30)**	0.03(0.13)	0.03(0.13)
C	-22.40(14.41)	-25.27(14.31)*	-11.38(13.84)	-13.78(13.84)

Note: *i* denotes the country index (*i* = South Korea and U.S.). ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. For calculation methods, please refer to Pesaran *et al*. (2001, Table CII, Case III, p. 303). AP = air passenger demand; AF = air freight demand; GDP = gross domestic product; IPI = industrial production index; CPI = consumer price index; WTI = West Texas Intermediate

4.3. Short-run dynamics

The short-run analysis highlighted how air passenger and air freight demand respond to GDP fluctuations, IPI, CPI, and WTI. The ECT indicated that both countries correct imbalances caused by short-term shocks, with the U.S. adjusting faster than South Korea. Table 4 provides detailed short-run dynamics and ECT values.

4.3.1. South Korea: Short-term dynamics

Air passenger demand showed moderate increases from positive GDP shocks, whereas negative shocks had a stronger impact and significantly reduced demand. Air freight demand demonstrated a similar asymmetry, with delayed effects from positive shocks but strong reductions from negative shocks.

4.3.2. United States: Short-run dynamics

In the U.S., air passenger demand was less affected by positive GDP shocks but significantly impacted by negative shocks, whereas air freight demand showed asymmetric responses, with negative shocks increasing demand. Other variables, including CPI, had no significant short-term effects.

4.4. Wald test of asymmetric GDP effects

The Wald test confirmed that GDP changes affect air passenger and air freight demand asymmetrically in both countries. Recessions result in sharper declines in demand compared to expansions, underscoring the aviation sector's vulnerability to economic downturns. Table 4 also summarizes the detailed Wald test results.

Table 4. Short-run dynamics and error correction term for air passenger (AP) and air freight (AF) demand in South Korea and the U.S.

	i = South Korea		*i* = U.S.	
	AP	AF	AP	AF
Δ(ln AP/AF (-1))			0.10(0.10)	0.10(0.10)
Δ(ln AP/AF (-2))			-0.14(0.06)**	-0.14(0.06)**
Δ(ln AP/AF (-3))			0.06(0.04)	0.06(0.04)
Δ(Pos)	4.88(2.56)*	4.91(2.55)*	-6.28(3.28)*	-6.28(3.28)*
Δ(Pos(-1))	5.42(2.34)**	5.43(2.33)**	-3.03(3.06)	-3.03(3.06)

Continuation of Table 4

	i = South Korea		*i* = U.S.	
	AP	AF	AP	AF
Δ(Pos(-2))	-4.96(2.27)**	-5.07(2.26)**		
Δ(Pos(-3))	4.36(2.27)*	4.49(2.25)**		
Δ(Neg)	21.59(2.54)***	21.85(2.53)***	40.67(3.62)***	40.67(3.62)***
Δ(Neg(-1))	9.48(2.66)***	9.57(2.65)***	1.38(5.34)	1.37(5.34)
Δ(Neg(-2))	6.88(2.56)***	6.94(2.54)***		
Δ(Neg(-3))	6.61(2.45)***	6.66(2.44)***		
Δ(ln IPI)			1.74(1.76)	1.74(1.76)
Δ(ln IPI(-1))			-4.34(1.56)***	-4.33(1.56)***
Δ(ln CPI)	17.28(2.68)***	17.55(2.67)***	-6.11(4.66)	-6.12(4.66)
Δ(ln CPI(-1))	3.55(2.56)	3.55(2.55)	4.51(4.03)	4.51(4.03)
Δ(ln CPI(-2))	7.41(2.54)***	7.40(2.52)***		
Δ(ln WTI)			0.21(0.14)	0.21(0.14)
Δ(ln WTI(-1))			-0.07(0.13)	-0.07(0.13)
D01	-0.81(0.11)***	-0.81(0.10)***	0.13(0.12)	0.13(0.12)
ECT	-0.29(0.03)***	-0.29(0.03)***	-0.43(0.07)***	-0.43(0.07)***
Wald	17.41***	18.07***	113.66***	113.66***

Note: *i* denotes the country index (*i* = South Korea and U.S.). ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. For calculation methods, refer to Pesaran *et al.* (2001, Table CII, Case III, p. 303). AP = air passenger demand; AF = air freight demand; GDP = gross domestic product; IPI = industrial production index; CPI = consumer price index; WTI = West Texas Intermediate

4.5. Comparative analysis and summary of key findings

This section synthesizes the key findings related to the asymmetric effects of economic growth on air passenger and freight demand in South Korea and the U.S. and analyzes both short- and long-run dynamics.

