Short-term Effects of Aircraft Movements, Passengers, and Freight on Air-Transport GRDP in Sulawesi Barat (2014–2024): An ARDL Analysis

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Diterima: 14 Januari 2025, direvisi: 21 April 2025, disetujui: 28 Mei 2025,
tersedia daring: 26 Juni 2025, diterbitkan: 30 Juni 2025

Abstract

This study aims to analyze the influence of the aircraft movements, passenger numbers, and the air freight volume on the Gross Regional Domestic Product (GRDP) of the air transport subsector in Sulawesi Barat. The study uses quarterly data from Q1 2014 to Q4 2024 (44 observations) and applies the ARDL (3,4,0,0) model selected based on the Akaike Information Criterion (AIC). Stationarity and long-run relationships were tested using the Augmented Dickey-Fuller and Bounds tests, respectively, with no control variables included. The results indicate that only short-run effects were found, while no evidence of long-run cointegration exists among the variables. In the short run, aircraft movements have a positive and statistically significant association with the GRDP of the air transport subsector, whereas passenger numbers and the air freight volume show no significant relationship. However, the model's high adjusted R^2 and absence of robustness checks suggest caution in interpretation, as omitted variable bias and limited causal inference may exist. These findings suggest that enhancing aircraft operations and connectivity could support short-term growth in the regional air transport subsector. However, further research incorporating structural breaks and robustness analyses is recommended to strengthen policy conclusions. These insights are relevant for policymakers seeking evidence-based strategies to improve regional air connectivity and optimize the economic role of the air transport subsector in Sulawesi Barat.

Keywords: Air connectivity, air transport GDRP, ARDL cointegration, regional connectivity, Sulawesi Barat.

Abstrak

Efek Jangka Pendek Pergerakan Jumlah Pesawat, Penumpang, dan Kargo Udara terhadap PDRB Subsektor Angkutan Udara di Sulawesi Barat (2014–2024): Analisis ARDL: *Penelitian ini menganalisis pengaruh pergerakan jumlah pesawat, jumlah penumpang, dan volume barang udara terhadap Produk Domestik Regional Bruto (PDRB) subsektor angkutan udara di Provinsi Sulawesi Barat. Penelitian ini menggunakan data triwulanan dari Triwulan I 2014 hingga Triwulan IV 2024 (44 observasi) dan menerapkan model ARDL(3,4,0,0) yang dipilih berdasarkan Akaike Information Criterion (AIC). Uji stasioneritas dan hubungan jangka panjang dilakukan masing-masing dengan menggunakan uji Augmented Dickey-Fuller dan Bounds Test, tanpa memasukkan variabel kontrol dalam model. Hasil menunjukkan tidak terdapat hubungan kointegrasi jangka panjang antarvariabel, sementara dalam jangka pendek, pergerakan jumlah pesawat berpengaruh positif dan signifikan terhadap PDRB subsektor angkutan udara. Sebaliknya, jumlah penumpang dan volume barang udara tidak berpengaruh signifikan. Nilai adjusted R^2 yang tinggi dan ketiadaan uji robustness menunjukkan perlunya kehati-hatian dalam interpretasi, mengingat potensi bias variabel terabaikan dan keterbatasan inferensi kausal. Temuan ini mengimplikasikan bahwa peningkatan operasional dan konektivitas penerbangan dapat mendukung pertumbuhan jangka pendek subsektor angkutan udara. Penelitian lanjutan dengan pengujian structural break dan analisis robustness diperlukan untuk memperkuat rekomendasi kebijakan. Hasil penelitian ini diharapkan dapat menjadi masukan bagi pembuat kebijakan dalam merumuskan strategi berbasis bukti untuk meningkatkan konektivitas udara regional dan mengoptimalkan peran ekonomi subsektor angkutan udara di Sulawesi Barat.*

Kata kunci: *Kointegrasi ARDL, konektivitas regional, konektivitas udara, PDRB angkutan udara, Sulawesi Barat.*

