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RESEARCH ARTICLE

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Time for carbon neutrality and other emission reduction measures at European airports

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Abstract

Since 2009, one out of five European airports participate in carbon dioxide (CO_2) reduction programmes, although only 8% of them are certified as CO_2 neutral. This study aims to examine empirically internal as well as external factors of importance for airport participation in emission reduction programmes at different levels of involvement. Estimates of the Cox proportional hazard model based on almost 600 airports for the period 2009 to 2017 reveal that the likelihood and timing of participation increase with the size of the airport (number of passengers), independent of level of commitment. Performance (growth in number of passengers) and if the airport is part of a group are crucial for the advanced levels of the programme. Environmental progress at the country level is also a significant predictor, most distinctly represented by renewable electricity generation, whereas airports serving as hubs for low-cost airlines are less likely to enter the carbon reduction programmes.

KEYWORDS

adoption, airports, Cox proportional hazard model, diffusion, emission reduction programmes, environmental certification programmes, sustainable development

1 | INTRODUCTION

Many firms are increasingly aware of environmental issues, and those dealing with emissions may also be particularly exposed to pressure from interest groups and stakeholders (Nakamura, Takahashi, Vertinsky, 2001; Carter, 2006; King and Lenox, 2000; Vazquez-Brust, Liston-Heyes, Plaza-Ubeda, & Burgos-Jiménez, 2010; Tuppura, Toppinen and Puumalainen, 2016). The aviation sector, for instance, is a growing source of greenhouse gas emissions and air pollution (Macintosh & Wallace, 2009; Masiol & Harrison, 2014; European Union Aviation Safety Agency, 2016).

Since the 1990s, different environmental certifications schemes are available, such as the ISO14000 family and the Eco-Management and Audit Scheme (EMAS), although there is no overall certification for the aviation industry despite general awareness of the need to reduce emissions (Efthymiou & Papatheodorou, 2018). However, this will be changed as from 2021, when the globally agreed on Carbon Offsetting and Reduction Scheme for International Aviation will be in effect.[1] Meanwhile, the industry has the opportunity to take part in international carbon reduction programmes for airports.

Starting in 2009, the carbon dioxide (CO_2) reduction programmes encompass every fifth European airport, although only 8% of them are certified at the highest level possible, as carbon neutral (source: Airport Carbon Accreditation Agency).[2] Airports in the Nordic countries are at the forefront of these environmental standards, with Stockholm Arlanda being the first airport worldwide certified as carbon neutral in 2009. The certification rests on several pillars, including the use of renewable energy, energy conservation and energy efficiency, fuel switch (electrical vehicles in airside, alternative fuels),

[1]https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx.
[2]https://www.airportcarbonaccreditation.org/.

environmentally friendly passenger access to the airport, off-site waste management, sourcing of carbon credits, waste management, and reduction of emissions during aircraft landing and take-off (source: Airport Carbon Accreditation agency).

This study aims to empirically examine internal as well as external factors of importance for airport participation in emission reduction programmes at different levels of involvement (from carbon reduction to carbon neutral). A Cox proportional hazard duration model is used to estimate the likelihood and timing of entrance to the programme. The duration model allows an identification of the main determinants of entering the emission reduction programmes, including both time-varying and time-invariant airport specific features such as size, performance, part of an airport group, ownership, kind of airport (low-cost hub), and country-level measures of progress in emission reduction. Technically, the dependent variable is the number of years the airport resists entering one of the certification programmes. The analysis encompasses information on almost 600 European airports for the period 2009–2017 (see Data Section for sources).

Several studies investigate adoption of or participation in environmental certification and management system programmes as well as carbon reduction initiatives from the perspective of a firm (Darnall, Henriques, & Sadorsky, 2010; Frondel, Horbach, & Rennings, 2008; Halkos & Evangelinos, 2002; Haque & Ntim, 2018; Nakamura, Takahashi, & Vertinsky, 2001; Singh, Jain, & Sharma, 2014; Ziegler & Nogareda, 2009). More specifically, this relates to the EU EMAS (Bracke, Verbeke, & Dejonckheere, 2008; Heras-Saizarbitoria, Molina-Azorín, & Dick, 2011) or the ISO 14001 Environmental ManagementSystems (Chiarini, 2017; Marimon Viadiu, Casadesús Fa, & Heras Saizarbitoria, 2006; Merli & Preziosi, 2018; Morrow & Rondinelli, 2002; Nishitani, 2009). There are also analyses focussing on the adoption of environmental management programmes in industries with high emissions from production of chemicals (King & Lenox, 2000), road freight transport (Oberhofer & Fürst, 2013), construction (Chiarini, 2019), or forestry (Tuppura, Toppinen and Puumalainen, 2016). Environmental certifications are also widespread in the travel and tourism industries, which includes airports (Gössling & Buckley, 2016). A general finding in the literature is that large firms and groups (multinational companies) more regularly participate in environmental management programmes (Morrow & Rondinelli, 2002). Additional factors of importance are management attitudes towards social responsibility, general environmental awareness, regulatory pressure, kind of ownership (public, private, or foreign), and costs of implementation or certification.