4.5.1. Asymmetric impact of GDP changes on airline demand

A major result of this study is the clear asymmetry in how GDP fluctuations affect airline demand in both countries. Negative GDP shocks (recessions) had a significantly stronger and more immediate impact on reducing air passenger and freight demand than positive GDP changes (economic growth). This was particularly evident in the short run, as confirmed by the Wald test results, which rejected the symmetric effects hypothesis.

In South Korea, the negative impact of GDP shocks was more pronounced on air passenger demand, signaling greater sensitivity to economic downturns. Nevertheless, air freight demand also experienced a significant decline during negative GDP shocks, suggesting that the South Korean airline sector is very vulnerable to economic contractions.

In the U.S., the negative impact of GDP shocks led to marked declines in both air passenger and air freight demand, whereas positive GDP growth had weaker effects. The ECT indicated a faster adjustment in the U.S., suggesting that its airline sector recovers more quickly from short-term shocks.

4.5.2. Comparative dynamics of South Korea and the U.S.

The comparative analysis reveals several notable differences between the two countries, which are described hereinafter.

- Short-run dynamics: both countries exhibited asymmetric responses to economic changes in the short run; however, the U.S. airline sector showed a faster adjustment to the long-run equilibrium, reflecting its greater resilience and recovery capacity compared to that of South Korea.

- Long-run dynamics: in the long run, the impacts of GDP changes were not statistically significant for either country, indicating that factors other than GDP, such as industry-specific developments or shifts in consumer behavior, might be more important in shaping long-term demand.
- Sensitivity to recessions: both countries demonstrated heightened sensitivity to recessions, with air passenger demand being more severely impacted by downturns, and air freight demand showing a little more resilience.

4.5.3. Summary of key findings

In summary, this study highlights the asymmetric impact of GDP changes on airline demand in South Korea and the U.S. Recessions consistently led to larger and more immediate reductions in air passenger and air freight demand compared to the relatively weaker effects of economic growth. While both countries' airline industries are vulnerable to economic downturns, the U.S. market demonstrated a faster recovery, suggesting a more adaptive and resilient sector.

4.6. Model stability and diagnostic tests

4.6.1. Autocorrelation test

We applied the Breusch-Godfrey serial correlation Lagrange Multiplier test to assess autocorrelation in the residuals for the air passenger and air freight demand models in South Korea and the U.S. The test results indicated no evidence of serial correlation across all models, confirming that the residuals are free from autocorrelation and the models are appropriately specified.

4.6.2. Stability tests

All points plotted in the cumulative sum test fell within the 5% significance bounds, indicating that the model parameters remained stable over time and that the model is valid and reliable (see Figures 1–8 for details). Although the cumulative sum of squares test indicated some variance instability, the cumulative sum test results—focused on long-term parameter shifts—confirmed that the model's key coefficients are stable. Table 5 summarizes the results of the Breusch-Godfrey Lagrange Multiplier test and the CUSUM/CUSUMSQ stability diagnostics.

Additional diagnostic and stability checks (e.g., unit root, cointegration, and Wald tests) were conducted to reinforce the robustness of the NARDL estimations. The absence of serial correlation and the consistent parameter stability throughout the estimation period confirm that the models are well specified and methodologically sound. These findings align with the methodological standards proposed by Shin et al. (2014) and later applied by Bahmani-Oskooee and Gelan (2019), Allen and McAleer (2021), and Chi (2024).

Focused on South Korea and the United States, the study's comparative design serves as an implicit robustness check, demonstrating that the identified asymmetric responses are structurally consistent across two economies with distinct policy environments. This cross-country consistency underscores the reliability and generalizability of the empirical conclusions.