1. Introduction

Air transportation holds an important role in the development of a region, specifically in an archipelagic country like Indonesia [1][2]. As a mode of transport, it not only accelerates the movement of people and goods but also enhances inter-regional connectivity, supports the expansion of the service sector, and fosters economic integration across geographically dispersed regions. Strong air connectivity is widely recognized as a fundamental prerequisite for improving logistical efficiency, attracting investment, and enabling labor mobility [3][4]. However, significant disparities in air connectivity persist among Indonesia's provinces, posing challenges for equitable regional development. Aside from the newly established provinces in Papua, Sulawesi Barat is the only province with no direct flight to Jakarta, the center of governance and national economy [5]. Available flights from Mamuju, the provincial capital of Sulawesi Barat, where the only operating airport is located, provide only two routes as shown in Figure

http://dx.doi.org/10.25104/wa.v51i1.573.22-31
0852-1824/ 2580-1082
Nomor akreditasi: (RISTEKDIKTI) 72/E/KPT/2024 (Sinta 4).

1. MJU-UPG, namely the Mamuju-Makassar route, and MJU-BPN, which is the route connecting Mamuju and Balikpapan [5]. This limited air access substantially hinders the province's economic potential, resulting in higher transportation costs, reduced mobility for people and goods, and restricted access to central government services [6]. In 2021, the airport in Sulawesi Barat, Tampa Padang Airport, was recorded as having the lowest direct connectivity index among Indonesian airports [7], further exacerbating the region's logistical isolation.

The province's structural limitations compound these issues. As the only Indonesian province without a municipality, Sulawesi Barat consists entirely of regencies [8], which typically lack robust infrastructure, including comprehensive airport facilities. This condition increases the risk of economic marginalization, particularly in the context of national development efforts that often prioritize well-connected urban centers [9].

A comparison with Gorontalo Province offers a compelling illustration of how disparities in air connectivity and infrastructure can influence regional economic performance, even among provinces with similar baseline characteristics. Both Gorontalo and Sulawesi Barat are relatively young provinces; Gorontalo was established in 2000, and Sulawesi Barat in 2004, and are both situated on the island of Sulawesi. Despite these similarities, Sulawesi Barat possesses structural advantages in terms of population and economic size. In 2024, the population of Sulawesi Barat reached 1.5 million people, and its Gross Regional Domestic Product (GRDP) stood at Rp64,214.88 billion. By contrast, Gorontalo had a smaller population of 1.2 million and a lower GRDP of Rp54,554.50 billion.

However, in terms of the air transport subsector's contribution to the economy, Gorontalo significantly outperforms Sulawesi Barat. In 2024, Gorontalo's air transport sector generated Rp622.52 billion in GRDP, which is nearly nine times higher than the Rp72.12 billion recorded in Sulawesi Barat [10][11]. This striking gap cannot be explained by population or general economic scale alone. It closely reflects the difference in air connectivity between the two provinces. Gorontalo is served by four commercial flight routes as shown in Figure 2, including a direct route to the national capital, Jakarta [5]. Sulawesi Barat, on the other hand, operates only two routes and lacks any direct connection to Jakarta, limiting its integration with national logistics and mobility flows.

