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Aviation Pollution, Tourism, and Economic Development: A Study of the EKC Hypothesis at the Regional Level[1]

Abstract. The study aims to revisit the relationship between aviation pollution, tourism, and economic development through the lens of the Environmental Kuznets Curve (EKC), particularly at the regional level, using New Zealand as a case study. We are the first to estimate aviation pollution at regional airports in New Zealand and use them as proxy for the regional pollution in an EKC setting. Our findings provide evidence of an EKC at New Zealand regions, indicating that tourism and economic development contribute to the long-term regional environment improvement. This highlights the necessity for environment policy to be tailored at a regional level, rather than solely at the national scale. Additionally, our research introduces a novel approach to EKC studies by incorporating new pollution estimations, which enhances the understanding of regional environmental dynamics. Among others, we discovered that that the sustainable tourism policy has, and will, work well in New Zealand. This study underscores the importance of considering regional factors in environmental policymaking and offers insights that could inform future strategies for balancing economic growth with environmental sustainability.

Keywords: environmental Kuznets curve (EKC), CO_2 emissions, aviation, economic development, tourism, New Zealand regions

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ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

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Загрязнения от авиации, туризм и экономическое развитие: исследование гипотезы экологической кривой Кузнеца на региональном уровне

Аннотация. Целью исследования является пересмотр взаимосвязи между загрязнениями от авиации, туризмом и экономическим развитием на региональном уровне. Гипотеза экологической кривой Кузнеца (ЭКК) была проверена на примере регионов Новой Зеландии. В статье впервые оценивается загрязнение от авиации в региональных аэропортах в Новой Зеландии; в условиях ЭКК этот показатель используется в качестве косвенных показателей регионального загрязнения. Результаты анализа показали существование экологической кривой Кузнеца на региональном уровне, указывая на то, что развитие туризма и экономики способствует улучшению окружающей среды в долгосрочной перспективе. Это означает, что политика в области охраны окружающей среды должна разрабатываться на региональном уровне, а не только на национальном. Предложенная методика оценки загрязнений предполагает новый подход к исследованиям ЭКК на уровне регионов. Проведенный анализ также подтвердил эффективность политики устойчивого туризма в Новой Зеландии. Результаты данного исследования подтверждают важность учета региональных факторов в экологической политике и могут быть использованы для разработки стратегий для обеспечения экономического роста и экологической устойчивости.

Ключевые слова: экологическая кривая Кузнеца, выбросы CO_2, авиация, экономическое развитие, туризм, регионы Новой Зеландии

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1. Introduction

It is widely accepted that there are some trade-offs between economic development and other aspects of well-being such as equality, welfare, and the environment. Among those theories, the environmental Kuznets curve (EKC) has become a popular approach applied in the field of environmental economics (Kaika & Zervas, 2013a, 2013b). The EKC hypothesises that the relationship (or trade-off) between economic growth (which is normally proxied by per capita income) and the environment (normally proxied by the per capita index of pollution in terms of CO_2 or SO_2 emissions) follows an inverted U-shape curve, suggesting that economic growth in the short term may damage the environment but, in the long term, it may improve the environment (Chow & Li, 2014; Al-Mulali et al., 2016). In its extended version, the EKC model also incorporates other variables or indicators regarding tourism, urbanisation, deforestation, energy consumption, technology, and total factor productivity (Friedl & Getzner, 2003; Baiardi, 2014; Liu et al., 2016). Empirical evidence supporting the EKC hypothesis has been found in the US (Aldy, 2005; Ongan et al., 2019), Europe (Lee & Brahmasrene, 2013; Katircioglu et al., 2014), Asia (Attari et al., 2016; Azam et al., 2018), Africa (Al-Mulali et al., 2016), and so on.

Countries often report the pollution data at an aggregated level. Hence, most previous studies on the EKC hypothesis used national data of income and pollution in their analysis (Mardani et al., 2019; Ghosh, 2020). Particularly, Friedl and Getzner (2003) argued that since time series data on CO_2 have only been available at the country level for many years, it would be more reasonable to conduct a time series analysis of CO_2 in the single-country EKC situation. In tandem, EKC studies on the regional level are still limited, mainly due to the regional data availability issue. A few exceptions are found for 20 Italian regions (Baiardi, 2014), various Chinese provinces and cities (Liu et al., 2016; Zhang & Gao, 2016), and 51 US states and federal districts (Ongan et al., 2019) where regional environmental data (e.g., CO_2 emissions) are publicly reported. A reasonable assumption is that if one can estimate the pollution/environmental data for regions, one can test for the EKC hypothesis at regional level.

Although the EKC relationship between tourism, economic development and environment has been well studied and proven in many countries (Paramati et al., 2017; Azam et al., 2018), it has not been examined in the New Zealand context, not to mention the role of aviation and tourism in New Zealand. It is acknowledged that tourism is "a key sector in the transformation of the New Zealand economy and contributes significantly to economic growth both nationally and regionally" (Tourism Strategy Group, 2009, p. viii) while the contributions of aviation to New Zealand's tourism and economic development have been shown in studies by Hakim and Merkert (2016), Alsumairi and Tsui (2017) and Tsui et al. (2019), among others. This study therefore aimed to revisit the EKC relationships among aviation pollution, tourism, and economic development at the regional level using New Zealand as a case study.