Several analyses examine the adoption of and participation in environmental certification of management system programmes at the country level (Daddi, Frey, De Giacomo, Testa, & Iraldo, 2015; Neumayer & Perkins, 2004; Perkins & Neumayer, 2004). Based on such data, literature demonstrates that the number of environmental certifications follows the growth of gross domestic product per capita. The degree of international openness of the country and confidence in environmental associations are also factors of importance, whereas expenditure on education or research and development are not relevant.

However, few studies explicitly focus on determinants of participation in environmental certification programmes for airports, although there are suggestions on evaluation methods. These studies mainly employ qualitative approaches including questionnaires to management and external aviation experts, for instance (Chang & Yeh, 2016; Chao, Lirn, & Lin, 2017; Upham & Mills, 2005). By proposing indicators suggested in literature to a group of experts, the most important dimensions for the environmental protection performance at airports are identified as energy saving, easy access by public transportation, and aircraft carbon management (Chao et al., 2017). Kumar, Aswin, and Gupta (2020) explore criteria for evaluating green performance of airports and find that green policies and regulations are the most important factors. According to Kivits, Charles, and Ryan (2010), a cleaner aviation sector (including aircrafts) may be in need of a different than prevailing infrastructure (fuel provision, fuel storage, aircraft design, engine design, airport planning, etc.).

In a case study of the environmental commitment of Scandinavian airlines, Lynes and Dredge (2006) identifies several drivers of importance: markets, scientific knowledge, political/institutional system, and the social system within and outside the airline, where no single system is considered more important than the other. At that time, customer requests do not appear as an important driver.

Besides the rare use of a dataset including all commercial airports in Europe and the unexplored research question, an additional novelty of this study is methodological, in that a duration model is used instead of the more common approaches Logit or Probit in the eco-innovation literature, as mentioned by del Río, Peñasco, and Romero-Jordán (2016). This implies that both factors affecting the time to event and diffusion over time can be taken into account (for exceptions see Marimon Viadiu et al., 2006; Albuquerque, Bronnenberg, & Corbett, 2007).

The structure of this study is as follows: Section 2 outlines the conceptual background, whereas Section 3 presents the empirical model. Data and descriptive statistics are found in Section 4; the empirical results are revealed in Section 5, and Section 6 concludes.

2 | CONCEPTUAL BACKGROUND

Literature demonstrates that the introduction of environmental management systems may be motivated by external (e.g., pressure from the market and government agencies and markets) as well as internal factors (e.g., conscious managers, operational aspects of the products, and cost minimisation; Heras-Saizarbitoria, Boiral, & Arana, 2016). In line with this, Perkins and Neumayer (2004) highlight internal factors connected with firm efficiency and external or institutional motives related to the social pressure exerted by various actors to persuade business managers to adopt certain practices. There are also suggestions that participation in emission saving systems at one end is used to cover up for less environmentally friendly aspects at the other end of operations, so-called green washing (Delmas & Burbano, 2011).

González-Benito and González-Benito (2005) distinguish four drivers behind the introduction of environmental management systems: operational competitive motives (cost, productivity), commercial competitive motives (market, image, customers), ethical motives, and relationship motives (regulators, local organisations). Several economic or management studies also investigate the determinants of environmental management systems or ISO 14001 adoption (Bracke et al., 2008; Darnall et al., 2010; Frondel et al., 2008; Heras-Saizarbitoria et al., 2011; Merli & Preziosi, 2018; Nishitani, 2009; Tuppura, Toppinen, & Puumalainen, 2016; Ziegler & Nogareda, 2009) and reveal that firm size, private/public ownership, management attitudes towards social responsibility, financial performance, and foreign ownership are crucial aspects. A related literature that focusses on the determinants of eco-innovations or investments find similar evidence (Bönte & Dienes, 2013; Triguero, Moreno-Mondéjar, & Davia, 2016; Ziegler & Nogareda, 2009).