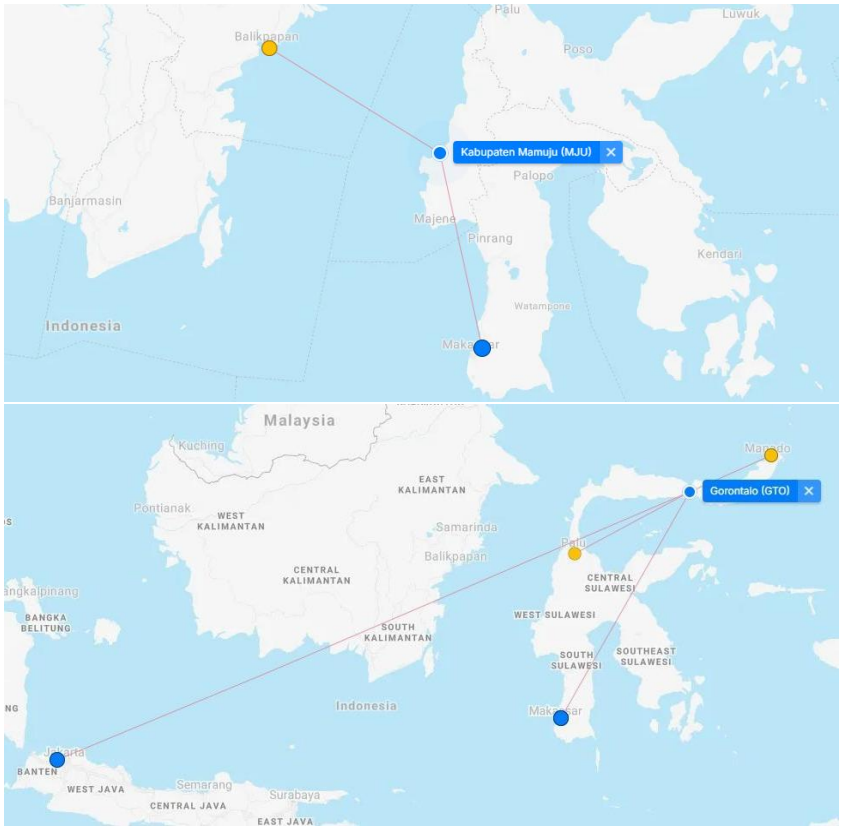

Figure 2. Direct Flights from and to Gorontalo (GTO) [13]

The disparity is also evident in operational metrics. Gorontalo consistently reports higher annual volumes of scheduled flights, passenger traffic, and cargo shipments by air compared to Sulawesi Barat. These patterns suggest that air transport connectivity plays a pivotal role in facilitating economic activity, particularly by improving accessibility, reducing transaction costs, and enabling faster movement of goods and people. In provinces where other economic inputs are relatively similar, such as in the case of Gorontalo and Sulawesi Barat, enhanced air transport networks can be a decisive factor in accelerating regional development and competitiveness [14][15].

Despite these constraints, the air transportation subsector in Sulawesi Barat continues to contribute to the province's economic structure. Although it ranks as the fourth smallest contributor to the provincial GRDP, the subsector shows signs of resilience and latent potential. Over the past decade, aircraft movements increased steadily from 2014 to a peak in 2018, before experiencing a sharp decline during the COVID-19 pandemic in 2020, a trend that has yet to fully recover as of 2024. Passenger numbers followed a similar trajectory, growing between 2015 and 2018, plunging in 2020, and remaining below pre-pandemic levels. Interestingly, even as flight frequencies decreased, the volume of cargo handled and the GRDP contribution of the air transport subsector continued to rise, hinting at untapped opportunities for sectoral expansion if traffic could be restored or improved.

The relationship between air traffic and economic performance has been widely explored in the literature. Recent studies have increasingly emphasized the role of air transportation in regional economic development, particularly in emerging and archipelagic countries such as Indonesia. One study found that among various air transport indicators, air freight per capita has the strongest positive influence on regional GDP, followed by passenger volume and flight frequency [1]. Other regional factors, such as manufacturing potential, skilled labor, and tourism attractiveness, also increase the probability of airport development. At the Southeast Asian level, research further confirmed that air transport significantly contributes to economic growth in both the short and long term, while the tourism sector showed mixed impacts, particularly during the pandemic [16]. These findings collectively underscore the strategic role of air transport, especially air freight, in supporting regional economic performance.

In the Indonesian context, prior research identified a bidirectional causality between air transport infrastructure and economic growth, although road infrastructure was found to have a larger contribution to GDP [17]. Another study presented a different view, finding unidirectional causality from economic growth to infrastructure, with air and sea transport showing no long-run effect [18]. By adding spatial dimensions, further work revealed that airport infrastructure generates significant positive spillovers to adjacent regions, in contrast to road infrastructure, which may provoke interregional competition [19]. On a city-level analysis, it was shown that air transport infrastructure independently contributes significantly to urban GRDP [20], reinforcing the importance of contextualized air connectivity investments [21].