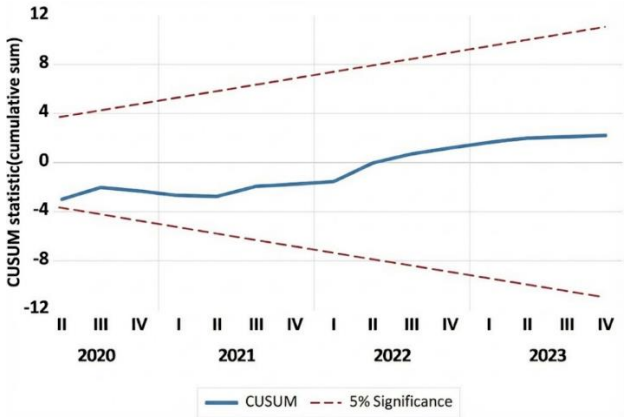

Figure 1. CUSUM results for air passenger demand in South Korea
Note: CUSUM, cumulative sum. Source: Authors

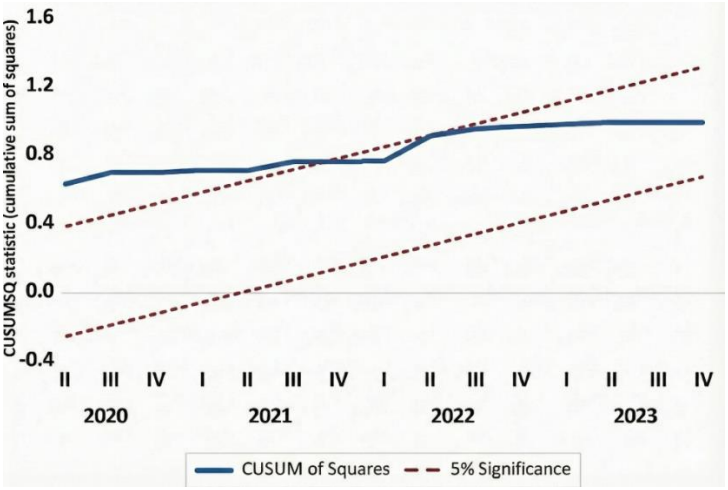

Figure 2. CUSUMSQ results for air passenger demand in South Korea
Note: CUSUMSQ, cumulative sum of squares. Source: Authors

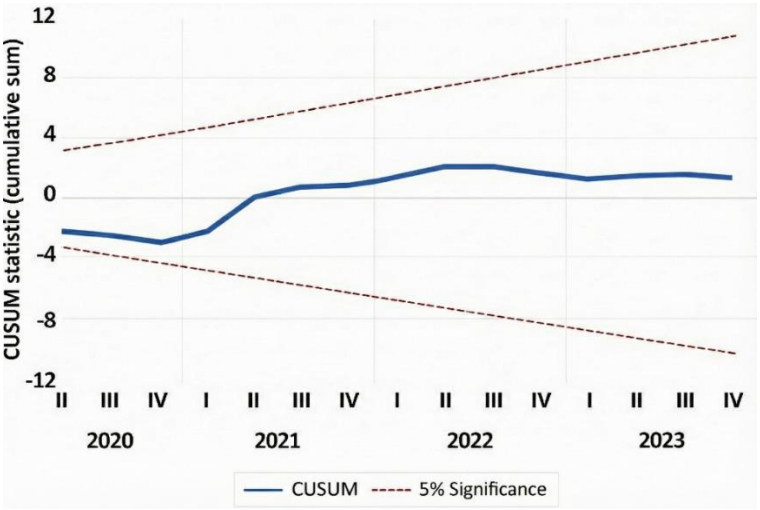

Figure 3. CUSUM results for air passenger demand in the U.S.
Note: CUSUM, cumulative sum. Source: Authors

