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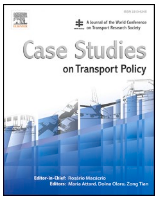

Gravity models of airfreight exports during the pre-COVID era: Evidence from New Zealand

Kan Wai Hong Tsui [*], Huan Wang, Yan Liu

School of Business, University of Southern Queensland, Toowoomba, Queensland, Australia

A R T I C L E I N F O

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A B S T R A C T

This study examines key determinants of New Zealand's airfreight exports to its key overseas trading partners by empirically estimating augmented gravity models using panel from 2015 to 2018. Consistent estimation results were obtained from static panel-IV gravity model and dynamic panel data GMM mode specifications. The estimation results confirm that GDP per capita and population size of New Zealand's key trading partners have positive impacts on the gross weight and value of airfreight exports. Scheduled air cargo capacity had limited positive effects on airfreight export weight and value. Alongside findings that the gross weight of airfreight exports was sensitive to transport costs, and the gross value of airfreight exports were sensitive to flying distance and exchange rate, respectively. Dynamic model specifications further suggest persistent trading patterns in airfreight exports. Overall, our analysis suggests that in order to further grow the airfreight export sector in New Zealand, it is important to increase air cargo capacity and reduce transport costs in a sustainable manner, especially at existing hub airports in New Zealand that providing services to both passenger aircraft and freighters. Major aviation and trade liberalisation efforts are called for in facilitating New Zealand's airfreight exports and air cargo operations.

1. Introduction

Air cargo services are of critical importance to the aviation industry and also play vital roles in international trade and supply chains (Global Shippers' Forum, 2015; Gong et al., 2018). In terms of value, airfreight accounts for approximately 35 % of global trade (Shepherd et al., 2016). However, airfreight has been considered as secondary to passenger transport (Merkert et al., 2017), with relatively few studies dedicated to air cargo (Irandu, 2019; Zhang & Zhang, 2002). This is changing, as interest by governments, policymakers and aviation researchers has been growing, partly because of the rapid growth of airfreight even amid the COVID-19 pandemic (Czerny et al., 2021) and because of the increasing importance of airfreight services on the economic growth of a country (e.g., Chang & Ying, 2008; Tan & Tsui, 2017; Yeung et al., 2010; Zhang & Zhang, 2002). It is widely recognised that if a product has a high value and a short lifetime and is time-sensitive (e.g., perishable commodities), manufacturers and exporters prefer to choose air transport to export their goods and products to their final destinations (Alexander & Merkert, 2020; Grosso & Shepherd, 2011; Kristjánsdóttir, 2005).

In the context of New Zealand, as an island country, air transport has become one of the key transportation modes for exporting high-value, perishable and time-sensitive goods overseas (Ministry of Transport, 2016). New Zealand exports goods and products to almost any point on the globe with its extensive flight connectivity. Importantly, maritime transport is typically not an ideal substitute for faster air transport as it arrives destination markets much slower (Hummels & Schaur, 2012) and, therefore, it is important to analyse New Zealand's airfreight export sectors. Prior to COVID-19, airfreight exports is a crucial part of New Zealand's international trade and total exports, accounting for NZ $7531.02 million and NZ$10,017.63 million in 2015 and 2018, respectively, or approximately 16.09 % and 18.14 % of the gross value of exports during the same years (Ministry for Primary Industries, 2020; Statistics New Zealand, 2019a, 2019b). Despite airfreight's growing importance in New Zealand's international trade, relatively little is known beyond the report released by the New Zealand Ministry of Transport in 2016 (Ministry of Transport, 2016).

In addition, it is widely recognised in the literature that the demand for air cargo is a derived demand (Kupfer et al., 2017). However, key important issues related to New Zealand's airfreight export sector

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* Corresponding author.
E-mail addresses: kan.tsui@unisq.edu.au (K.W. Hong Tsui), brook.wang@unisq.edu.au (H. Wang), liuyan896@gmail.com (Y. Liu).

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remain to be identified, for example, what are the characteristics and trends of airfreight exports in New Zealand during the pre-COVID-19 pandemic? How was New Zealand's airfreight related to its economy during the pre-COVID-19 pandemic? What are key determinants and drivers of New Zealand's airfreight exports? Considering the perspectives of aviation and business literature, despite the growing importance of airfreight exports and international trade to New Zealand's economy, few published international air cargo studies related to New Zealand have been carried out in recent years – especially applying the gravity model to investigate New Zealand's airfreight exports and international trade (Chang & Ying, 2008; Genç & Law, 2014; Tsui et al., 2018). This study aims to complement existing studies by empirically investigating the determinants and drivers of airfreight exports in New Zealand. Specifically, we provided: (i) a detailed discussion on the characteristics and trends of airfreight exports of New Zealand; (ii) analysed whether the availability of air cargo capacity has significant positive effects on New Zealand's airfreight exports or if it is simply a 'by-product' of passenger services that brings marginal revenues; and (iii) whether New Zealand's bilateral trade agreements have a strong impact on airfreight exports.

Examining of these issues is important in view of the growing importance of airfreight exports to New Zealand's economy and the establishment of more trade treaties between New Zealand and its key trading partners. There are several important empirical findings to highlight: (i) gross domestic product (GDP) per capital and population size of New Zealand's trading partners increased its airfreight exports (weight and value) to those markets; (ii) Scheduled air cargo capacity only played a limited effect on New Zealand's airfreight exports (weight and value) to its trading partners; (iii) New Zealand's airfreight export weight were sensitive to transport costs; and (iv) airfreight export value from New Zealand impacted by flying distance and exchange rate between New Zealand and its trading partners. These empirical findings will help identify the relationships among airfreight exports, air cargo capacity and the trade openness of New Zealand, allowing the New Zealand government, airlines, and air cargo operators to understand the effects of trading agreements on airfreight export volumes and economic development, and to evaluate the roles played by air cargo transport in New Zealand's exports and economy.

In addition to providing robust understanding for a specific market's airfreight export sector applying the gravity methodology, our study also contributes to the general literature on air cargo and trade. As mentioned above, the demand for international air cargo is a derived demand (Kupfer et al., 2017), but has complex relationships between the economies and aviation policies. Also, it is quite challenging to identify the interactive relationships between air cargo transportation and other factors, including the roles played by different transport modes such as maritime and land transport (Fu et al., 2020). Given New Zealand's geographical isolation from the world, inter-modal substitution is not a critical issue for its international airfreight exports, and thus facilitates econometric identification – we will have more confidence in separating and accurately identifying the determinants and drivers of New Zealand's airfreight exports.

This paper is organised as follows. Section 2 provides a brief overview of New Zealand's airfreight exports during the pre-COVID-19 pandemic. Section 3 offers a review of studies that applied the gravity model to analyse airfreight exports. Section 4 describes the methodology of the augmented gravity model and the data used. Section 4 presents the key empirical results. Section 6 discusses policy implications of our study's key findings. Conclusions and future research directions are reported in the last section.

2. Overview of New Zealand's airfreight exports

This section provides an overview of New Zealand's international airfreight markets, notably the performance and characteristics of airfreight exports.

- *Value and weight of airfreight exported from New Zealand*

Airfreight is carried by a mixture of dedicated freighters and the belly-hold compartments of passenger aircraft (Merkert et al., 2017; Reis & Silva, 2016; Zhang & Zhang, 2002). Air cargo capacity usually refers to cargo space in units of tonnes, comprising the space in the belly of passenger flights, airfreight integrators, and dedicated freighters. The air cargo capacity of one route, in this study, includes the cargo space of a scheduled flight on a one-way origin and destination pair (Feng et al., 2015; Official Airline Guide, 2020). In the New Zealand context, passenger aircraft carry the majority of airfreight, but passengers and their baggage typically have the highest priority and, therefore, airfreight can only use the 'extra' capacity not required by passengers (Ministry of Transport, 2016). However, a growing number of network airlines, which used to focus primarily on passenger traffic, have started to offer dedicated wide-body freighters in the New Zealand's aviation market, such as EVA Air, Emirates, Qatar Airways, and Singapore Airlines, as well as airfreight integrators or express carriers (e.g., UPS, DHL, FedEx, TNT, etc.).