From a transport economics perspective, the relationship between air traffic indicators and economic output can be explained through direct, indirect, and induced effects. Aircraft movements primarily represent the operational intensity of the air transport subsector, including flight frequency, airport utilization, employment in maintenance and ground services, and fuel consumption, all of which directly contribute to the subsector's value added. In contrast, passenger and freight volumes largely reflect demand-side activities that may depend on broader macroeconomic conditions rather than the internal performance of the air transport sector itself. Consequently, fluctuations in aircraft movements are more closely linked to the production-side capacity and operational efficiency of the subsector, which in turn determines its contribution to regional GRDP. This theoretical framing helps explain why aircraft movements may exert a stronger short-run effect on GRDPA compared to passenger or freight indicators, particularly in regions with limited market size and route concentration, such as Sulawesi Barat.

Despite the growing literature, many studies remain focused on national or urban levels, leaving peripheral and underconnected regions underexplored. Furthermore, limited research utilizes long-term time-series data to analyze the dynamic interplay between air transport indicators, such as passenger numbers, aircraft movements, air freight volumes, and GRDP. This is particularly relevant for provinces like Sulawesi Barat, which, despite having a higher population and GRDP than Gorontalo, significantly

lags in air connectivity and air transport sector performance. Gorontalo, with better flight access and infrastructure, illustrates how air connectivity strongly correlates with regional economic outcomes. However, few studies employ quarterly time-series approaches such as ARDL to examine these dynamics at the provincial level, making the methodological understanding of linkages in underconnected regions still limited.

This study seeks to address this gap by examining the factors influencing the role of the air transportation subsector in the economic development of Sulawesi Barat Province. It provides a dual contribution. A descriptive analysis of long-term trends in air traffic and the GRDP contribution of the air transport subsector, and an econometric investigation of the relationship between air traffic indicators (aircraft movements, passenger numbers, and air freight volume) and regional economic output, accounting for time-lag effects and dynamic interactions across variables.

By employing time series methods and analyzing data over the past decade, this study aims to reveal the extent to which air transport dynamics affect economic activity in underconnected regions. The findings are expected to offer valuable insights for policymakers, particularly in designing more effective regional connectivity strategies and supporting the development of aviation infrastructure in disadvantaged provinces. Moreover, the results can guide collaborative initiatives between governments and airline operators to optimize air service provision and regional accessibility.

Specifically, this study analyzes the short-term and long-term effects of aircraft movements, passenger numbers, and air freight volume on the GRDP of the air transport subsector in Sulawesi Barat Province. The dependent variable is defined as the GRDP of the air transport subsector (GRDPA), representing the subsector's direct contribution to the regional economy. The selection of these three air traffic indicators (PLANE, PASS, and FREIGHT) is based on their consistency in quarterly reporting and their relevance as the most direct measures of regional air transport activity. Accordingly, the study hypothesizes that increases in aircraft movements, passenger numbers, and air freight volume are expected to have positive effects on the GRDP of the air transport subsector in Sulawesi Barat.

2. Method

2.1. Data Source

This study used secondary data from the BPS-Statistics Sulawesi Barat Province and the Tampa Padang Mamuju Airport Management Unit Office. The data covered the information on GRDP of the air transport subsector (GRDPA), aircraft movements (PLANE), passenger numbers (PASS), and air freight volume (FREIGHT). These variables were selected to represent the main dimensions of air transport performance and its economic impact. Specifically, aircraft movements capture the intensity of flight operations, passenger numbers reflect the mobility of people, while air freight volume indicates the flow of goods and logistics capacity, all of which are theoretically linked to regional economic activity and productivity growth. The observation period spanned from Q1 2014 to Q4 2024, 44 observations, providing a comprehensive view of air transport activity and its economic implications in Sulawesi Barat.

2.2. Data Processing

All data were processed using RStudio, an open-source statistical computing software. The data were first organized into a time series format and underwent several preparation steps, including handling of missing values, checking for consistency, and transforming into a logarithmic scale when required. Before modeling, unit root tests were conducted to assess the stationarity of each variable, as a prerequisite for time series regression analysis.

2.3. Data Analysis

This study employed the Autoregressive Distributed Lag (ARDL) model to examine the short- and long-run relationships between the air transport indicators and the performance of the air transport subsector GRDP in Sulawesi Barat. The ARDL approach was chosen because it is particularly suitable for time series data with a relatively small sample size and for models where variables exhibit different orders of integration, either at level I(0), first difference I(1), or a combination of both, as long as none

are integrated at order two I(2), which is the exact condition of the data used in this study. The model estimation included the following steps: stationarity testing using the Augmented Dickey-Fuller (ADF) test, cointegration testing using the Bounds Test, and interpretation of both short-run and long-run coefficients [22][23]. All statistical procedures were performed in RStudio using the relevant econometrics packages.