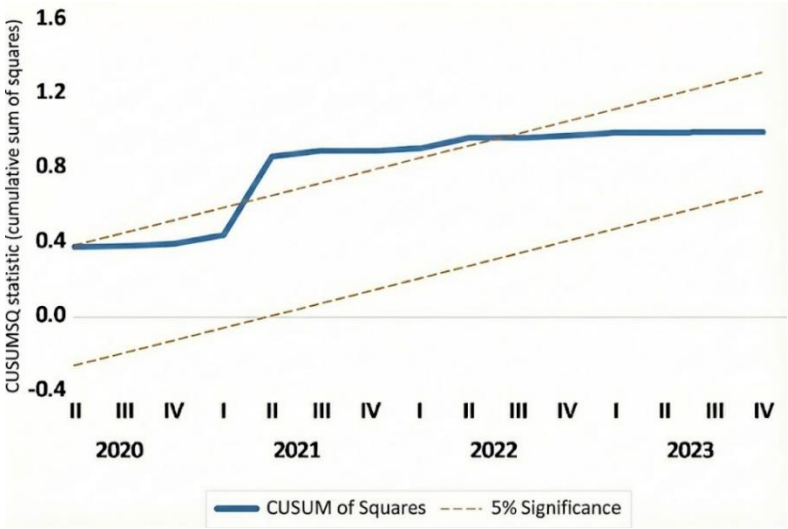

Figure 4. CUSUMSQ results for air passenger demand in the U.S.
Note: CUSUMSQ, cumulative sum of squares. Source: Authors

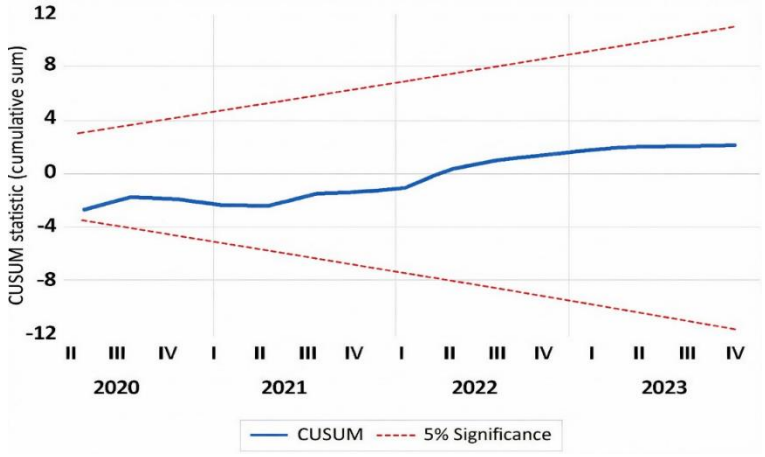

Figure 5. CUSUM results for air freight demand in South Korea.
Note: CUSUM, cumulative sum. Source: Authors

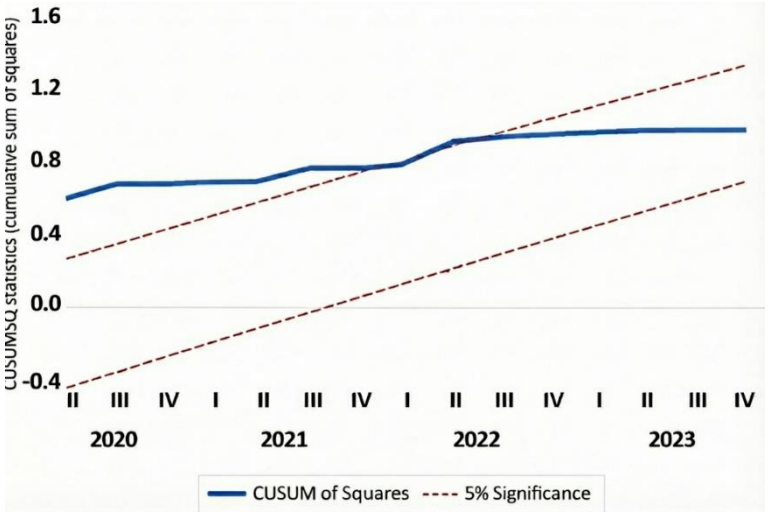

Figure 6. CUSUMSQ results for air freight demand in South Korea
Note: CUSUMSQ, cumulative sum of squares. Source: Authors