Fig. 1 summarises the value and weight of airfreight exported from New Zealand during a period of 2011–2018. The export value, as measured by the free on board (FOB) value, increased from NZ $8,080.23 million in 2011 to NZ$10,017.63 million in 2018, corresponding to a compound annual growth rate (CAGR) of 3.12 % for the period. Total airfreight export weight also experienced steady growth, although its CAGR figure was only 1.82 %, increasing from101,446 tonnes in 2001 to 115,109 tonnes in 2018. The relatively low CAGR could have been partly ascribed to the disruptions caused by the major Christchurch earthquakes in 2011 and a severe drought in 2013, which reduced the country's quarterly economic growth from 3.3 % in December 2011 to 0.3 % in June 2013. During the same period, airfreight export value retained a stable share of New Zealand's total exports, recorded as 17.06 % and 18.14 % in 2001 and 2018, respectively, and a CAGR figure of 16.23 %.

- *Distribution of airfreight exports by New Zealand airports*

Table 1 displays the airfreight exports (value and weight) from different airports in New Zealand for the period of 2001–2018. Airfreight exported from New Zealand to its international markets were concentrated in three key international airports: Auckland, Christchurch, and Wellington. Auckland Airport is the largest international aviation hub in New Zealand. During this period, it handled an annual average of NZ$5,648.04 million and 86,671.38 tonnes of airfreight exports, which accounted for 72.04 % and 80.24 % of New Zealand's total airfreight export value and weight, respectively. Christchurch Airport handled only 26.01 % and 18.65 % of New Zealand's total airfreight export by value and weight. On average, Christchurch and Wellington airports transported less than 1 % of New Zealand's total annual airfreight export value and weight. Nevertheless, Wellington Airport led the pack with strong growth rates of 8.74 % by value and 7.94 % by weight. Other smaller airports had a minimal role in exporting New Zealand's goods and products, accounting for less than 1 % of the country's total airfreight exports.

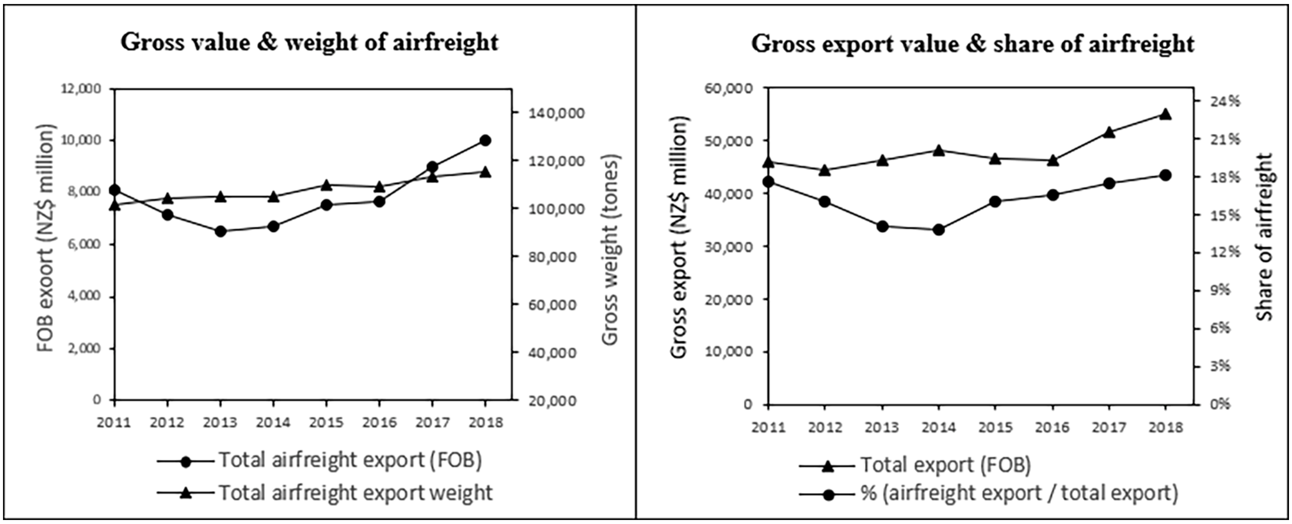

Fig. 1. Airfreight exports (value and weight) of New Zealand (2011–2018). .
Source: Statistics New Zealand (2019b)

Table 1
Airfreight exports by New Zealand airports (2011–2018).

Year	**Export value (FOB) (NZ$ million)**				**Export weight (tonnes)**			
	Auckland	**Christchurch**	**Wellington**	**Other**	**Auckland**	**Christchurch**	**Wellington**	**Other**
2011	4,672.00	2,779.25	42.19	5.89	81,728	20,001	871	20
	57.82 %	34.40 %	0.52 %	0.07 %	80.56 %	18.36 %	0.04 %	0.02 %
2012	4,651.21	2,390.29	30.16	2.21	83,720	18,685	1,075	14
	65.23 %	33.52 %	0.42 %	0.03 %	79.95 %	19.10 %	0.03 %	0.01 %
2013	4,596.84	1,869.49	19.31	2.85	85,432	18,804	1,154	12
	70.42 %	28.64 %	0.30 %	0.04 %	81.28 %	17.78 %	0.02 %	0.01 %
2014	5,140.24	1,535.67	16.73	0.50	84,736	20,390	1,045	40
	76.79 %	22.94 %	0.25 %	0.01 %	80.89 %	17.95 %	0.02 %	0.04 %
2015	5,864.83	1,565.60	26.43	0.07	88,894	21,418	531	7
	77.88 %	20.79 %	0.35 %	0.001 %	80.74 %	18.52 %	0.02 %	0.01 %
2016	6,019.28	1,595.67	22.36	0.30	87,255	22,039	555	5
	78.53 %	20.82 %	0.29 %	0.004 %	79.76 %	19.58 %	0.02 %	0.005 %
2017	6,838.76	2,059.35	55.26	0.15	89,647	21,306	901	6
	75.77 %	22.82 %	0.61 %	0.002 %	78.87 %	19.39 %	0.05 %	0.01 %
2018	7,400.90	2,417.37	75.84	10.54	91,959	19,670	1,487	33
	73.88 %	24.13 %	0.76 %	0.11 %	79.89 %	18.51 %	0.07 %	0.03 %
Min	4,596.84	1,535.67	16.73	0.07	81,728.00	18,630.00	531.00	5.00
	57.82 %	20.79 %	0.25 %	0.001 %	78.87 %	17.78 %	0.02 %	0.005 %
Max	7,400.90	2,779.25	75.84	10.54	91,959.00	22,039.00	1,487.00	40.00
	78.53 %	34.40 %	0.76 %	0.11 %	81.28 %	19.58 %	0.07 %	0.04 %
AVG	5,648.01	2,026.58	36.04	2.81	86,671.38	20,159.13	952.38	17.13
	72.04 %	26.01 %	0.44 %	0.03 %	80.24 %	18.65 %	0.03 %	0.02 %
CAGR	6.79 %	−1.97 %	8.74 %	8.66 %	1.70 %	1.94 %	7.94 %	7.42 %

Remarks: Sourced from Statistics New Zealand (2019b). The percentage figures represent the share of New Zealand's annual airfreight exports in terms of value (FOB) or weight. FOB, free on board; CAGR, compound annual growth rate. Other New Zealand airports include Dunedin, Hamilton and other small airports exporting airfreight overseas.

- *Airfreight exports to New Zealand's key trading partners*

Fig. 2 and Table 2 reveal that New Zealand's 15 key trading partners accounted for 45.5–58.6 % of total airfreight export value between 2015 and 2018. Australia received New Zealand's largest share of airfreight exports valued at NZ$2,013.1 million in 2018. China and the United States (US) were the second and third largest markets, receiving NZ $782.4 million and NZ$709.6 million, respectively. Together, these top three countries received 35.1 % of New Zealand's total airfreight export value. Other major trade partners were Hong Kong (NZ$203.4 million), the United Kingdom (UK) (NZ$172 million), Singapore (NZ$157.1 million), Japan (NZ$117.7 million), and Germany (NZ$108.8 million). The remaining overseas trading partners only received NZ$14.3–79.6 million worth of New Zealand's airfreight exports. Note that New Zealand's top five busiest air cargo routes were Australia, the US, Singapore, China, and Hong Kong in 2019 (IATA, 2019).