The contribution of this study to the literature is twofold. Firstly, to the best of our knowledge, this is the original study to estimate the level of pollution (CO_2 equivalent or CO_2e emissions)[1] resulting from aviation activities at regional airports in New Zealand. Since each region in New Zealand has its own airport (Ngo & Tsui, 2020), the airport's CO2e can represent the pollution created by the aviation industry in each region. In this sense, our study proposes a new approach for EKC studies at the regional level via such pollution estimation opening an important door for future studies in the field. Secondly, it is also the first study to test if the EKC hypothesis is still valid at the regional level in New Zealand. It therefore contributes to the limited number of EKC studies at the regional level. Practically, the findings of this study may help local/regional governments or councils in New Zealand in their decision-making processes regarding sustainable regional development with respect to aviation and tourism development as well as environmental sustainability. If the EKC hypothesis still holds in New Zealand regions, this would suggest that the development of regional aviation, tourism and economics would be sufficient to restore and protect the environment and, therefore, local/regional governments can justify speeding up their regional development.

The rest of the paper is organised as follows. Section 2 reviews the EKC literature, with a special focus on the relationships among tourism, economic development and CO_2 emissions in a single country setting and at the regional level. Section 3 describes the data and methodology used in this study, especially for estimating CO_2 emissions in New Zealand regions based on its aviation activities. The empirical results and relevant discussions are presented in Section 4. The last section summarises the key findings and discusses policy implications.

2. Review of EKC studies on economic development, the environment and tourism

The EKC hypothesis has been well examined in the literature (Kaika & Zervas, 2013a, 2013b; Mardani et al., 2019). Although most of the evidence supports the inverted U-shape relationship between economic growth and environment, there are cases where the EKC hypothesis has been rejected; therefore, additional evidence can still contribute to this debate. For the scope of our study, this section will focus on the literature that examines the EKC hypothesis involving tourism, economic development, and the environment. We show that EKC studies at the regional or provincial levels, however, are rather limited (Table 1).

Our summation from Table 1 is that two-thirds of the articles could statistically verify the EKC hypothesis between environment, tourism, and economic development. Notably, only two studies, namely those by Ng et al. (2016) and Bella (2018), examined the role of transportation (air and land) and its effect on tourism and the EKC relationship. In addition, nearly all EKC studies in Table 1 have used national data. Generally, panel data analysis was applied for cross-country settings, whereas time series analysis was applied for single-country settings. The only exception is Zhang and Gao (2016), who examined the EKC hypothesis in 30 Chinese regions via a panel dataset for the period of 1995–2011. Since there are differences in the development of regions within a country as well as differences in the contributions of each region to the national development, extensions and revisits of the 'conventional' EKC hypothesis under different circumstances, especially at the regional level and incorporating the role of air transportation, are therefore justified in this study.

3. Methodology and Data

3.1. Estimation of regional airports' CO_2e emissions

The environmental issues, especially greenhouse gas (GHG) emissions, have been discussed widely in the context of transportation

[1] CO_2e is the most common variable used in the EKC literature but is normally unavailable for regions, provinces, and metropolitan cities, unlike macroeconomic data. For example, Friedl and Getzner (2003) argued that CO_2 emissions are the main driving force behind the global warming issue and thus CO_2 is an important part of greenhouse gas (GHG) emissions. Erdogan et al. (2020) also stated that the aviation sector is the second largest contributor to GHG emission.

Table 1

EKC studies on the inter-relationship between economic development, environment, and tourism