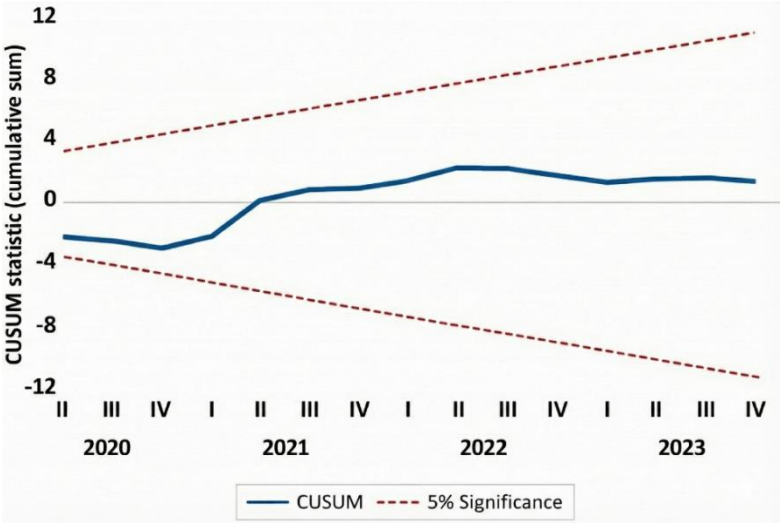

Figure 7. CUSUM results for air freight demand in the U.S.
Note: CUSUM, cumulative sum. Source: Authors

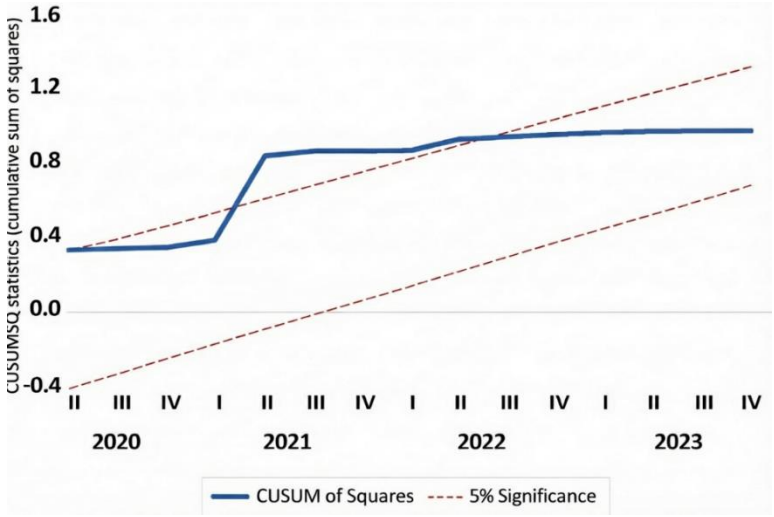

Figure 8. CUSUMSQ results for air freight demand in the U.S.
Note: CUSUMSQ, cumulative sum of squares. Source: Authors

Table 5. Results of the Breusch-Godfrey Lagrange Multiplier test and CUSUM/CUSUMSQ stability diagnostics

		Lagrange Multiplier Test	CUSUM/CUSUMSQ	Stability summary
South Korea	AP	F(2,110) = 1.80, Prob. F = 0.17	S/U.S.	No autocorrelation, stable (CUSUM)
	AF	F(2,110) = 1.93, Prob. F = 0.15	S/U.S.	No autocorrelation, stable (CUSUM)
U.S.	AP	F(2,109) = 1.74, Prob. F = 0.18	S/U.S.	No autocorrelation, stable (CUSUM)
	AF	F(2,109) = 1.74, Prob. F = 0.18	S/U.S.	No autocorrelation, stable (CUSUM)

Note: AP = air passenger demand; AF = air freight demand; CUSUM = Cumulative Sum; CUSUMSQ = Cumulative Sum of Squares

5. Conclusions

5.1. Summary of key findings

This study reveals significant asymmetries in how air passenger and freight demand in South Korea and the U.S. respond to GDP fluctuations. In both countries, negative GDP shocks (recessions) had a sharper, more immediate impact on reducing air passenger and freight demand compared to positive GDP growth's more modest effects. This asymmetric response highlights the airline sector's vulnerability to economic downturns. South Korea's airline sector exhibited a particularly heightened sensitivity to negative shocks, while the U.S. airline sector exhibited faster recovery, as indicated by a stronger ECT. Additionally, CPI played a positive role in both countries' airline demand, particularly in South Korea, where shifts in consumer behavior during inflationary periods drove demand. The COVID-19 pandemic had a profoundly negative impact on air passenger demand, while air freight demand was more resilient, aligning with the global shift toward cargo transport during supply chain disruptions.