The same growth patterns can be observed for airfreight export by weight. Australia, China, and the US were still the top three countries in 2018: Australia (32,927.5 tonnes), China (21,918.3 tonnes), and the US (11,487.6 tonnes). Together, they accounted for more than half (57.9 %)

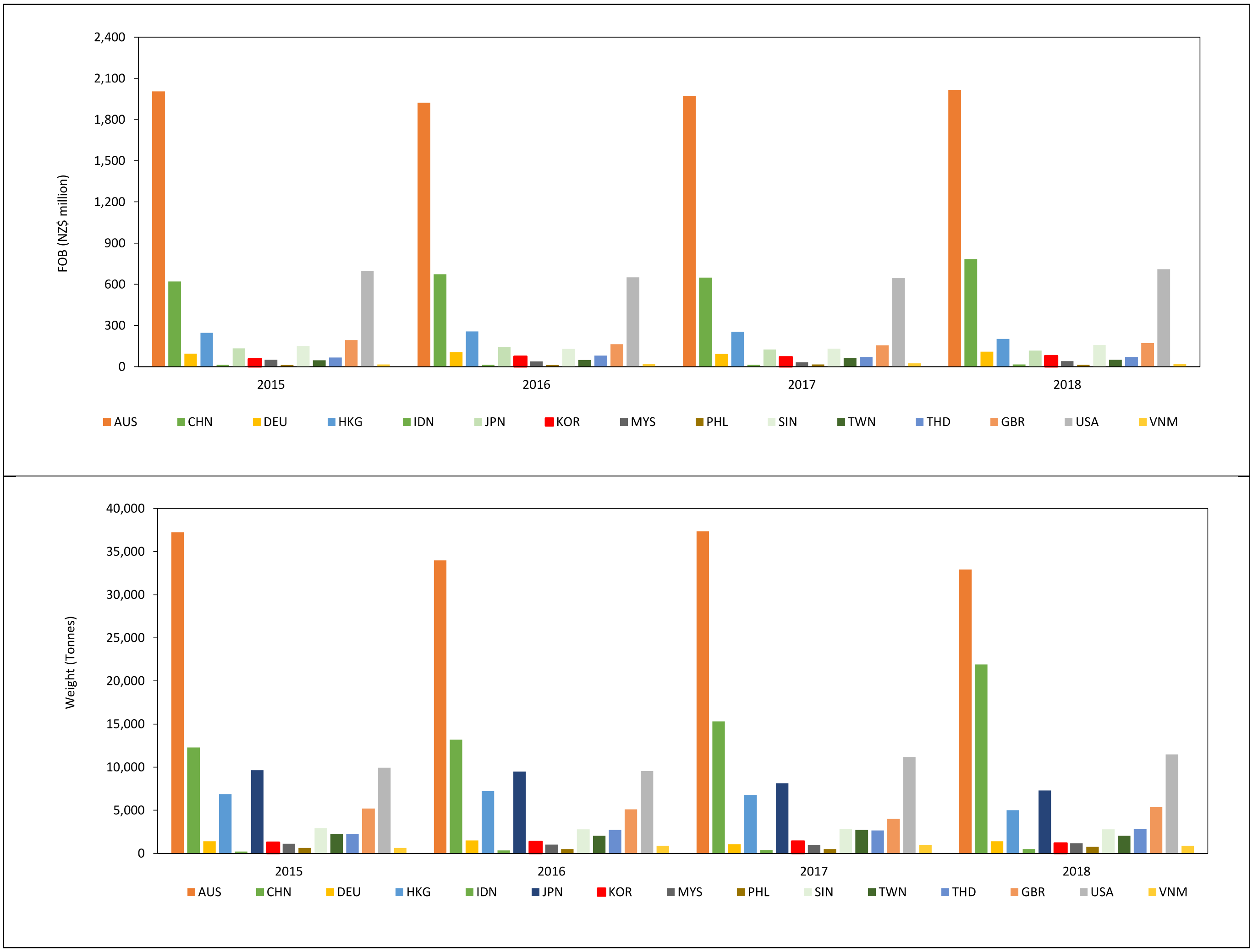

Fig. 2. Airfreight exports (value and weight) to New Zealand's 15 trading partners (2015–2018). .
Source: Statistics New Zealand (2019b)

of New Zealand's total airfreight export weight. Over time, the trend for the combined share of these leading trading partners of New Zealand seemed to be declining. Despite such signs of market diversification, total airfreight exported from New Zealand to these key trading partners has been fairly stable, with other countries being individually much less important.

3. Literature review

Many studies have identified the airfreight sector as a facilitator of international trade or an engine of economic development (e.g., Button & Yuan, 2013; Fu et al., 2020; Kasarda et al., 2004; Senguttuvan, 2006). The gravity model and many of its extensions have been widely used for analysing airfreight traffic (e.g., Grosso & Shepherd, 2011; Kepaptsoglou et al., 2010; Vega, 2014; Yamaguchi, 2008; Yotov et al., 2016; Zhang et al., 2018). Kepaptsoglou et al. (2010) concluded that the gravity model has been extensively used in international trade research for the last 40 years because of its considerable empirical robustness and explanatory power. Yotov et al. (2016) argued that the gravity model is intuitive, has solid theoretical foundations, represents a general equilibrium environment, and has a very flexible setting and good predictive power. Zhang et al. (2018) also revealed that recent empirical research on air transport has incorporated the theoretical advances in estimating the gravity models. Therefore, this section mainly focuses on a review of the existing literature that applied the gravity models to analyse international airfreight.

Matasumoto (2004) used the gravity model to analyse the patterns of international air passenger and cargo flows across Asia, Europe, and the US from 1982 to 1998. The gravity models controlled factors such as GDP, population, distance, and city dummy variables, and the empirical results confirmed that the concentration of air traffic at key cities strengthened their positions as international hubs. A similar finding was reported by Matsumoto (2007), who used the gravity models to examine international air passenger and cargo flows between and within Asia, Europe, and the US in 2000. Yamaguchi (2008) applied a gravity model to analyse international trade and air cargo exports in the US, and suggested that distance and transport costs are the important determinants of international trade, although it is not clear which of these is more relevant. Wadud (2013) suggested that in the context of a gravity model, population and GDP represented the attraction factors in

Table 2
Airfreight exports (value and weight) to New Zealand's 15 key trading partners (2015–2018).

Year	Australia	China	Germany	Hong Kong	Indonesia	Japan	South Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand	United Kingdom	United States	Vietnam	% of NZ's total airfreight exports
Airfreight exports – value (FOB) (NZ$ million)																
2015	2,005.9	621.6	95.3	246.6	15.1	133.3	57.7	51.0	11.7	151.6	46.1	67.0	193.6	697.5	16.3	58.6 %
2016	1,923.1	674.2	105.0	256.8	13.8	141.6	75.2	38.9	11.9	129.8	48.7	82.0	164.7	651.1	19.6	56.6 %
2017	1,973.7	648.3	92.2	254.0	15.1	126.2	70.5	33.1	16.6	130.8	62.5	71.8	155.8	645.5	24.0	47.9 %
2018	2,013.1	782.4	108.8	203.4	16.0	117.7	79.6	39.8	14.3	157.1	51.5	71.9	172.0	709.6	20.6	45.5 %
Airfreight exports – weight (tonnes)																
2015	37,224.4	12,270.9	1,421.2	6,891.7	205.3	9,639.4	1,281.7	1,111.0	620.0	2,911.4	2,257.6	2,233.9	5,195.9	9,930.5	648.5	85.2 %
2016	33,970.9	13,194.2	1,520.3	7,217.9	351.2	9,472.6	1,389.9	1,024.8	515.3	2,788.1	2,067.6	2,734.2	5,095.5	9,554.0	891.8	83.9 %
2017	37,352.3	15,309.0	1,067.8	6,782.2	364.3	8,140.9	1,396.2	954.3	502.8	2,828.5	2,741.5	2,662.7	4,014.4	11,163.9	963.6	84.7 %
2018	32,927.5	21,918.3	1,400.4	5,013.5	512.3	7,311.7	1,169.4	1,194.2	751.5	2,793.1	2,056.3	2,837.1	5,360.9	11,487.6	894.8	84.8 %

Source: Statistics New Zealand (2019b).

an analysis of passenger and air cargo demand at Bangladeshi airports. Grosso and Shepherd (2011) used the gravity model to assess the link between air cargo and bilateral merchandise trade in the Asia-Pacific region, applying the air liberalisation index developed by the World Trade Organisation. They found that increased air liberalisation is associated with an increase in bilateral trade of time-sensitive products, parts, and components. Hwang and Shiao (2011) also developed a gravity model to analyse the air cargo flows of Taiwan Taoyuan International Airport for the period of 2004–2007. Possible determining factors in their study were geo-economic factors (e.g., GDP per capita, population size, and distance between two destinations), service-related factors (flight frequency and airfreight rate) and other factors (trade blocs, open skies agreements, and colonial links). Importantly, they suggested that the distance between two airports is an important geographic factor affecting air cargo demand. Time has also been identified as having a large impact on trade volumes in the gravity model (Nordås et al., 2006).