Authors (Year)	Sample	Data type	EKC variables			EKC effect
			Economic development	**Environment**	**Tourism**	
Lee and Brahmasrene (2013)	27 European countries	Panel	Gross domestic product (GDP) per capita	CO_2	Tourism receipts	Yes
Katircioğlu (2014)	Singapore	Time series	GDP per capita	CO_2	Tourist arrivals	Yes
de Vita et al. (2015)	Turkey	Time series	GDP per capita	CO_2	Tourist arrivals	Yes
Jebli (2016)	Tunisia	Time series	GDP per capita	CO_2	Rail passengers	Yes
Leitão and Shahbaz (2016)	27 European countries	Panel	GDP per capita	CO_2	Tourist arrivals	Yes
Malik et al. (2016)	Austria	Time series	GDP per capita	CO_2	Tourist arrivals	Yes
Ng et al. (2016)	Malaysia	Time series	GDP per capita	CO_2T	Tourist arrivals	No
Zaman et al. (2016)	34 European countries	Panel	GDP per capita	CO_2	Tourism index	Yes
Zhang and Gao (2016)	30 Chinese regions	Panel	GDP per capita	CO_2	Tourism receipts	Yes
Dogan et al. (2017)	27 European countries	Panel	GDP per capita	CO_2	Tourist arrivals	No
Naradda Gamage et al. (2017)	Sri Lanka	Time series	GDP per capita	CO_2	Tourism receipts	No
Paramati et al. (2017)	44 countries	Panel	GDP per capita	CO_2	Tourism receipts	No
Qureshi et al. (2017)	37 tourism countries	Panel	GDP per capita	CO_2	Tourist arrivals, Tourist departures, Tourism receipts, Tourism expenditure	Yes
Shakouri et al. (2017)	12 Asia-Pacific countries	Panel	GDP per capita	CO_2	Tourist arrivals	Yes
Sherafatian-Jahromi et al. (2017)	5 Southeast Asia countries	Panel	GDP per capita	CO_2	Tourist arrivals	Yes
Azam et al. (2018)	Malaysia, Singapore, Thailand	Time series	GDP per capita	CO_2	Tourist arrivals	Yes
Bella (2018)	France	Time series	GDP per capita	CO_2T	Tourist arrivals	Yes
Danish and Wang (2018)	BRICS countries	Panel	GDP per capita	CO_2	Tourism receipts	Yes
Wang and Wang (2018)	35 OECD countries	Panel	GDP per capita	CO_2	Tourist arrivals	No
Ahmad et al. (2019)	Indonesia, Philippines, Vietnam	Time series	GDP per capita	CO_2	Tourist arrivals	Yes
Akadiri, Akadiri, et al. (2019)	7 small islands	Panel	GDP per capita	CO_2	Tourist arrivals	Yes
Akadiri, Lasisi, et al. (2019)	15 tourism countries	Panel	GDP per capita	CO_2	Tourist arrivals	Yes
Sghaier et al. (2019)	Egypt, Morocco, Tunisia	Time series	GDP per capita	CO_2	Tourist arrivals	Yes
Zhang and Liu (2019)	10 East Asian countries	Panel	GDP per capita	CO_2	Tourist arrivals	No
Chan and Wong (2020)	30 Chinese provinces	Panel	Regional GDP per capita	CO_2	Tourist arrivals, tourism revenue	Yes
Ghosh (2020)	95 countries	Panel	GDP per capita	CO_2	Tourist arrivals	Yes
Sharif et al. (2020)	Malaysia	Time series	GDP	CO_2	Tourist arrivals	Yes

Notes: CO_2 denotes the overall CO_2 emissions; CO_2T denotes the CO_2 emissions generated from transport (The World Bank, 2020); BRICS: Brazil, Russia, India, China and South Africa.

and aviation, but much of the focus has been on airlines and their aircraft operations, and not on airports. According to Masiol and Harrison (2014), aircraft emissions have been extensively studied since the late 1960s but airport emissions have been increasingly considered only in the recent years. Nevertheless, it is believed that the rapid growth of air transport and emissions from airport activities (both airside and landside) significantly affect air quality of the airport's neighbourhood (Song & Shon, 2012; Postorino & Mantecchini, 2014). Because modern aircraft and engines are technically designed for high performance while cruising at high attitudes, most aircraft emissions are generated on the ground/tarmac as well as during the landing and take-off (LTO) cycle (ICAO, 2011; European Environment Agency, 2019). Although aircraft emissions at cruising altitudes are linked to the global air pollution issue, their LTO emissions are more localised and their direct impacts on the airport's neighbourhood are more apparent (Song & Shon, 2012).

There are several methods for estimating airport emissions generated by aircraft operations (Federal Aviation Administration, 2007; ICAO, 2011; Environmental Protection Agency, 2013; European Environment Agency, 2019). These methods are all based on the aircraft emissions generated during the LTO cycle, in combination with other emissions from various sources such as auxiliary power units, ground support equipment, airside and landside vehicles, and so on. To keep this paper consistent with previous studies in the New Zealand context, we follow the methods of DEFRA (2008), Smith and Rodger (2009), and the New Zealand Ministry for the Environment (2019) to estimate the CO_2 emissions of New Zealand's regional airports, then applies a radiative forcing index (RFI) of 1.9 to transform those emissions into CO_2e (for more details, please check the above references). To be specific, the CO_2e emissions generated by a flight between two New Zealand domestic airports can be estimated by Equation (1):

$$CO_2 = EI \cdot GCD \quad (1)$$

where represents the RFI-accounted emissions index of a flight (which is associated with the aircraft type and size involved) and represents the great circle distance of a flight (in kilometres) between two airports. Note that the generation of CO_2e in Equation (1) involves both the origin airport (the take-off phase) and the destination airport (the landing phase). In New Zealand's domestic aviation market, the longest flight is between Auckland and Invercargill airports, which is approximately 1 173 km (a two hours flight by a jet aircraft); therefore, it is reasonable to assume that the LTO cycles account for most flight emissions and the values of CO_2e can be split into 50 percent for the origin and 50 percent for the destination airport (Aviation Environment Federation, 2006). Unfortunately, we do not have the information on the load factor of each flight, and the application of an (estimated) average loading factor for all flights will be consistent to the figures reported in this study. We leave this issue for future research and only use the data without the load factor in this study.

According to the New Zealand Ministry for the Environment (2019), nine aircraft types operate in New Zealand's domestic aviation market, which generate different amounts of per-passenger per-flight CO_2e, ranging from 0.072kg for an Airbus A320 to 0.552kg for a Cessna aircraft. For other types of aircraft, this study follows the recommendations of the New Zealand Ministry for the Environment (2019) and uses the national average emissions index (EI) of 0.130kg CO_2e per-tpassenger per-flight. Table 2 presents the per-passenger per-flight EI values of different aircraft types with and without the RFI adjustment. The New Zealand Ministry for the Environment (2019) also divided aircraft into three categories depending on their sizes: big aircrafts with more than 70 seats, medium aircrafts with 50 to 70 seats, and small aircrafts with less than 50 seats (see Table 2). This study, therefore, applies both approaches in estimating the airport emissions of New Zealand's regional airports to strengthen the robustness of our CO_2e estimations.