3. Results and Discussion

3.1. Results

Building on the methodological framework outlined in the previous section, this part presents the empirical findings obtained from the descriptive statistics and the ARDL estimations. The analysis begins with descriptive statistics to see dynamic of the variables in this study, and then the Bounds cointegration test was implemented to evaluate the presence of a long-run equilibrium relationship among the variables, followed by an examination of the estimated short-run and long-run dynamics. The results are reported in a structured manner to align with the research objectives and to provide statistical evidence for evaluating the proposed hypotheses.

3.1.1. Descriptive Statistics

The air transportation subsector in Sulawesi Barat exhibits several notable trends across the key indicators: the GRDP of the air transport subsector (GRDPA), aircraft movements (PLANE), passenger numbers (PASS), and air freight volume (FREIGHT). The analysis covers quarterly data from Q1 2014 to Q4 2024.

The GRDP of the air transport subsector demonstrates a long-term upward trajectory, increasing from IDR 3,247.8 million to a peak of IDR 19,839.4 million. The mean GRDP value is approximately IDR 10,941.7 million. Quarterly growth rates (QoQ) range from -29.82% to +36.07%, with an average of 5.33%. These fluctuations suggest some seasonal volatility, potentially linked to the pandemic, holidays, weather, or operational disruptions. The strongest annual growth (YoY) recorded was 47.1%, underscoring the sector's rebound capacity in the post-pandemic era.

This long-term GRDP growth corresponds with trends in aircraft movements, which also exhibit significant fluctuations over the observed period. Aircraft movements ranged from 34 to 978 per quarter, with an average of 476. Despite a general increasing trend before 2020, the pandemic caused a significant contraction, as reflected in the minimum quarterly growth of -87.4%. The highest quarterly spike reached over +1055%, possibly indicating route reinstatements or pent-up travel demand during reopening phases. However, the YoY trend (-1.95% on average) suggests that flight frequency has not yet stabilized to pre-pandemic levels. Aircraft movements show intermittent recovery and post-pandemic volatility.

Closely tied to aircraft activity, passenger numbers also display pronounced volatility. Passenger numbers fluctuated sharply, from a minimum of 642 to a maximum of 54,031 per quarter. The average quarterly count stands at around 22,402. The extreme variation in quarterly growth rates (from -94.93% to +2298.75%) reflects the sector's sensitivity to external shocks, especially COVID-19. Interestingly, the post-crisis recovery seems more robust in passenger numbers than in aircraft frequency, as evidenced by a positive average YoY growth (4.8%).

Table 1. Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
GRDPA	10 941.68	4 276.40	3 247.80	19 839.40
PLANE	475.98	251.80	34.00	978.00
PASS	22 402.59	13 227.50	642.00	54 031.00
FREIGHT	119.82	73.00	1.88	303.77

Source: primary data processed with Rstudio

Table 2. Stationarity Test Result

Variable	Level			First Difference			Order
	test-statistic	tau3	Stationarity	test-statistic	tau3	Stationarity	
GRDPA	-2.1326	-3.50	✗	-6.5006	-3.50	✓	I(1)
PLANE	-3.6778	-3.50	✓	-	-	-	I(0)
PASS	-2.4544	-3.50	✗	-5.8763	-3.50	✓	I(1)
FREIGHT	-2.7519	-3.50	✗	-6.5933	-3.50	✓	I(1)

Source: primary data processed with RStudio

Meanwhile, air freight volume presents the most volatile trend among all indicators, ranging from 1.88 to 303.77 tonnes per quarter. The sector experienced quarterly changes from -97.03% to +3911.17%, with an average increase of 109.12%, reflecting erratic logistics flows. Such inconsistency may be linked to Sulawesi Barat's limited industrial base, uneven cargo demand, and supply chain fragility. Despite contributing a smaller share to the subsector's GRDP, air freight remains a critical yet unstable component in regional connectivity and economic logistics.