Vega (2014) used the gravity model to measure the effect of airfreight costs on airfreight export flows from low-income countries to the US and the European Union. They considered factors such as GDP per capita, distance, open skies agreements, trade imbalance, airfreight rate, and landlocked and island countries. One of the key findings was that GDP per capita increased perishable exports and high-value exports. Gong et al. (2018) used the gravity model to identity key drivers of international airfreight of the Chinese air cargo sector in 2011, controlling for variables such as GDP, population, distance, tertiary products, border effects, culture, and Sino–US liberalisation. They found GDP could be a significant facilitator, and distance and border effects to be barriers. More recently, Alexander and Merkert (2020) used the gravity model to estimate the US international airfreight markets during the post-global financial crisis period, and explicitly accounted for factors such as consumer spending patterns, sea freight, transport costs, distance, free trade agreements, and regional dummies. They found that the US demand for international airfreight was sensitive to transport costs, competition from sea freight, and consumer spending patterns on perishable goods.

4. Methodology and data

This study applies the established gravity model specifications to analyse New Zealand's airfreight exports, an island country that primarily relies on air transport for exporting high-value and perishable goods and products with a distinctive airport system (Fu et al., 2020; Tsui et al., 2014). The gravity methodology in modelling airfreight flows and bilateral trade flows between two destinations i and j, specifying the flows as a function of GDP, distance, as well as other geographical and institutional factors (e.g., Anderson, 2011; Button et al., 2019; Kimura & Lee, 2006; Yamaguchi, 2008). In analyses of airfreight demand, economic conditions and distance factors have been identified as important determinants and drivers (e.g., Grosso & Shepherd, 2011; Vega, 2014; Yamaguchi, 2008; Zhang et al., 2018). Distance is an important factor because it approximates transport costs (Grosso & Shepherd, 2011; Park & Jang, 2014) and because airfreight or trade flows tend to be higher between geographically close areas (Oguledo & MacPhee, 1994). Distance between two destinations is also an important geographical factor affecting air cargo transport demand (Hwang & Shiao, 2011).

A standard form of the gravity model can be established to analyse changes in airfreight flows between countries i and j, which can also be affected by geographical and institutional factors (Button et al., 2019; Genç & Law, 2014; Kristjánsdóttir, 2005). The basic gravity model can be specified in Equation (1):

$$A_{ij} = \frac{(GDP_i)(GDP_j)}{(Distance_{ij})} + Z_{ij} \tag{1}$$

where A_{ij} denotes airfreight flows from countries i to j at time t, GDP

Table 3
Variable definition.

Time series variables	Definition
$\ln(\text{Freight\_weight})_{ijt}$	The logarithm of the gross weight of airfreight exported from New Zealand airport *i* to country *j* in month *t* (in tonnes).
$\ln(\text{Freight\_value})_{ijt}$	The logarithm of gross value (FOB) of airfreight exported from New Zealand airport *i* to country *j* in month *t* (in NZD).
$\ln(\text{GDP per capita})_{jt}$	The logarithm of GDP per capita of country *j* in month *t* (in USD).
$\ln(\text{GDP per capita})_{it}$	The logarithm of GDP per capita of New Zealand in month *t* (in USD).
$\ln(\text{POP})_{jt}$	The logarithm of the population size of country *j* in month *t* (in people).
$\ln(\text{DIS})_{ijt}$	The logarithm of the average great circle flying distance from New Zealand airport *i* to country *j*'s airports at month *t* (in km).
$\ln(\text{ATK})_{ijt}$	The logarithm of available tonne kilometre offered by scheduled airlines from New Zealand airport *i* to country *j*'s airports in month *t* (in km).
$\ln(\text{Fuel})_{t}$	The logarithm of jet fuel prices per gallon in month *t* (in USD).
$\ln(\text{EX})_{jt}$	The logarithm of the exchange rate between New Zealand dollars and country *j*'s currency in month *t*.
$\text{CUL \& LAN}_{jt}$	A dummy variable used to identify if country *j* has cultural links with New Zealand or speaks the same language (English). It takes 1 for the country speaks the same language (English) with New Zealand and 0 otherwise.
TRA_{jt}	A dummy variable used to identify if country *j* had a bilateral trade agreement with New Zealand in month *t*. It takes 1 for the country has a bilateral trade agreement with New Zealand and 0 otherwise.
Month_{t}	The vector of monthly dummies to control the monthly time effect.

Table 4
Descriptive statistics of the variables (2015 M1–2018 M12).

Time series variables	Unit	Observations	Mean	Standard deviation	Maximum	Minimum
$\text{Freight\_weight}_{ijt}$	million tonnes	806	0.421	0.591	3.938	0.001
$\text{Freight\_value}_{ijt}$	million NZD	806	19879.271	34509.453	192229.563	76.436
$\text{GDP per capita}_{jt}$	USD	806	2960.910	1770.102	5387.706	239.395
$\text{GDP per capita}_{it}$	USD	806	3481.505	193.116	3690.599	3161.641
POP_{jt}	million people	806	200.855	411.892	1427.648	5.531
DIS_{ijt}	km	806	8374.220	4112.844	19,248	0
ATK_{ijt}	million km	806	43.138	59.590	332.173	0.024
Fuel_{t}	USD	806	1.598	0.330	2.249	0.930
EX_{jt}	NZD *vs.* a country	806	353.103	1651.495	10017.540	0.413
$\text{CUL \& LAN}_{jt}$	–	806	0.298	0.458	1	0
TRA_{jt}	–	806	0.942	0.234	1	0
Tonne_{ijt}	million tonnes	806	0.009	0.018	0.123	0.00001

denotes the gross domestic product of a country, $Distance_{ij}$ is a time-invariant variable that measures the distance between countries *i* and *j* (Bussière et al., 2008), and Z_{ij} represents a set of control variables that enhance or impede airfreight flows (Genç & Law, 2014).

Note that the variable of GDP in the standard gravity model above is broken down into GDP per capita and population in order to reflect and control for the level of national development of the sampled countries and the size of the economy (Aydın & Ülengin, 2022; Yamaguchi, 2008). Our study uses an augmented gravity model similar to those used in Alexander and Merkert (2020), Baier et al., (2022), and Gong et al. (2018). Thus, the basic gravity model above is modified to log–log augmented panel gravity models for estimating New Zealand's airfreight export weight and value in Equations 1a and 2b:

$$\begin{aligned}\ln(\text{Freight\_weight})_{ijt} = {} & \beta_0 + \beta_1\ln(\text{GDP per capita})_{jt} + \beta_2\ln(\text{GDP per capita})_{it} + \beta_3\ln(\text{POP})_{jt} + \beta_4\ln(\text{DIS})_{ijt} + \beta_5\ln(\text{ATK})_{ijt} + \beta_6\ln(\text{Fuel})_{t} + \beta_7\ln(\text{EX})_{jt} \\ & + \beta_8\text{CUL \& LAN}_{jt} + \beta_9\text{TRA}_{jt} + \beta_{10}\text{Month}_t + \varepsilon_{ijt}\end{aligned} \tag{1a}$$

$$\begin{aligned}\ln(\text{Freight\_value})_{ijt} = {} & \alpha_0 + \alpha_1\ln(\text{GDP per capita})_{jt} \\ & + \alpha_2\ln(\text{GDP per capita})_{it} + \alpha_3\ln(\text{POP})_{jt} \\ & + \alpha_4\ln(\text{DIS})_{ijt} + \alpha_5\ln(\text{ATK})_{ijt} \\ & + \alpha_6\ln(\text{Fuel})_{t} + \alpha_7\ln(\text{EX})_{jt} + \alpha_8\text{CUL \& LAN}_{jt} \\ & + \alpha_9\text{TRA}_{jt} + \alpha_{10}\text{Month}_t + \mu_{ijt}\end{aligned} \tag{2b}$$

where ln denotes the natural logarithmic form. β_0 and α_0 denote constants. Subscript *i* denotes a New Zealand airport. Subscript *j* denotes a country or trading partner of New Zealand. *t* denotes month. β_s and α_s are the coefficients to be estimated. ε and μ are the error terms. The statistical program of Stata 18.5 was used for estimation.

- *Dataset and descriptive statistics*

Table 5
Summary of panel unit root tests for variables.