3.2. Testing the EKC hypothesis at the regional level

Once the data of the CO2e emissions of regional airports had been estimated, the next step was to test the EKC hypothesis for the sampled New Zealand regions using Equation (2), following Chan and Wong (2020) and Sharif et al. (2020), among others:

$$CO_2e_{it} = \alpha_{0i} + \alpha_{1i}GDP_{it} + \alpha_{2i}GDP^2_{it} + \alpha_{3i}TOUR_{it} + \varepsilon_{it} \quad (2)$$

where represents the CO_2e emissions of region in year , represents real gross domestic product per capita of region in year (with 2010 as the base year), is the squared term of , and measures the total number of visitor arrivals to region in year . To account for the differences in the scales and units of the variables (see Table 3 below), all variables were transformed into their logarithmic form. It was expected for the coefficient signs of and to be statistically positive and statistically negative, respectively, since the former variable represents

Table 2

Per-passenger per-flight emissions index (EI) for aircraft operating in New Zealand's domestic aviation market

	EI without radiative forcing (kg CO_2e)	EI with radiative forcing (kg CO_2e)
Aircraft types		
Airbus A320	0.038	0.072
Aerospatiale/Alenia ATR 72	0.039	0.074
British Aerospace Jetstream 32	0.125	0.237
Beechcraft Beech 1900D	0.098	0.186
Cessna light aircraft	0.291	0.552
De Havilland Canada DHC-8-300 Dash 8/8Q	0.075	0.143
Pilatus PC-12	0.099	0.188
Saab SF-340	0.051	0.097
Fokker F50	0.048	0.091
Others (national average)	0.069	0.130
Aircraft sizes		
Big (>70 seats)	0.072	0.134
Medium (50–70 seats)	0.114	0.213
Small (<50 seats)	0.353	0.659

Source: The calculations are based on the New Zealand Ministry for the Environment (2019).

Table 3

Descriptive statistics of the variables (2008–2019)

Regions	FLIGHT		SEAT		GDP		TOUR	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Auckland	48 346.88	2 592.45	4 395 602.67	814 307.81	52 597.42	5 117.13	3 222 129.42	387 539.36
Bay of Plenty	8 797.21	854.27	376 591.46	52 493.44	40 162.54	3 616.47	1 953 175.25	187 483.99
Canterbury	31 273.04	621.35	2 847 490.58	216 466.22	47 511.76	4 224.61	2 817 205.17	344 736.45
Gisborne	3 084.96	751.31	97 983.42	11 074.21	33 252.21	2 561.76	163 826.25	9 229.29
Hawke's Bay	6 207.04	797.16	342 112.38	64 100.28	38 605.90	2 813.85	597 344.42	53 036.98
Manawatu-Wanganui	7 571.83	607.97	365 153.04	45 898.38	36 923.43	1 934.05	638 015.00	57 552.05
Marlborough	6 078.50	590.25	157 547.08	28 607.02	49 117.65	5 235.12	390 000.08	32 447.63
Northland	4 142.79	1 257.07	124 975.33	10 902.43	33 286.31	2 199.00	775 858.17	76 691.96
Otago	9 990.79	832.98	1 135 313.08	253 764.37	44 110.60	3 535.86	2 405 736.83	325 600.13
Southland	2 924.92	105.65	177 268.67	7 570.41	49 965.97	2 679.73	240 123.33	21 851.00
Taranaki	4 515.13	351.43	240 416.08	30 204.77	71 247.50	6 887.86	275 797.83	22 148.91
Tasman/Nelson	10 852.75	2 232.32	523 290.71	93 669.45	39 774.55	2 674.47	565 710.42	46 382.55
Waikato	6 165.38	810.02	258 128.17	20 066.42	42 942.39	2 342.78	1 211 685.67	123 322.10
Wellington	38 208.63	1 794.56	2 988 144.46	274 492.59	59 804.69	3 230.46	1 297 755.67	86 679.03
West Coast	1 753.75	261.03	38 420.63	2 401.50	45 853.91	2 328.23	860 460.67	103 926.40
National measures	29 699.94	44 542.10	2 788 379.51	5 350 885.23	45 677.12	10 427.34	1 160 988.28	966 634.88

Notes: FLIGHT represents the total scheduled flights to and from a region's airport; SEAT represents the total scheduled airline seats to and from a region's airport; GDP measures gross domestic product per capita of a region at the 2010 constant price (in NZD); TOUR measures the total number of visitor arrivals to a region (in persons); SD stands for standard deviation.

a short-run while the latter represents a long-run relationship between economic development and environmental pollution i. e., the EKC hypothesis (Lee & Brahmasrene, 2013; Chow & Li, 2014). It is noted that other factors such as oil prices, technology development, and renewable energy can also play some roles in the EKC analysis (Chen et al., 2021; Ngo et al., 2022); however, we only focus on the two key factors of GDP and TOUR that impact the environment (CO2), assuming that all other factors are accounted for in the error term .