5.2. Implications for the airline and tourism industry

The findings suggest that several strategies can be useful for strengthening airline and tourism sectors in both countries, as follows.

- Revenue diversification: airlines can enhance their resilience by diversifying into non-core services, such as cargo transport, to buffer against sharp declines in air passenger demand during recessions. This strategy was effective for airlines, such as Singapore Airlines, which has successfully maintained its market share through service diversification.

- Operational flexibility: the faster recovery of airlines in the U.S. can be attributed to structural flexibility and supportive government policies, which enable a rapid response to market shocks. Similar flexibility in pricing and capacity management could benefit airlines globally.
- Expanding air cargo services: the relatively stable performance of air freight demand during economic downturns underscores the importance of further investment in cargo operations. Governments should support logistics infrastructure to enable airlines to maintain profitability through cargo services during passenger slumps.

Beyond these sectoral insights, the study's findings have broader implications for both policymakers and industry practitioners. Recognizing the asymmetric effects of macroeconomic volatility can facilitate the design and implementation of adaptive policy instruments to minimize the risk of downturns. For policymakers, integrating macroeconomic indicators (e.g., industrial production, consumer prices, and oil prices) into national air transport forecasting systems enhances crisis preparedness and responsiveness. Temporary route subsidies or flexible fuel tax adjustments may also be employed to cushion airlines during recessions.

These results highlight the importance of data-driven and proactive management in the aviation industry. Airlines can adopt dynamic pricing strategies, flexible fleet allocation, and demand forecasting systems to better respond to market contractions. To further enhance the sector's long-term stability, cooperation between government agencies and industry stakeholders can be strengthened through joint crisis monitoring or aviation resilience frameworks.

5.3. Policy recommendations and directions for future research

Based on the study's findings, several policy recommendations are suggested, as outlined below.

- Risk management and contingency planning: airlines should strengthen their contingency plans to mitigate the effects of recessions by optimizing costs and diversifying revenue streams.
- Promote flexibility: policymakers should encourage airlines to adopt more flexible business models, enabling them to adjust rapidly to short-term economic shocks.
- Support cargo services: government policies to support expanding cargo operations could help airlines maintain stability during periods of low passenger demand.
- Sustainability and innovation: policymakers could incentivize innovation, including sustainable aviation fuels (SAF) and energy-efficient aircraft, to ensure the industry's long-term growth while addressing environmental concerns.

5.4. Limitations

This study has some limitations. First, it focuses primarily on South Korea and the U.S., limiting its generalizability to other countries with different economic structures. Second, while GDP is a central factor, other important variables, such as technological advancements and political instability, are not considered and warrant further investigation.

Declaration of Generative AI and AI-assisted technologies in the writing process:

- During the preparation of this manuscript, the author did not use generative AI and AI-assisted technologies. The author takes full responsibility for the content of the publication.

References

1. Ahmad, A. H. and Aworinde, O. B. (2019) Are fiscal deficits inflationary in African countries? A new evidence from an asymmetric cointegration analysis. *North American Journal of Economics and Finance*, 50, 100999. DOI:10.1016/j.najef.2019.100999.
2. Albuquerque, A. P. G. D., Melo, F. J. C. D. and Dumke de Medeiros, D. (2022) Airline quality assessment towards strategic tourism management improvements. *Tourism Review*, 77, 570–591. DOI: 10.1108/TR-07-2020-0354.
3. Allen, D. E. and McAleer, M. (2021) A nonlinear autoregressive distributed lag (NARDL) analysis of the FTSE and S&P500 Indexes. *Risks*, 9, 195. DOI: 10.3390/risks9110195.
4. Ampofo, G. K. M., Cheng, J., Ayimadu, E. T. and Asante, D. A. (2021) Investigating the asymmetric effect of economic growth on environmental quality in the next 11 countries. *Energies*, 14, 491. DOI: 10.3390/en14020491.