Variables	Level		First-differencing	
	ADF	PP	ADF	PP
$\ln(\text{Freight\_weight})_{ijt}$	0.0000***	0.0000***	0.0000***	0.0000***
$\ln(\text{Freight\_value})_{ijt}$	0.0000***	0.0000***	0.0000***	0.0000***
$\ln(\text{GDP per capita})_{jt}$	0.0001***	0.0001***	0.0000***	0.0001***
$\ln(\text{GDP per capita})_{it}$	0.0001***	0.0001***	0.0000***	0.0000***
$\ln(\text{POP})_{jt}$	0.0000***	0.0000***	0.0000***	0.0000***
$\ln(\text{DIS})_{ijt}$	0.5698	0.5698	0.0000***	0.0000***
$\ln(\text{ATK})_{ijt}$	0.0000***	0.0000***	0.0000***	0.0000***
$\ln(\text{Fuel})_{t}$	0.9827	0.9827	0.0000***	0.0000***
$\ln(\text{EX})_{jt}$	0.0000***	0.0000***	0.0000***	0.0000***
$\text{CUL \& LAN}_{jt}$	0.0000***	0.0000***	0.0000***	0.0000***
TRA_{jt}	0.0000***	0.0000***	0.0000***	0.0000***
$\ln(\text{TONNE})_{ijt}$	0.0000***	0.0000***	0.0000***	0.0000***

Remarks: The values indicate *p*-values. The unit root test is shown for the constant only. *** indicates the rejection of the null hypothesis (H_0) that the variable has a panel unit root at the 1% significance level. ADF, augmented Dickey-Fuller; PP, Phillips–Perron.

Table 6
Correlation matrix.

Time series variables	$\ln(\text{GDPpercapita})_{jt}$	$\ln(\text{GDPpercapita})_{it}$	$\ln(\text{POP})_{jt}$	$\ln(\text{DIS})_{ijt}$	$\ln(\text{ATK})_{ijt}$	$\ln(\text{Fuel})_{t}$	$\ln(\text{EX})_{jt}$	$\text{CUL\&LAN}_{jt}$	TRA_{jt}
$\ln(\text{GDPpercapita})_{jt}$	1.000								
$\ln(\text{GDPpercapita})_{it}$	−0.025	1.000							
$\ln(\text{POP})_{jt}$	−0.600	0.028	1.000						
$\ln(\text{DIS})_{ijt}$	−0.211	0.032	0.199	1.000					
$\ln(\text{ATK})_{ijt}$	0.447	0.051	−0.002	−0.191	1.000				
$\ln(\text{Fuel})_{t}$	−0.007	0.572	0.018	0.029	0.019	1.000			
$\ln(\text{EX})_{jt}$	−0.536	0.012	0.266	0.192	−0.431	0.014	1.000		
$\text{CUL\&LAN}_{jt}$	0.496	−0.162	0.018	−0.476	0.327	−0.031	−0.552	1.000	
TRA_{jt}	−0.075	0.165	−0.120	−0.086	−0.012	0.090	−0.332	0.165	1.000

Remarks: The relationship between two variables was determined by the coefficient of correlation *r*. No correlation ($|r| < 0.29$), weak correlation ($0.30 < |r| < 0.49$), moderate correlation ($0.50 < |r| < 0.79$), and strong correlation ($0.80 < |r| < 1$) (Sadjapong et al., 2020).

Tables 3 and 4 present the definition, descriptive statistics of all variables of interest. The analysis period is from 2015 M1 to 2018 M12 as Statistics New Zealand has only published the data on total airfreight export value and weight to New Zealand's trading partners only since 2015 (Statistics New Zealand, 2019b). The dataset of this study is structured in the airport-level format based on the total airfreight export (weight and value) handled by three key international airports in New Zealand to the sampled international markets.[1] The dependent variables, $\text{Freight\_weight}_{ijt}$ and $\text{Freight\_value}_{ijt}$, are the gross weight and values (FOB) of airfreight exported from New Zealand's three key international airports (Auckland, Christchurch, and Wellington), respectively, which were sourced from Statistics New Zealand. The three key gravity model variables of $\text{GDP per capita}_{jt}$, $\text{GDP per capita}_{it}$, and POP_{jt} for analysing New Zealand's airfreight exports were collected from the World Bank. Note that the monthly $\text{GDP per capita}_{jt}$, $\text{GDP per capita}_{it}$, and POP_{jt} used for estimation were interpolated from their respective annual figures.[2] Other key gravity model variables, DIS_{ijt} and ATK_{ijt}, were collected from the Official Airline Guide (OAG), for scheduled airline services from New Zealand airports to the overseas trading partners. Moreover, the data for Fuel_t and EX_{jt} were sourced from the US Energy Information Administration (EIA) and the New Zealand Reserve Bank, respectively. Note that all dependent and explanatory variables were transformed into their logarithmic form, except for the dummy variables ($\text{CUL \& LAN}_{jt}$, TRA_{jt}, and Month_t). The data for $\text{CUL \& LAN}_{jt}$ were based on New Zealand Foreign Affairs & Trade,[3] and the values for TRA_{jt} between New Zealand and its key trading partners were obtained from various government websites such as the New Zealand–Australia Closer Economic Relations and New Zealand–China Free Trade Agreement (2008) websites.

5. Empirical analysis

- *Panel data unit root test*

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[1] The advantage of using the airport-level data is that measurement errors can be avoided in analysing the shares of three key international airports' airfreight export on New Zealand's airfreight export (i.e., Auckland, Christchurch, and Wellington airports). At the same time, each of the sampled airport's airfreight export weight and value to the sampled markets are the good overall measures of controlling its contributions to New Zealand's airfreight export. This approach takes advantage of the data's panel nature (Hsiao, 2007); However, the airport-level panel dataset of this study may suffer from interporal dependencies, autocorrelation, endogeneity, and other aspects of statistical problems (Wooldridge, 2016). Importantly, we are aware of the significance of Auckland Airport on New Zealand's airfreight export weight and value relative to Christchurch and Wellington Airports during estimation and the interpretations of results.

[2] For estimation, the time series variables of annual GDP per capita and population size had to be interpolated to avoid missing values during the estimation (Gunter & Zekan, 2021).

[3] The website of New Zealand Foreign Affairs & Trade: https://www.mfat.govt.nz/en/trade/nz-trade-policy/.

Table 7
Estimation results of New Zealand's airfreight weight and value (2015 M1−2018 M12).

Dependent variables	$\ln(\text{Freight\_weight})_{ijt}$		$\ln(\text{Freight\_value})_{ijt}$	
Explanatory variables	**Static panel-IV gravity model (1A)**	**Dynamic panel data GMM model (1B)**	**Static panel-IV gravity model (2A)**	**Dynamic panel data GMM model (2B)**
$\ln(\text{Freight\_weight})_{ijt-1}$	–	0.355*** (0.080)	–	–
$\ln(\text{Freight\_weight})_{ijt-2}$	–	−0164 (0.156)	–	–
$\ln(\text{Freight\_weight})_{ijt-3}$	–	−0.048 (0.076)	–	–
$\ln(\text{Freight\_value})_{ijt-1}$	–	–	–	0.115*** (0.355)
$\ln(\text{Freight\_value})_{ijt-2}$	–	–	–	−0.355** (0.180)
$\ln(\text{GDP per capita})_{jt}$	0.986*** (0.318)	1.880** (0.813)	0.926*** (0.192)	2.019*** (0.381)
$\ln(\text{GDP per capita})_{it}$	−0.706 (0.465)	−1.073 (0.902)	−1.146*** (0.351)	−1.603*** (0.451)
$\ln(\text{POP})_{jt}$	0.665*** (0.172)	2.666 (2.779)	0.734*** (0.156)	2.812 (2.637)
$\ln(\text{DIS})_{ijt}$	−0.199 (0.211)	−0.162 (0.118)	0.478*** (0.052)	0.105** (0.050)
$\ln(\text{ATK})_{ijt}$	0.055 (0.035)	0.024 (0.025)	0.052 (0.038)	−0.006 (0.039)
$\ln(\text{Fuel})_{t}$	−0.060 (0.163)	−0.280*** (0.094)	−0.099 (0.121)	−0.222 (0.094)
$\ln(\text{EX})_{jt}$	0.004 (0.107)	0.152 (0.477)	−1.523** (0.074)	−0.0004 (0.0005)
$\text{CUL \& LAN}_{jt}$	0.300 (0.984)	–	0.113 (0.939)	–
TRA_{jt}	−0.100 (0.111)	0.034 (0.072)	0.052 (0.154)	0.113 (0.127)
Constant	−2.162 (5.292)	−41.676 (47.067)	4.302 (4.020)	−33.362 (44.718)
Month_t	Yes		Yes	
R^2	0.334		0.385	
No. of observations	766	692	766	716
Hausman test (*p*-value)	0.455		0.890	
Sargan test (*p*-value)		0.169		0.108
AR (1) (*p*-value)		0.005		0.004
AR(2) (*p*-value)		0.288		0.117
AR(3) (*p*-value)		0.514		

Remarks: *, **, and *** indicate the explanatory variable at the 0.10, 0.05, and 0.01 significance levels, respectively. Robust standard errors in parentheses. When the Hausman test (*p*-value) is statistically significant, the FE estimator should be adopted. The coefficients of $\text{CUL \& LAN}_{jt}$ omitted from Models 1B and 2B because of collinearity.