Following Attari et al. (2016), Al-Mulali et al. (2016) and Sharif et al. (2020), among others, Equation (2) was estimated using the panel autoregressive distributed lag (ARDL) (Pesaran & Shin, 1999) instead of the generalised method of moments (GMM) approach. The ARDL estimates the short-run and long-run components of the model simultaneously and therefore is more efficient than the GMM approach in providing unbiased estimates for the long-run model (Attari et al., 2016; Ng et al., 2016). It is also noted that a cause-effect relationship between aviation pollution, tourism, and economic development may exist within the EKC setting; however, we could not examine it using the ARDL approach. We thus leave this task for future studies. The error correction model (ECM) incorporating the panel ARDL(p, q) estimation of Equation (2) can also be established as:

$$\Delta CO_2e_{it} = \beta_{0i} + \varnothing_i \left(CO_2e_{i(t-1)} - \theta_1 GDP_{it} - \theta_2 GDP_{it}^2 - \theta_3 TOUR_{it} \right) + \\ + \sum_{j=1}^{p-1} \beta_{1i} \Delta GDP_{i(t-j)} + \sum_{j=1}^{q-1} \beta_{2i} \Delta GDP_{i(t-j)}^2 + \sum_{j=1}^{q-1} \beta_{3i} \Delta TOUR_{i(t-j)} + \varepsilon_{it} \quad (3)$$

where is the first differencing operator, measures the speed of adjustment, represents the vector of the short-run coefficients and represents the vector of the long-run coefficients of the variables of interest. Note that is expected to be significantly negative because the ECM will push the CO_2e emissions back towards equilibrium in the long run.

If the EKC relationship exists, one can further identify the ‘turning point’ for each New Zealand region where the regional CO_2e emissions reached its highest level and started to drop as the regional economy develops further. This may help local/regional governments to understand their economic situations (e.g., where are they on the EKC) and can make developmental policies accordingly. Based on Equation (2), the turning point for a region can be estimated using Equation (4):

$$GDP_i^{TURN} = -\frac{\alpha_{1i}}{2 \cdot \alpha_{2i}} \quad (4)$$

where measures the value of *GDP* per capita of region *i* at the maximum point of its inverted U-shape curve.

3.3. Data on New Zealand regions

This study collects and analyses the annual data on 15 New Zealand regions which is a balanced panel data consisting of their respective CO_2e emissions, GDP per capita and tourist arrivals. The first variable was estimated using scheduled flight data retrieved from the Official Airline Guide (2022) for the period of 2008–2019 — data after 2019 were not included to avoid the disruptions from the COVID-19 pandemic. The latter two variables were collected from Statistics New Zealand (2020). Table 3 presents the descriptive statistics of the variables of interest used in this study where, on average, New Zealand regions catered to approximately 3.4 million visitors annually; New Zealand airports also served by approximately 940,000 scheduled airline seats and 13,000 scheduled domestic flights annually. Among all the regions, Canterbury and Otago were the most attractive tourist destinations in New Zealand, whilst West Coast was the least busy region.

4. Empirical Results and Discussion

4.1. CO_2e generated by air transportation in New Zealand regions

Estimations of Equation (1) that used the two different emissions indexes (EI) (see Table 2) yielded consistent results at the national level (with the Spearman’s rank correlation value of 0.997) with the CO2e emissions estimated by aircraft types are slightly higher than those estimated by aircraft sizes (statistically significant at the 1 percent level). Nevertheless, there was a significant increase in CO_2e emissions generated by air transportation, with the CO_2e emissions generated in 2019 being about 30 percent higher than the 2008 figures (see Figure 1).

Figure 2 provides a closer look at the regional level where the contributions of air transportation in Auckland, Otago, and Canterbury to the national GHG emissions are the highest among the sampled regions (this difference is statistically significant at the 1 percent level). For example, the amount of CO_2e emissions in Auckland increased from approximately 300,000 tonnes in 2008 to 500,000 tonnes in 2019, equalling a 1.5-fold increase. In contrast, smaller regions such as Northland and Gisborne showed improvements regarding their CO_2e emissions from air transportation.

4.2. The EKC relationship in New Zealand regions

The unit root test results from the tests of Im et al. (2003) (IPS), Levin et al. (2002) (LLC), and Maddala and Wu (1999) (Fisher-ADF and Fisher-PP) show that the variables have both stationary and non-stationary characteristics: and are stationary while , and and are not (see Table 4). Table 5 reports the results of the Kao (1999) test, the Pedroni (1999) test and the Westerlund (2005) test for cointegration between the dependent variables (i. e. and) and the three explanatory variables