Among all indicators, air freight and passenger numbers exhibit the greatest relative standard deviation, pointing to significant unpredictability. Meanwhile, aircraft movement trends appear more structurally constrained, likely due to limited airport infrastructure and available routes, which is an issue compounded by the province's status as the only one without direct flights to Jakarta. While some seasonal patterns can be inferred, the data also highlight structural limitations in the region's air transport sector, such as the lack of route diversification, reflected in limited changes in aircraft movement despite economic shocks, vulnerability to external disruptions, especially for passenger and air freight volumes, and a possible mismatch between GRDP growth and operational metrics, indicating inefficiencies or underutilization.

3.1.2. Stationarity Test

The stationarity test is conducted as a preliminary step in time series analysis to examine whether each variable under investigation contains a unit root. This test is crucial, as the presence of a unit root can significantly affect the validity of the relationships among variables in the regression model. If a unit root is present, there is a risk of spurious regression, a condition in which the regression between two or more variables appears to be statistically significant. Still, the relationship is not meaningful in the real context. Therefore, it is essential to ensure that the time series data being analyzed are stationary, meaning they possess statistical properties that do not change over time.

The following presents the results of the stationarity test using the Augmented Dickey-Fuller (ADF) Test.

The results of the stationarity test indicate that only the aircraft variable is stationary at the level form, while the GRDP, passenger, and freight variables are not stationary at the level. The notation tau3 refers to the critical value for the Augmented Dickey-Fuller (ADF) test under the model specification that includes both an intercept and a deterministic trend. This specification is appropriate for economic time series data, which typically exhibit trending behavior over time. Accordingly, all variables in the analysis were tested against the tau3 critical value (–3.50) to ensure consistent evaluation of stationarity under the trend-included assumption. The decision regarding the presence or absence of unit roots was therefore based on this model specification. However, after applying the first difference, all variables show no indication of a unit root and become stationary at the first difference at the 5% significance level. Since the variables are stationary at either level or first difference, the ARDL approach is applicable, as it does not require all variables to be stationary at the same level.

3.1.3. Optimum Lag Test

The optimum lag length was determined using the Akaike Information Criterion (AIC) by selecting the model with the lowest AIC value among various lag combinations tested. In RStudio, the ARDL

model was constructed using the auto ardl function, which automatically selects the best-fitting model based on both specification and selection criteria. As a result, the optimal ARDL model identified was ARDL(3, 4, 0, 0).

3.1.4. Classical Assumption Test

To ensure the reliability and robustness of the ARDL model, a series of diagnostic tests was conducted. The Shapiro-Wilk normality test yielded a p-value of 0.2315, indicating that the residuals are normally distributed at the 5% significance level, as the null hypothesis of normality cannot be rejected. This satisfies one of the classical linear regression assumptions and supports the statistical validity of the model. The Breusch-Pagan test for heteroscedasticity produced a p-value of 0.6232, implying that there is no significant evidence of heteroscedasticity in the model residuals. Thus, the variance of the errors can be considered constant across observations. Furthermore, the Durbin-Watson test was used to detect the presence of autocorrelation in the residuals. With a test statistic of 1.902 and a p-value of 0.2221, the result indicates no significant autocorrelation, affirming the independence of residuals. Together, these diagnostic results confirm that the model satisfies the assumptions of normality, homoscedasticity, and no serial correlation, reinforcing the robustness and validity of the estimated ARDL model.

3.1.5. Cointegration Test

The Bound Test approach to cointegration was employed to examine the existence of a long-run relationship among the variables. The initial test, using the full dataset from 2014Q1 to 2024Q4 under the restricted intercept and no trend specification (case = 3), produced an F-statistic value of 0.9242 with an associated p-value of 0.9085. Given that the p-value exceeds the conventional significance threshold of 0.05, the result suggests that there is no statistically significant evidence of cointegration among the variables in the model. In other words, the air transport indicators do not maintain a stable long-term relationship with GRDPA over the observed period.