As this study uses the balanced panel dataset,[4] therefore the panel unit root tests are estimated to determine whether the variables of interest are stationary. To estimate the panel data gravity models specified in Models 1a and 2b, all the variables need to be stationary to avoid the problem of spurious correlation (e.g., Balli et al., 2016; Salesi et al., 2021; Wooldridge, 2016). Table 5 shows the results of the augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) panel unit roots of all variables of interest. The first-differencing technique was applied to convert the nonstationary variables to stationary, including $\ln(\text{DIS})_{ijt}$ and $\ln(\text{Fuel})_t$. Table 6 shows the correlation matrix which confirmed that there is no strong correlation among all variables of interest.

- *Static panel-IV gravity model estimations*

The airfreight sector serves as a facilitator of international trade and an engine of economic development (Button & Yuan, 2013). This study thus estimates alternative augmented gravity specifications, as shown in Models 1a and 2b above. One possible issue is that the key variable of $\ln(\text{ATK})_{ijt}$ could be endogenous, because it may have causal relationship or loop/reverse causality with the dependent variables, $\ln(\text{Freight\_weight})_{ijt}$ and $\ln(\text{Freight\_value})_{ijt}$, in the gravity models (Wooldridge, 2016).[5] The endogeneity problem of $\ln(\text{ATK})_{ijt}$ may lead to inconsistent estimators or biased estimation results. On the one hand, scheduled air cargo capacity may largely be a 'by-product' of passenger flight operations, as freighter operations were limited. On the other hand, more available tonne-kilometres (ATKs) may be scheduled by airlines, airfreight integrators, and dedicated freighters when there are substantial airfreight export demands. Therefore, scheduled air cargo tonne capacity offered by airlines, airfreight integrators, and dedicated freighters, $\ln(\text{TONNE})_{ijt}$, is used as the instrumental variable (IV) of $\ln(\text{ATK})_{ijt}$ in Models 1a and 2b (e.g., Ngo & Tsui, 2020; Ohashi et al., 2005; Salesi et al., 2021; Yamaguchi, 2008). Considering the relationship between airfreight exports and scheduled air cargo capacity from New Zealand to the sampled 13 trading partners should hold in general rather than show unique correlations for all New Zealand's trading partners (Yamaguchi, 2008).

Table 7 reports the estimation results of static panel-IV gravity models and dynamic panel GMM models. The Hausman test was used to determine between the fixed effects (FE) and random effect (RE) models for estimating the static panel-IV gravity models (Models 1A and 2A) (Chen & Jiang, 2020). The results of Hausman test (p-values = 0.455 for Model 1A and 0.890 for Model 2A) suggested that the RE estimator is preferable for $\ln(\text{Freight\_weight})_{ijt}$ and $\ln(\text{Freight\_value})_{ijt}$, respectively.

Overall, both static panel-IV gravity models yielded fairly consistent estimation results in Table 7 (Models 1A and 2A). The variable of $\ln(\text{GDP per capita})_{jt}$ is statistically significant with the values of 0.986 in Model 1A and 0.926 in Model 2A, respectively. This indicates that for every 1 % increase in GDP per capita of the sampled trading partners, airfreight exported from New Zealand increased by 0.986 % (in weight) and 0.926 % (in value). Interestingly, the variable of $\ln(\text{GDP per capita})_{it}$ is reported to have an insignificant negative coefficient in Model 1A, which is consistent to the findings of Gong et al. (2018). In addition, the variable of $\ln(\text{POP})_{jt}$ is statistically significant with a value of 0.665 in Model 1A and 0.734 in Model 2A, suggesting that for every 1 % increase in the population size of the sampled trading partners, the weight and value of airfreight exported from New Zealand to those countries increased by 0.665 % and 0.734 %. The findings of these statistically significant and positive variables related to $\ln(\text{POP})_{jt}$ are consistent with the literature (e.g., Gong et al., 2018; Kepaptsoglou et al., 2010; Vega, 2014; Yamaguchi, 2008).

The impact of $\ln(\text{DIS})_{ijt}$ on airfreight export value is statistically significant and positive in Model 2A, with a value of 0.478. It suggests that for every 1 % increase in flying distance between a New Zealand airport and the sampled trading partners' airports, the value of airfreight exported from New Zealand increased by 0.478 %. That is, the value of airfreight exported from New Zealand to the sampled trading partners increased with geographic distance (flying distance). This is against the

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[4] Due to the data availability of some variables of interest (e.g., ASK), our study only analyses key determinants and drivers for New Zealand's airfreight exports to the top 13 trading partners listed by Statistics New Zealand. 13 trading partners included Australia. China, Hong Kong, Indonesia, Japan, South Korea, Malaysia, the Philippines, Singapore, Taiwan, the United Kingdom, and the United States (not including Germany and Vietnam).

[5] It is also evident that because the capacity form airfreight integrators and dedicated freighters accounted for a certain percentage of New Zealand's airfreight exports. Additionally, the inclusion of $\ln(\text{ATK})_{ijt}$ would introduce significant endogeneity issues during estimation but also did not allow us to accurately examine the effects of scheduled available air cargo capacity on airfreight market outcomes.

standard theory that distance reduces trade flows and air transport demand (Chaney, 2018; Li et al., 2020), but is nevertheless consistent with the remarks made by the Ministry of Business and Innovation and Employment (2018) that “There were two key drivers in the movement away from New Zealand manufacturing. One was the tyranny of distance which our competitors played on continually”. It is also consistent with Matsumoto (2004)’s study about the impact of distance on air cargo flows. Alternatively, the significant positive sign of $\ln(\mathrm{DIS})_{ijt}$ could be the result of higher value goods and perishable commodities, which are preferred and required to be transported to their destinations by air transport, which implies that manufacturers and importers of New Zealand’s key trading partners were more willing to pay for transportation time reduction (i.e., seamless and much faster air logistics mode) (Kristjánsdóttir, 2005; Rietveld & Vickerman, 2004). That is, whereas its negative effects on air cargo flows hold at an aggregate level, airfreight is much more preferred for long-distance deliveries to their destinations. It is evident that New Zealand’s seasonal products (e.g., cherries) demanded by Northern Hemisphere countries, which can be a reason why flying distance has a positive relationship with airfreight export value reported in Model 2A.

The coefficient of a key scheduled air cargo capacity (supply) variable, $\ln(\mathrm{ATK})_{ijt}$, has been reported with the expected positive signs but are statistically insignificant in both Models 1A and 2A. These findings partly suggested that as scheduled air cargo capacity in general promoted airfreight exported from New Zealand, which is consistent with the relationship identified between demand and capacity in air transportation (Barnhart et al., 2012). On the other hand, the coefficient signs suggested the stimulation effect on airfreight exports, if any, tends to be quite limited. After all, air cargo is a derived demand and the air cargo capacity’ stimulation effect was limited in New Zealand’s airfreight export market.

It is worth noting that another key economic variable, $\ln(\mathrm{Fuel})_t$, has the expected negative coefficient signs in Models 1A and 2A. It measures transport costs and thus airfreight rates for manufacturers, farmers, and exporters to ship their high-value and perishable goods and products to overseas markets by air transport (Chao & Hsu, 2014; Kupfer et al., 2017). However, both models presented statistically insignificant and negative coefficients, respectively. These findings partly suggested that an increase in transport costs reduced the weight and value of airfreight exported from New Zealand to the sampled trading partners, respectively. This is in line with the statement by the Ministry of Business and Innovation and Employment (2018) that “Transporting goods…from New Zealand is expensive.” In addition, the variable of $\ln(\mathrm{EX})_{jt}$ measures the impact of exchange rate volatility on New Zealand’s trade flows and exports of goods and products by air transport (e.g., Bahmani-Oskooee and Hegerty, 2007; Choudhry, 2008; Karunathilake & Fernando, 2024; Lo et al., 2015; Mabin, 2011; Smith, 2004). The significant negative coefficient of $\ln(\mathrm{EX})_{jt}$ is only reported in Model 2A, with a value of −1.523, suggesting that an appreciation of New Zealand dollars negatively impacted New Zealand’s airfreight export value. It also means that for every 1 % increase of New Zealand dollars against the US dollar, the value of airfreight exported from New Zealand declined by 1.532 %. This finding agreed with the comments by the Ministry of Business and Innovation and Employment (2018) that “Manufacturers are very much dependent on freight rates, demand and exchange rates…those are the challenges of a manufacturer in New Zealand.” These findings related to two economic variables confirm that they negatively influenced New Zealand’s airfreight exports, particularly the value of New Zealand’s airfreight exports. Interestingly, the expected significant impacts of the two dummy variables for a shared culture and or language, $\mathrm{CUL\,\&\,LAN}_{jt}$, and bilateral trade agreements, TRA_{jt}, on both airfreight export weight and value were not observed, although their positive and negative signs of the coefficients reported in Models 1A and 2A are in line with their expected effects on New Zealand’s airfreight exports.