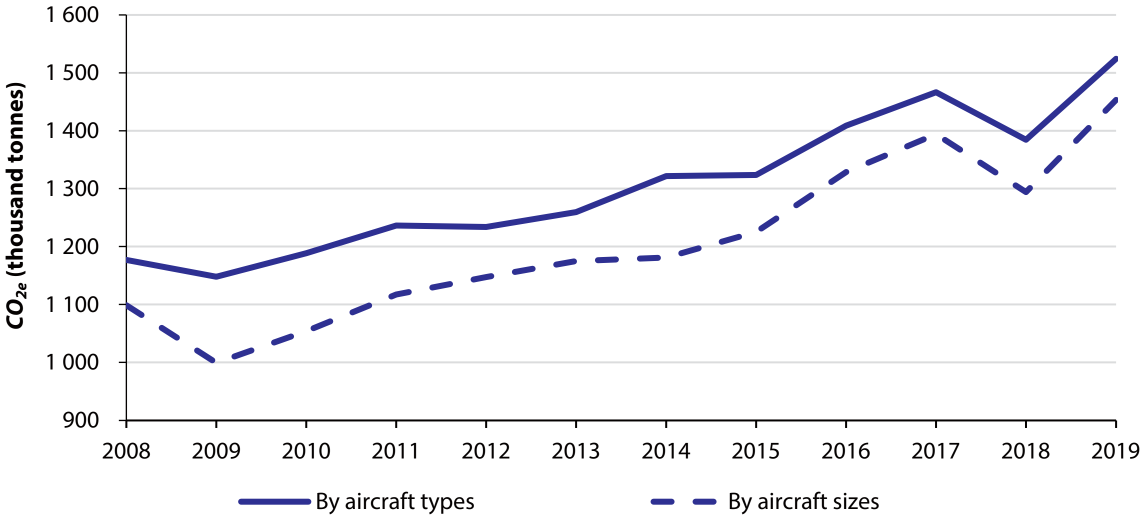

Fig. 1. *CO_2e generated by air transport in New Zealand (2008–2019)*

(i. e. , and) of Equation (2). These cointegration results verify that there is a long-run relationship among CO2e emissions, economic development, and tourism in New Zealand regions, and thus the panel ARDL analysis approach is justified.

It is noted that the panel ARDL model in Equation (3) can be estimated using four estimators: (i) the mean group (MG) estimators (Pesaran & Smith, 1995), (ii) the pooled mean group (PMG) estimators (Pesaran et al., 1999), (iii) the cross-section augmented distributed lag (CS-DL) estimators, or (iv) the cross-section augmented ARDL (CS-ARDL) estimators (Chudik et al., 2013, 2016). Chudik et al. (2013, 2016) pointed out that the CS-DL and CS-ARDL methods outperform the other two methods in cases of small or micro panel dataset, which is similar to our study. We therefore use the Hausman (1978) test to compare the results between those four estimators and concluded that the CS-ARDL estimator for the case of as the dependent variable is the most robust and efficient one. Such results are consequently used in our following analyses.

As reported in Table 6, in the short run, only regional tourism growth has a significant and negative impact on the regional CO_2e emission growth (i. e., regional air transportation emissions), suggesting that short-run development of tourism may improve the environment in New Zealand regions. In the long run, the impact of regional tourism activity on regional CO_2e emissions as well as the EKC relationship for New Zealand regions is further strengthen, 1 with the statistically significant coefficients for , and , respectively. It means that regional CO_2e emissions declined (i. e., reduction in air transportation emissions) as regional economy (i. e., regional GDP per capita) developed and tourism activities (i. e., tourist arrivals) increased. As expected, the speed of adjustment () was reported to be significantly negative, which, showing the long-run convergence among the variables, could be sped up by 53 percent per year. It suggests that any deviation from the long-run equilibrium will converge back to the equilibrium within 2 years.

Since the EKC relationship at New Zealand regions has been proven, Equation (4) is justified. Table 7 reports the turning points (∅) of the regions regarding the inverted U-shape EKC. For example, the for Auckland is NZD66,326 which was achieved in 2018: GDP per capita of Auckland region in 2017, 2018 and 2019 were NZD64,278, NZD67,570 and NZD69,974, respectively. Accordingly, the last column of Table 7 suggests that all the sampled regions are on the right side of their EKC curves, meaning that New Zealand regions are now experiencing a negative relationship between economic development and CO_2e emissions. It suggests that if New Zealand regions can continue to increase their economic development and GDP per capita, they can also keep reducing their environmental pollution.

5. Conclusions and Policy Implications

This study estimated the level of CO_2e emissions generated from aviation activities at regional airports in New Zealand and used them to test for the EKC relationship among tourism, economic development, and aviation environmental quality in New Zealand regions for the period of 2008–2019. Using the panel ARDL approach, we found evidence that the EKC exists at

[1] However, the short-run EKC relationship between regional economic development and air transportation emissions is not significant.