To ensure the robustness of this finding, a sensitivity analysis was conducted by excluding the years 2020 and 2021, which represent the peak disruption period of the COVID-19 pandemic. These years were marked by unprecedented declines in flight activity and economic output, which could have potentially distorted the long-run dynamics. However, even after removing these outlier years, the Bound Test continued to yield statistically insignificant results. The absence of cointegration in both the full sample and the adjusted sample reinforces the conclusion that the relationship between air transport variables and regional economic performance in Sulawesi Barat is not stable in the long run.

This consistent lack of cointegration, even under different timeframes, suggests that fluctuations in air transport activities do not lead to sustained changes in economic output, but rather reflect short-term or cyclical dynamics. It also points to the possibility that the economic role of the air transportation subsector in the province remains operationally supportive rather than structurally integrative. Its influence is real, but not persistent across extended periods.

3.1.6. Autoregressive Distribution Lag (ARDL) Model Result

The results of the time series regression indicate that the model exhibits a strong explanatory power, with an adjusted R-squared of 0.9032. This suggests that approximately 90.3% of the variation in the dependent variable is explained by the selected independent variables. The F-statistic value of 37.4, accompanied by a p-value of 7.002e-14, confirms the overall significance of the model. Residuals appear to be symmetrically distributed, with a median close to zero and a residual standard error of 1256, indicating that prediction errors are relatively moderate. These findings collectively validate the model's robustness and reliability.

The following presents the results of the short-term relationship within the observed variables.

Table 3. ARDL Model Result

Variables	Estimate	p-value	Significance
(Intercept)	1 475.69095	0.2567	
L(GRDPA, 1)	0.81256	1.29e-05	***
L(GRDPA, 2)	-0.19372	0.3168	

Variables	Estimate	p-value	Significance
L(GRDPA, 3)	0.39108	0.0189	*
PLANE	2.95445	0.1605	
L(PLANE, 1)	-2.28574	0.0913	.
L(PLANE, 2)	-1.64902	0.1997	
L(PLANE, 3)	1.34930	0.3692	**
L(PLANE, 4)	-3.41824	0.0063	
PASS	0.06268	0.2302	
FREIGHT	-7.93520	0.3474	

Source: primary data processed with RStudio

*** *: Significant in 0.001* * *: Significant in 0.05*

** *: Significant in 0.01* . *: Significant in 0.1*

Table 3 shows the significant influence of the GRDPA's past values, particularly at lag *t-1* and $t-3$, highlighting the persistence and autoregressive nature of regional economic growth. This suggests that current economic performance is heavily dependent on previous economic conditions, a characteristic often observed in regional macroeconomic dynamics. Furthermore, aircraft movements operating in the region show a strong and statistically significant effect on GRDPA, especially at lag periods of two and four quarters. This delayed impact implies that increases in air transportation capacity do not immediately influence economic output but rather take time to manifest, possibly through increased mobility, improved connectivity, and the gradual stimulation of economic activities. The variables representing the number of air passengers and the volume of air freight do not show statistically significant effects within the model. This may be due to the possibility that their influence is either indirect or already encapsulated by the aircraft variable. For instance, aircraft availability might inherently reflect potential passenger and cargo capacities, thus diminishing the additional explanatory power of these two variables.

3.2. Discussion

This study offers meaningful insights into the role of the air transportation subsector in the economy of Sulawesi Barat. Despite a long-term increase in the sector's Gross Regional Domestic Product (GRDP), statistical analysis using the ARDL approach reveals no cointegration relationship among the variables. This indicates that the link between air transport and economic growth in Sulawesi Barat is limited to short-term dynamics and lacks a stable long-run equilibrium. Such a result may be attributed to structural constraints, including limited air connectivity and underdeveloped aviation infrastructure.

Temporal analysis of air transport indicators, aircraft movement, passenger numbers, and air freight volume demonstrates volatility rather than consistent growth. Aircraft movements peaked in the third quarter of 2017 but declined in subsequent years. A temporary spike occurred in early 2021, likely due to the logistics demand following the Mamuju earthquake. Similar trends are found in passenger and air freight volumes, with intermittent growth followed by declines and stagnation. These fluctuations reflect the sector's vulnerability to external shocks, seasonal variation, and inconsistent service provision.