- *Robustness checks*

A distinctive characteristic of bilateral trade flows in the economics literature is that there is a tendency for repeated transactions between trading partners, or persistence in trade patterns (Greif, 1992; Nitsch & Wolf, 2013). This study assumes that New Zealand’s airfreight exports rely on air cargo capacity to transport high-value and perishable goods and products to its trading partners and the established bilateral trade relationships. Theoretically, apart from the endogeneity issue of $\ln(\mathrm{ATK})_{ijt}$, the static panel-IV gravity models estimated above (Models 1A and 2A) could be subject to misspecification if persistent effects (i.e., repeated trading actions) are omitted. For example, the model specifications in Models 1A and 2A could have neglected the effect of buyers or importers from overseas markets deciding to import New Zealand’s goods and products again after their bilateral good trading relationships have been established in the previous period(s). Not incorporating such persistence in trade patterns (i.e., lagged effects from the previous period(s)) in Models 1A and 2A may lead to overestimated parameters, which effectively reflect both the immediate (direct) and lagged (indirect) effects (Balli et al., 2016). Therefore, This study tests this issue by estimating dynamic specifications that incorporate the lagged value(s) of two dependent variables, $\ln(\mathrm{Freight\_weight})_{ijt}$ and $\ln(\mathrm{Freight\_value})_{ijt}$, using the same panel data and the same set of explanatory variables as in the static specification (Models 1A and 2A). This approach considers the variables of autoregressive nature of the two dependent variables (i.e., $\ln(\mathrm{Freight\_weight})_{ijt}$ and $\ln(\mathrm{Freight\_value})_{ijt}$) are the good predictors of their respective current values, respectively.

Additional econometric problems nevertheless emerge when the lagged values of two dependent variables are included as the explanatory variables, because ordinary least squares (OLS) estimations no longer produce unbiased estimates because of the endogeneity. The dynamic GMM model is an alternative in which the lagged value(s) of the dependent variables and the first-differencing explanatory variables are used as the IVs in Models 1B and 2B, respectively (Arellano & Bond, 1991; Bilotkach, 2015). It is noted that two well-accepted diagnostic tests (Sargan test and test for autocorrelation) were performed to verify the confirmed models of dynamic panel data GMM models reported in Table 7 for $\ln(\mathrm{Freight\_weight})_{ijt}$ and $\ln(\mathrm{Freight\_value})_{ijt}$, respectively. The dynamic panel data GMM estimators for airfreight weight and value are specified in Models 1B and 2B:

$$\begin{aligned}\ln(\mathrm{Freight\_weight})_{ijt} = {} & \beta_0 + \beta_1\ln(\mathrm{Freight\_weight})_{ijt-x} \\ & + \beta_2\Delta\ln(\mathrm{GDP\ per\ capita})_{jt} \\ & + \beta_3\Delta\ln(\mathrm{GDP\ per\ capita})_{it} + \beta_4\Delta\ln(\mathrm{POP})_{jt} \\ & + \beta_5\Delta\ln(\mathrm{DIS})_{ijt} + \beta_6\Delta\ln(\mathrm{ATK})_{ijt} \\ & + \beta_7\Delta\ln(\mathrm{Fuel})_t + \beta_8\Delta\ln(\mathrm{EX})_{jt} + \beta_9\Delta\mathrm{CUL\,\&\,LAN}_{jt} \\ & + \beta_{10}\Delta\mathrm{TRA}_{jt} + \varepsilon_{ijt}\end{aligned} \tag{1B}$$

$$\begin{aligned}\ln(\mathrm{Freight\_value})_{ijt} = {} & \alpha_0 \\ & + \alpha_1\ln(\mathrm{Freight\_value})_{ijt-x} + \alpha_2\Delta\ln(\mathrm{GDP\ per\ capita})_{jt} \\ & + \alpha_3\Delta\ln(\mathrm{GDP\ per\ capita})_{it} + \alpha_4\Delta\ln(\mathrm{POP})_{jt} \\ & + \alpha_5\Delta\ln(\mathrm{DIS})_{ijt} + \alpha_6\Delta\ln(\mathrm{ATK})_{ijt} \\ & + \alpha\beta_7\Delta\ln(\mathrm{Fuel})_t + \alpha_8\Delta\ln(\mathrm{EX})_{jt} + \alpha_9\Delta\mathrm{CUL\,\&\,LAN}_{jt} \\ & + \alpha_{10}\Delta\mathrm{TRA}_{jt} + \mu_{ijt}\end{aligned} \tag{2B}$$

Where ln denotes the natural logarithmic form. Δ denotes first-differencing. β_0 and α_0 denote constants. Subscript i denotes a New Zealand airport. Subscript j denotes a country or trading partner of New Zealand. t denotes month. β_s and α_s are the coefficients to be estimated. ε

and μ are the error terms. The statistical program of Stata 18.5 was used for estimation.

The two lagged dependent variables, $\ln(\text{Freight\_weight})_{ijt-1}$, and $\ln(\text{Freight\_value})_{ijt-1}$, have a statistically significant and positive coefficient in Models 1B and 2B, respectively, thus confirming persistence in the weight and value of airfreight exported from New Zealand to the sampled trading partners. The same significant positive impact of GDP per capita of trading partners, $\ln(\text{GDP per capita})_{jt}$, are reported in Models 1B and 2B, which are similar to those in Models 1A and 2A. However, the negative coefficient of $\ln(\text{GDP per capita})_{it}$ (i.e., New Zealand's GDP per capita) in Model 2B became statistically significant, but remained statistically insignificant in Model 1B. Additionally, the statistically significant and positive coefficient of $\ln(\text{POP})_{jt}$ (i.e., the population size of the sampled trading partners) in Models 1A and 2A became statistically insignificant in Models 1B and 2B. The same statistically significant and positive coefficient of $\ln(\text{DIS})_{ijt}$ (i.e., the flying distance between New Zealand and the sampled trading partners) reported in Models 2A and 2B. Importantly, the coefficient of $\ln(\text{Fuel})_{t}$ (i.e., airfreight rates or transport costs) become statistically significant and negative in Models 1B, but not in Model 2B, showing its significant negative impact on the weight of airfreight exported from New Zealand, but not on the value of New Zealand's airfreight exports. The reporting of an insignificant negative coefficient of $\ln(\text{EX})_{jt}$ in Model 2B also still partly supported the findings reported in Model 2A, with a negative coefficient sign. Overall, the estimation results of Models 1B and 2B for the dynamic panel data GMM models are largely consistent with those of Models 1A and 2A for the static panel-IV gravity models. However, a notable difference is the magnitude of income (i.e., GDP per capita) elasticity.

6. Discussions and conclusion

Airfreight services out of New Zealand's major airports (Auckland, Christchurch, and Wellington) to its trading partners played an important role in the country's exports and economy (Bilotkach, 2015; Tsui et al., 2014; Tsui et al., 2019). This study examines key determinants and drivers of the weight and values of airfreight exported from New Zealand to its key trading partners by empirically estimating the augmented gravity models with the monthly panel data from January 2015 to December 2018. The estimation results confirmed that GDP per capita and population size of New Zealand's key trading partners had positive impacts on the weight and value of airfreight exported from New Zealand, which is consistent with the existing literature (e.g., Gong et al., 2018; Kepaptsoglou et al., 2010; Vega, 2014; Yamaguchi, 2008). More importantly, we found scheduled air cargo capacity had a limited positive effect on airfreight exports. Fuel price (airfreight rates or transport costs) also had a limited negative effect on the weight and value of airfreight exports. Exchange rate volatility had its significant negative effects on airfreight value exported from New Zealand, which aligns with prior studies (e.g., Bahmani-Oskooee and Hegerty, 2007; Choudhry, 2008; Karunathilake & Fernando, 2024; Lo et al., 2015; Mabin, 2011; Smith, 2004). Importantly, these findings were consistent and robust across both static panel IV gravity model and dynamic panel data GMM model specifications reported in Table 7.