5. Bahmani-Oskooee, M. and Gelan, A. (2019) Asymmetric effects of exchange rate changes on the demand for money in Africa. *Applied Economics*, 51, 3365–3375. DOI: 10.1080/00036846.2019.1578854.
6. Balsalobre-Lorente, D., Driha, O. M., Bekun, F. V. and Adedoyin, F. F. (2021) The asymmetric impact of air transport on economic growth in Spain: Fresh evidence from the tourism-led growth hypothesis. *Current Issues in Tourism*, 24, 503–519. DOI: 10.1080/13683500.2020.1720624.
7. Bilotkach, V. and Lakew, P. A. (2014) On sources of market power in the airline industry: Panel data evidence from the US airports. *Transportation Research Part A: Policy and Practice*, 59, 288–305. DOI: 10.1016/j.tra.2013.11.011.
8. Bustos, S., Gomez, C., Hausmann, R. and Hidalgo, C. A. (2012) The dynamics of nestedness predicts the evolution of industrial ecosystems. *PloS One*, 7, e49393. DOI: 10.1371/journal.pone.0049393.
9. Button, K. and Taylor, S. (2000) International air transportation and economic development. *Journal of Air Transport Management*, 6, 209–222. DOI: 10.1016/S0969-6997(00)00015-6.
10. Chen, Q. (2023) The impact of economic and environmental factors and tourism policies on the sustainability of tourism growth in China: Evidence using novel NARDL model. *Environmental Science and Pollution Research*, 30, 19326–19341. DOI: 10.1007/s11356-022-22925-w.
11. Chi, J. (2024) Asymmetric effects of economic policy uncertainty and exchange rates on international air travel demand: The case from Hong Kong. *Journal of Air Transport Management*, 114, 102503. DOI: 10.1016/j.jairtraman.2023.102503.
12. Chi, J. and Baek, J. (2013) Dynamic relationship between air transport demand and economic growth in the United States: A new look. *Transport Policy*, 29, 257–260. DOI: 10.1016/j.tranpol.2013.03.005.
13. Doğan, B., Balsalobre-Lorente, D. and Nasir, M.A. (2020) European commitment to COP21 and the role of energy consumption, FDI, trade and economic complexity in sustaining economic growth. *Journal of Environmental Management*, 273, 111146. DOI: 10.1016/j.jenvman.2020.111146.
14. Escobari, D. (2013) Asymmetric price adjustments in airlines. *Managerial and Decision Economics*, 34, 74–85. DOI: 10.1002/mde.2575.
15. Fernandes, E. and Pacheco, R. R. (2010) The causal relationship between GDP and domestic air passenger traffic in Brazil. *Transportation Planning and Technology*, 33, 569–581. DOI: 10.1080/03081060.2010.512217.
16. Fu, Y. K. (2023) Airline brand image, passenger perceived value and loyalty towards full-service and low-cost carriers. *Tourism Review*, 78, 1433–1451. DOI: 10.1108/TR-07-2022-0369.
17. Ghosh, S. (2020) Asymmetric impact of COVID-19 induced uncertainty on inbound Chinese tourists in Australia: Insights from nonlinear ARDL model. *Quantitative Finance and Economics*, 4, 343–364. DOI: 10.3934/QFE.2020016.
18. Goh, C. and Law, R. (2011) The methodological progress of tourism demand forecasting: A review of related literature. *Journal of Travel & Tourism Marketing*, 28, 296–317. DOI: 10.1080/10548408.2011.562856.
19. Gómez López, C. S. and Barrón Arreola, K. S. (2024) Tourism and the environment in Mexico: Evidence of the relationship in the short and long term. *Tourism Review*, 79, 585–600. DOI: 10.1108/TR-01-2023-0060.
20. Hakim, M. M. and Merkert, R. (2016) The causal relationship between air transport and economic growth: Empirical evidence from South Asia. *Journal of Transport Geography*, 56, 120–127. DOI: 10.1016/j.jtrangeo.2016.09.006.
21. Hanson, D., Toru Delibasi, T. T., Gatti, M. and Cohen, S. (2022) How do changes in economic activity affect air passenger traffic? The use of state-dependent income elasticities to improve aviation forecasts. *Journal of Air Transport Management*, 98, 102147. DOI: 10.1016/j.jairtraman.2021.102147.
22. Hu, Y., Xiao, J., Deng, Y., Xiao, Y. and Wang, S. (2015) Domestic air passenger traffic and economic growth in China: Evidence from heterogeneous panel models. *Journal of Air Transport Management*, 42, 95–100. DOI: 10.1016/j.jairtraman.2014.09.003.
23. Jiang, Y. and Que, T. (2022) Asymmetric pricing and airline performance. *Applied Finance Letters*, 11, 9–18. DOI: 10.24135/afl.v11i.522.
24. Khan, N. T., Aslam, J., Rauf, A. A. and Kim, Y. B. (2022) The case of South Korean airlines-within-airlines model: Helping full-service carriers challenge low-cost carriers. *Sustainability*, 14, 3468. DOI: 10.3390/su14063468.
25. Kupfer, F., Meersman, H., Onghena, E. and Van de Voorde, E. (2017) The underlying drivers and future development of air cargo. *Journal of Air Transport Management*, 61, 6–14. DOI: 10.1016/j.jairtraman.2016.07.002.