Operational disruptions further highlight the fragility of air connectivity. A key example is the suspension of the MJU–UPG route in late 2023 following the phasing out of ATR aircraft by the operating airline. Service resumed only in mid-2025 under a public-private partnership, with reduced frequency. This underscores a broader issue in low-demand regions: smaller, more frequent flights may be more appropriate than infrequent services with larger aircraft. Daily operations can support consistent demand and provide greater flexibility to users.

The GRDP data for the sector also reflects short-term volatility, suggesting that economic contributions from air transport are not stable across quarters. The COVID-19 pandemic severely disrupted flight operations, and although there has been a partial recovery, especially in passenger numbers, pre-pandemic levels of activity have not yet been fully restored. Moreover, the region still lacks direct air routes to Jakarta, limiting integration into the national economic network and constraining growth opportunities.

From an econometric perspective, the ARDL model shows that aircraft movement is the only air transport variable with a statistically significant effect on GRDP, and even then, only at certain lags. This implies that improvements in air connectivity may take time to influence economic outcomes. Neither

passenger nor air freight volumes has a significant direct impact on GRDP, possibly because they serve as outputs of increased connectivity rather than independent drivers. This finding suggests that strategic focus should be placed on increasing the number and reliability of aircraft movements.

The policy implications are substantial and call for coordinated, evidence-based action. First, improving regional air connectivity should be prioritized through the development of more frequent and reliable routes, particularly by maintaining daily service schedules on key inter-island and feeder routes. Second, strategic incentives may be necessary to maintain routes that are not yet commercially viable. These could include government subsidies, regional aviation partnerships, or integrated transport planning that aligns with tourism, health, and education strategies. Third, the mismatch between sectoral output and operational indicators highlights the need for improved demand stimulation and service marketing. Enhancing digital accessibility, increasing awareness of available services, and expanding cargo facilities could help boost usage. Finally, although no long-run equilibrium was found, this should not be interpreted as a structural limitation but as an opportunity for institutional and operational improvements. Future efforts that combine route diversification, service reliability enhancement, and interregional coordination may transform Sulawesi Barat's air transport subsector into a more consistent contributor to economic development.

4. Conclusion

This study examined the relationship between air transportation activity and regional economic performance in Sulawesi Barat over the period 2014–2024, using the Autoregressive Distributed Lag (ARDL) model. The results show that aircraft movement is the only air transport indicator with a statistically significant short-term impact on the GRDP of the region, particularly with effects observed at certain lag periods. In contrast, passenger numbers and air freight volumes do not demonstrate significant contributions within the model, potentially due to their indirect effects or overlap with the aircraft movement variable. Additionally, the Bound Test reveals no long-term cointegration among the variables, indicating that changes in air transport operations do not lead to sustained long-run economic growth in the province. These findings suggest that while air transport contributes to economic fluctuations, its influence remains structurally limited in the long term.

While these findings provide exploratory evidence of short-run dynamics, they should be interpreted with caution. The model omits control variables such as infrastructure investment, tourism demand, and broader macroeconomic factors, which may influence both air transport activity and GRDP. Moreover, the study did not include robustness checks, structural break analysis, or demand elasticity estimation, limiting the strength of causal inferences. Consequently, the results represent associative, rather than causal, relationships based on available provincial-level quarterly data.

This study's contribution lies in presenting descriptive quarterly trends and exploratory ARDL-based evidence on the short-run linkage between air transport and regional output in an underconnected province, an area rarely examined in existing literature. Future research is encouraged to expand the scope through multi-provincial or panel analyses, the inclusion of infrastructure and investment variables, and the application of spatial econometric methods to capture interregional spillovers. Conducting demand and route profitability assessments would also provide a more rigorous basis for evaluating potential interventions.

For policymakers, these findings suggest that improving air transport efficiency may support short-term regional economic activity; however, any route expansion or frequency increase should be preceded by comprehensive demand and cost-benefit studies. Evidence-based coordination between government agencies, airlines, and regional planners will be essential to ensure that future connectivity initiatives are both economically viable and developmentally effective.

Acknowledgement

The author extends sincere gratitude to Pusat Pendidikan dan Pelatihan Badan Pusat Statistik for its support through the Technical Training on Scientific Writing for Statisticians, Batch I, 2025.

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