Although the positive effects of GDP per capita and population size on airfreight exports are not novel to the aviation and business literature, our study still offers some important findings. First, we found supporting evidence that scheduled air cargo capacity enhanced airfreight exports, but such effects are limited. Intuitively, airfreight is a derived demand that is dependent on airfreight volumes. When air cargo capacity increases as a 'by-product' of the joint production of passenger services (e.g., unused cargo capacity in the belly spaces of passenger aircraft), airlines and dedicated airfreight integrators may mark down airfreight rates, thus attracting more air cargo volumes that were previously priced out of the market. Such goods and products are likely to have lower values per kilogram compared with existing air cargos. This explains why scheduled air cargo capacity is important to the airfreight export sector (Suryani et al., 2012). Other estimation results in our study are, of course, consistent with the observations in which transport costs have the negative effects on airfreight exports (e.g., the effects of aviation fuel price on airfreight rates (Chao & Hsu, 2014). Although more in-depth analysis is needed, it is likely that increased air cargo capacity supply helped New Zealand's organisations and exporters to export more high-value air cargo or attracted new customers to the markets, instead of promoting increased shipments by existing airfreight users. Such a finding in our study would have mixed implications: On the one hand, this is not very good news for policymakers or supporters of subsidies to increase air cargo capacity from New Zealand, as 'marginal' users will be priced out of the market when such subsidies are removed. Such a temporary support policy is unlikely to lead to sustained growth of New Zealand's airfreight export sector. On the other hand, the positive news is that there are currently unexploited markets for New Zealand that are price sensitive. In a way, this is like the unserved price-sensitive passenger market before low-cost carriers entered the market.[6] Therefore, if there are methods that could cut operation costs for air cargo operations in a sustainable way, long-term market expansion can be expected and sustained for New Zealand's airfreight export sector. This is probably why proposals have been made to use low-cost and under-utilised airports for air cargo operations in many countries. Because, in the New Zealand market, most air cargo capacity has been provided by the belly space of passenger aircraft (Merkert et al., 2017; Reis & Silva, 2016; Zhang & Zhang, 2002), in the foreseeable future, international air cargo operations will continue to be concentrated at three major airports (i.e., Auckland, Christchurch, and Wellington) (Karunathilake & Fernando, 2024; Tsui et al., 2014). Therefore, reducing the operating costs and ensuring more air cargo capacity at these major airports are of great importance to New Zealand's airfreight export sector. Because major airports in New Zealand and Australia are under 'light-handed' regulation (Yang & Fu, 2015), both governments could not directly mandate airport charge reductions. Instead, efforts and policies by the New Zealand government should be made to reduce the operating costs to the aviation industry in general. In addition, since dominant airlines at hub airports often play important roles in aviation liberalisation and competition outcomes (Fu et al., 2015b; Homsombat et al., 2011), the New Zealand government may also need to examine individual airlines' roles and needs in their aviation policy considerations, and better involve them in liberalisation negotiations with key trading partners.

Another key contribution made by our study is the identification of persistent trading patterns in airfreight exports, alongside the insignificant effects of bilateral trade agreements and cultural and language factors reported in Table 7. These results suggested the importance of recognising their effects in empirical estimations. In addition, these findings offered mixed implications for policymaking and aviation operations in New Zealand. On the one hand, such results emphasised the importance of maintaining good cooperative relationships with traditional main trading partners. On the other hand, progressive liberalisation policies would not bring significant benefits. For example, the Australian–New Zealand market has already largely been liberalised for decades (Wilson, 2023). Further liberalisation will bring only limited returns. Other countries, notably large economies such as China (Young, 2023) and the UK (Szöllősi-Cira, & Szöllősi-Cira, 2022), have substantial potential in the long term. However, marginal liberalisation will not increase the market demand substantially. Therefore, in particular, New Zealand and China should consider major trade deals and facilitating the

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[6] Many studies have been carried out on low-cost carriers regarding their impacts on the price-sensitive passenger markets; for example, see Dresner et al. (1996), Fu et al. (2011, 2015a), Hofer et al. (2008), Morrison (2001), Oliveira (2008), Richards (1996), Su et al. (2020), and Wang et al. (2017, 2020).

growth of New Zealand's airfreight exports and aviation markets. Because of the joint production of the passenger and air cargo sectors, coordinated liberalisation of the two sectors is likely to be more effective. As witnessed in the liberalisation and market growth between China and the US, the relaxation of visa restrictions, airline capacity deregulation, and the promotion of competition are likely to increase air cargo and passenger traffic volumes substantially (Fu et al., 2010). New Zealand should also target and explore major liberalisation and trade deals beyond its current key trading partners, which have positive two-way relationships with airfreight sector's growth (Suryani et al., 2012).

Additionally, this study is among the first to empirically estimate an augmented gravity model for New Zealand's airfreight exports. Despite the consistent and robust results obtained via alternative model specifications (i.e., the static panel-IV gravity model and dynamic panel data GMM model in Table 7), some other areas warrant more in-depth analysis. First, airfreight rates were not factored in for estimations. Whereas this is not a usual requirement for the gravity model estimations and, to a large extent, removed the issue of endogeneity. It also prevents us from precisely revealing the market mechanism and dynamics, including how extra air cargo capacity is cleared out by airline pricing. In addition, the monthly data and the monthly dummies incorporated in our study allowed us to clearly reveal the demand and seasonal patterns of goods and products (e.g., perishable agricultural products) on New Zealand's airfreight exports. Traditionally, there is a strong demand for New Zealand's agricultural goods and products from January to May, such as cherry exported from the South Island of New Zealand to China for Chinese New Year celebrations, and premium lamb exports to the UK over the Easter period (Ministry for Primary Industries, 2020). Second, New Zealand exports of fruits and vegetables also played important roles to its economy (Sales, 2016) and tended to have seasonal patterns. This was suggested by Arnade and Pick (1998, p. 53), who mentioned that while seasonality exists in various times series, it is readily observed in agriculture. Production of agricultural goods in a particular region is confined to certain months of the year, thus leading to pronounced season variation in observed variables such as supply, demand, prices and others. For further research, the inclusion of perishable agricultural products is meaningful for analysing the demand for New Zealand's airfreight exports. These extensions can be conducted when more detailed monthly data are available. Third, airfreight exports may have behaved differently from other export mode such as sea exports, it would be meaningful to estimate the gravity models for examining the heterogeneity of different types of New Zealand's goods and products following the approaches of Rauch (1999, 2001) and Lankhuizen et al. (2015). Likewise, decisions of New Zealand's organisations and exporters for exporting goods and products using faster but expensive air cargo or slower but cheap sea cargo (maritime transport), thus future research on New Zealand organisations' choice of airfreight exports or sea exports will need to consider the price of elasticity of demand and the value of consumers attached to fast delivery. Similarly, as mentioned in Introduction, with the potential challenge to identify the association between the roles of air transport and other transport modes (e.g., maritime transport) on New Zealand's airfreight exports. In this, future research on New Zealand's airfreight exports should consider well-established maritime transport which serves a good substitute for airfreight exports to many international markets during the post-COVID-19 era. With the unique geographic and export features of New Zealand, we hope this study can lead to more in-depth analyses that can provide fresh insights into New Zealand's airfreight exports and air cargo operations in general. In terms of future estimation, the Poisson pseudo-maximum likelihood (PPML) estimator can be an alternative method combined with the OLS-based gravity models to analyse New Zealand's airfreight exports. If we extend our study period beyond the COVID-19 period, the dependent variable (airfreight export) might have a zero value, it will be excluded from the model because the logarithm of zero is undefined (Aydın & Ülengin, 2022). Additionally, the omission of observations with the value of zero of the dependent variable in the OLS-based gravity models may cause significant deviations in the sample selection and generate the biased coefficients when the dataset with zero-valued observations. Therefore, the PPML estimator can be an alternative method as it does not take the logarithm of the dependent variable. Importantly, the bias of PPML-gravity estimator is smaller compared to the OLS-based gravity model and with its better performance (Westerlund, & Wilhelmsson, 2011).

CRediT authorship contribution statement

Kan Wai Hong Tsui: . **Huan Wang:** Data curation, Investigation, Project administration, Validation, Writing – review & editing. **Yan Liu:** Investigation, Project administration, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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