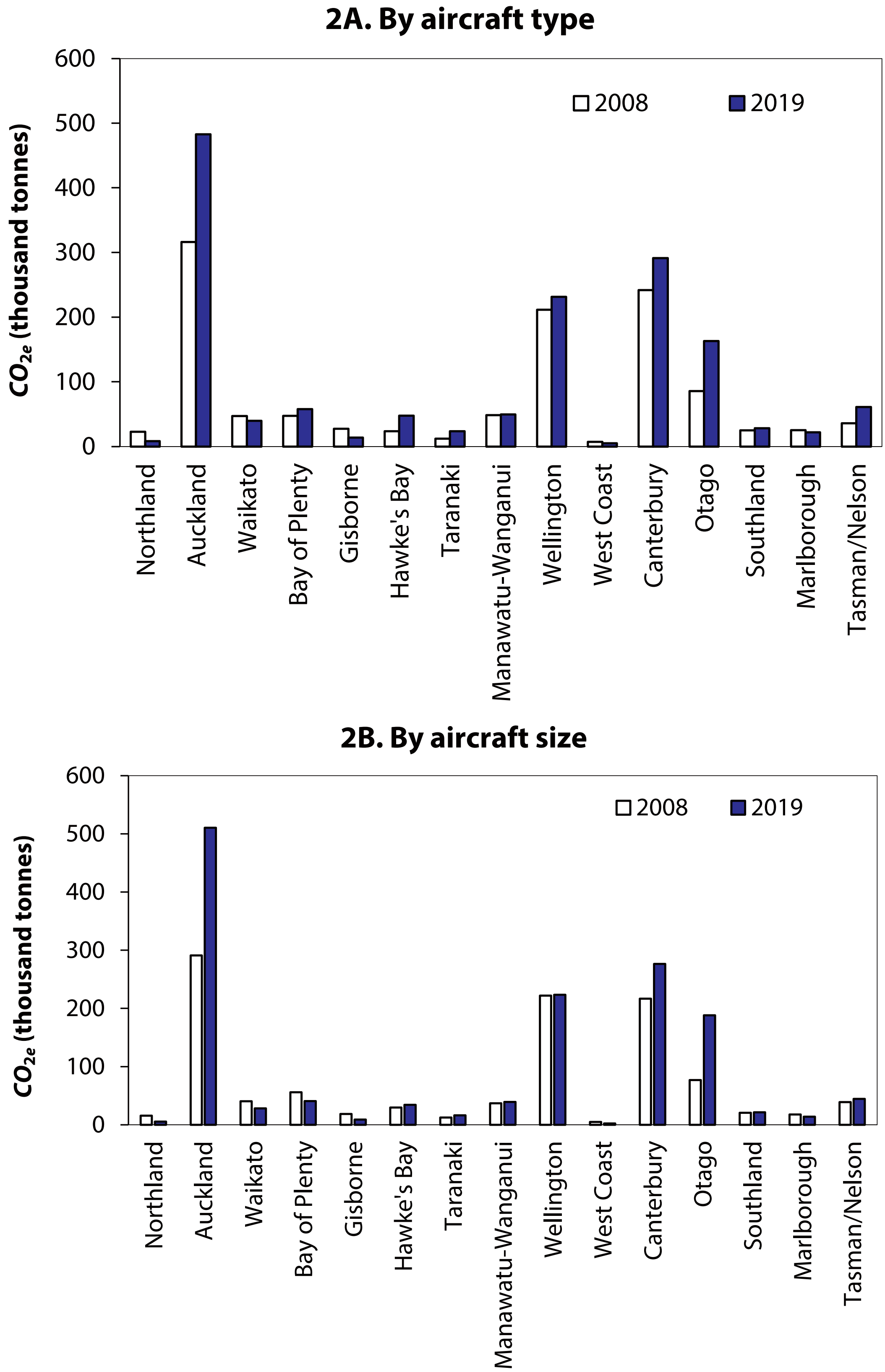

Fig. 2. *CO2e emissions generated by air transportation in different New Zealand regions (2008 vs. 2019)*

(New Zealand) regional level, whereas tourism and economic development help improve the regional environment in the long run. Methodologically, this study opens a new door for further EKC analyses at the regional level. Practically, our results suggest that the sustainable tourism policy, which was implemented since the 2010s (Tourism Strategy Group, 2009), has been and

Table 4

Panel unit root tests of the variables of interest

Variables	IPS		LLC		Fisher–ADF		Fisher–PP	
	Trend	No trend	Trend	No trend	Trend	No trend	Trend	No trend
				Tests at levels				
CO_2e_T	–3.16***	1.43	–2.75***	–3.51***	53.30***	47.93**	60.08***	46.66**
CO_2e_S	–3.99***	–0.05	–2.25**	–0.83	122.39***	126.89***	109.53***	111.46***
GDP	–1.22	8.29	–6.27***	5.51	26.94	5.91	28.68	6.08
GDP^2	–1.17	8.35	–6.23***	5.56	26.53	5.87	28.27	6.05
TOUR	0.61	–0.99	4.35	–4.39***	6.37	25.03	6.54	25.76
				Tests at first differences				
CO_2e_T	–5.07***	–5.08***	–4.60***	–5.08***	97.60***	136.99***	101.66***	146.22***
CO_2e_S	–4.75***	–5.47***	–2.31**	–2.097**	179.65***	242.92***	212.49***	256.29***
GDP	–5.53***	–4.61***	–4.87***	–5.07***	160.10***	126.43***	182.49***	128.45***
GDP^z	–5.53***	–4.59***	–4.87***	–5.03***	125.28***	159.78***	182.19***	127.23***
TOUR	–3.27***	–2.75***	–3.09***	–3.97***	58.73***	71.42***	69.27***	79.73***

Notes: measures the regional CO_{2e} emissions estimated by different aircraft types; measures the regional CO_{2e} emissions estimated by different aircraft sizes; measures the regional *GDP* per capita; is the squared measure of; measures the regional tourist arrivals; IPS stands for the Im-Pesaran-Shin test (Im et al., 2003); LLC stands for the Levin–Lin–Chu test (Levin et al., 2002); Fisher-ADF and Fisher-PP are the Maddala and Wu (1999) tests; *** and ** denote rejection of the null hypothesis of a unit root at the significance levels of 1 % and 5 %, respectively. All variables are in logarithmic form.