26. Law, C. C. H., Zhang, Y., Gow, J. and Vu, X. B. (2022) Dynamic relationship between air transport, economic growth and inbound tourism in Cambodia, Laos, Myanmar and Vietnam. *Journal of Air Transport Management*, 98, 102161. DOI: 10.1016/j.jairtraman.2021.102161.
27. Liasidou, S. (2017) Drafting a realistic tourism policy: The airlines' strategic influence. *Tourism Review*, 72, 28–44. DOI: 10.1108/TR-10-2016-0044.
28. Lütkepohl, H. and Xu, F. (2012) The role of the log transformation in forecasting economic variables. *Empirical Economics*, 42, 619–638. DOI: 10.1007/s00181-010-0440-1.
29. Organization for Economic Co-operation and Development. (2020) *COVID-19 and the Aviation Industry: Impact and Policy Responses*. OECD Publishing.
30. Pesaran, M. H., Shin, Y. and Smith, R. J. (2001) Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16, 289–326. DOI: 10.1002/jae.616.
31. Shahani, R. and Singhal, U. (2023) Do efficient commodity markets co-move: evidence from Indian base metals market. *Mineral Economics*, 36, 413–425. DOI: 10.1007/s13563-022-00353-z.
32. Shin, Y., Yu, B. and Greenwood-Nimmo, M. (2014) Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework, In: Sickles, R.C. (Ed.). *Festschrift in Honor of Peter Schmidt: Econometric Methods and Applications,* pp. 281–314. Springer. DOI: 10.1007/978-1-4899-8008-3_9.
33. Suk, M. and Kim, W. (2021) COVID-19 and the airline industry: Crisis management and resilience. *Tourism Review*, 76, 984–998. DOI: 10.1108/TR-07-2020-0348.
34. Wadud, Z. (2014) The asymmetric effects of income and fuel price on air transport demand. *Transportation Research Part A: Policy and Practice*, 65, 92–102. DOI: 10.1016/j.tra.2014.04.001.
35. Zhang, F. and Graham, D. J. (2020) Air transport and economic growth: A review of the impact mechanism and causal relationships. *Transport Reviews*, 40, 506–528. DOI: 10.1080/01441647.2020.1738587.
36. Zhang, H. Q. (2023) The impact of different phases of COVID-19 on the airline, financial services, and healthcare industry. In: *Dang, C. T., Cifuentes-Faura, J., and Li, X. (eds.) Proceedings of the 2nd International Conference on Business and Policy Studies (CONF-BPS 2023)*. Springer, pp. 1713–1721.