Table 5

Cointegration tests for Equation (2)

Dependent variable	CO_2e_T			CO_2e_S		
	t-statistic		*p-value*	*t-statistic*		*p-value*
Kao test						
Modified Dickey–Fuller	2.30	**	0.0108	1.76	**	0.0389
Dickey–Fuller	1.91	**	0.0278	1.21	**	0.1121
Augmented Dickey–Fuller	0.96		0.1700	1.00		0.1588
Unadjusted modified Dickey–Fuller	1.91	**	0.0283	1.71	**	0.0434
Unadjusted Dickey–Fuller	1.38	*	0.0833	1.16		0.1239
Pedroni test						
Modified Phillips–Perron	3.61	***	0.0002	3.33	***	0.0004
Phillips–Perron	–6.08	***	0.0000	9.75	***	0.0000
Augmented Dickey–Fuller	–3.54	***	0.0002	2.03	**	0.0209
Westerlund test						
Variance ratio	1.64	*	0.0507	1.41	*	0.0785

Notes: is the regional CO_2e emissions estimated by different aircraft types; is the regional CO_2e emissions estimated by different aircraft sizes; ***, ** and * denote the rejection of the null hypothesis of no cointegration at the 1 %, 5 % and 10 % levels of significance, respectively.

will be working well in New Zealand. Given that all New Zealand regions are enjoying the positive effects of tourism and economic development on the environment, local/regional governments can confidently speed up their regional developments without worrying much about their environmental impacts.

Several key findings can be discussed further as they may have policy implications for stakeholders and policymakers in New Zealand.

(i) As the (aviation) CO_2e emissions differed among regions, regional environment protection policies need to be tailored to each region, particularly to comprehend the regional air

Table 6

Panel ARDL results for the EKC hypothesis at New Zealand regions

Dependent variable: CO_2e_T	MG		PMG		CS-DL		CS-ARDL	
	Coefficient	***p-value***	**Coefficient**	***p-value***	**Coefficient**	***p-value***	**Coefficient**	***p-value***
Long-run estimation								
GDP	16.28	0.352	13.79	0.373	10032.8	0.280	641.16*	0.082
GDP^2	–1.18	0.287	–1.14	0.352	–480.1	0.282	–29.81*	0.085
TOUR	–1.58	0.750	0.056	0.985	–26.68	0.344	–1.19**	0.023
Speed of adjustment								
∅	–0.69***	0.000	0.02	0.995	–0.82***	0.003	–0.53***	0.000
Short-run estimation								
ΔGDP	194.12	0.208	152.85**	0.026	66.87	0.764	43.97	0.594
ΔGDP^2	–9.24	0.205	–7.16**	0.025	–3.21	0.761	–1.95	0.617
$\Delta TOUR$	–0.47**	0.011	–0.19**	0.014	–0.7*	0.085	–0.15*	0.074
Model statistics								
Observations	150		150		165		165	
F-statistic	1.29		1.54		1.27		10.66	
p-value	0.17		0.03		0.18		0.00	

Notes: MG represents the mean group estimators; PMG represents the pooled mean group estimators; CS-DL represents the cross-section augmented distributed-lag estimators; CS-ARDL represents the cross-section augmented ARDL estimators; represents the regional CO_2e estimated by different aircraft types; measures the growth rate; ∅ measures the speed of adjustment; ***, ** and * denote the significance levels of 1 %, 5 % and 10 %, respectively.

transportation policies (e.g., aviation subsidies). On the other hand, the trade-off between economic and tourism development and environmental degradation needs to be carefully considered. For instance, large regions such as Auckland and Canterbury are the country's most populous places; however, aviation activities also contributed immensely to the regional and even national tourism and economic development in New Zealand. This requires policymakers to 'striking the right balance' between the issues of tourism/economic development and environmental degradation, particularly regarding the short – and long-run effects of the two (Erdogan et al., 2020). Policies that promote clean and environmentally friendly energy sources for airline and airport operations (e.g., biofuel and all-electric aircraft tow tractors) should be also considered.

(ii) Since tourism development is found to have a negative relationship with the regional environment degradation in both the short – and long-run, it implies that the New Zealand 'sustainable tourism policy' (Tourism Industry Aotearoa, 2019) has been working well over the years. This finding should be of considerable value to New Zealand's policymakers, particularly for regions which are facing the policy dilemma of stimulating economic development via tourism-lead growth while ensuring improvements in environment sustainability and protection. When compared with other cases in European countries where similar sustainable tourism policies exist (Lee & Brahmasrene, 2013; Katircioglu et al., 2014), this study strengthens the debate that New Zealand's sustainable tourism policy is a robust policy promoting sustainable (tourism and economic) development across New Zealand regions.

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