Firm size is commonly regarded as the most important factor for participation in carbon reduction programmes. Most studies demonstrate a significant positive correlation between company size and environmental performance or participation in environmental programmes (Darnall et al., 2010; Etzion, 2007). For instance, results for the manufacturing sector show that larger firms are more likely to introduce EMAS (Frondel et al., 2008). Darnall et al. (2010) also demonstrate that size is related to proactive environmental practices. Participation in emission reduction programmes includes significant sunk costs and additional variable costs as they need to be renewed, something that raises economic barriers particularly for small firms (Darnall et al., 2010). Average cost of implementing EMAS is not fully identified; Vernon, Essex, Pinder, and Curry (2003) suggest an amount of €48,000 the first year and €26,000 each consecutive year, whereas Kube, von Graevenitz, Löschel, and Massier (2019) refer to an initial cost of €20,000 at the median for German manufacturers.

Participation in the carbon reduction programmes may require changes of systems at the airport, as suggested by Kivits, Charles, and Ryan (2010), for instance. Such changes resemble the introduction of process or organisational innovations. Regarded from this perspective, the level of programme adoption can be identified in accordance with the diffusion of innovation theory, which distinguishes among first movers, early adapters, early major, late majority, and laggards (Rogers, 2003).

Based on available literature, factors that are internal as well as external to the firm are expected to be of importance for starting the process towards emission reduction in accordance with the certification programme. However, airports do not represent the average firms, because their services are organised to support the incoming and outcoming flight operations, of which only the ground activities are in the hands of the local management. This raises the question whether the behavioural pattern of airports differs from firms in general.

Costs for the airport emission reduction programmes are unknown but are not expected to be small and would thus be easier for large airports to carry. The introduction of environmental certification schemes might also be more important for sizeable hubs because larger firms are generally more visible, attract more public attention, and therefore operate under higher pressure to maintain an appropriate (possibly even symbolic) level of environmental performance (Etzion, 2007; Jiang & Bansal, 2003; Testa, Boiral, & Iraldo, 2018). Reversely, small firms could be subject to less external public pressure (Jiang & Bansal, 2003). A similar argument can be made for the relationship between participation in carbon reduction programmes and airport performance. Airports with a growing number of passengers are likely to be more profitable than shrinking airports and thus more willing to participate in CO_2 reduction programmes because they can easily afford it. This reasoning leads to the formulation of the first two hypotheses:

H1:. The probability of participating in emission reduction programmes increases with the size of the airport.

H2:. The probability of participating in emission reduction programmes increases with the performance of the airport.

Another important factor for adoption of environmental management systems is the kind of ownership (Darnall & Edwards, 2006), private, public, or belonging to a group. Publicly owned operations may experience pressure from the government to implement emission reduction programmes because they are subject to greater public control. Gangadharan (2006) argues that government-owned firms are extra likely to comply with environmental requirements. There is also evidence that publicly owned firms are more prone to disclose social and environmental information than private ones (Cormier & Gordon, 2001). Contradictory to this, Nakamura et al. (2001) state that the ownership structure is not a relevant driver for the introduction of ISO 14001 in Japan. Morrow and Rondinelli (2002) conclude that firms belonging to a group more regularly take part in environmental management programmes.

Thus, literature indicates that kind of ownership may be of importance, establishing the third and fourth hypotheses:

H3:. The probability of participating in emission reduction programmes is higher if the airport is part of a group.

H4:. The probability of participating in emission reduction programmes is lower if the airport is privately owned.

Another essential aspect that determines the probability and speed of participation in emission reduction programmes is the kind of firm, or, in this case, airport. Airports can be distinguished in several groups: domestic, international as well as low- and regular-cost airports. Low-cost airports are usually characterised by a minimum level of charges and taxes as well as the presence of low-cost airlines. Given that the flight market in general is very competitive with a narrow profit margin (Porter, 2008), the low-cost hubs are expected to be less enthusiastic about emission reduction programmes with high implementation costs, leading to the fifth hypothesis:

H5:. The probability of participating in emission reduction programmes is smaller for airports serving as low-cost hubs.

Beyond local environmental saving efforts, there are also country-level factors and programmes of importance. Studies at the aggregate level find that ISO 14001 implementation is positively correlated with per capita income and pressure from civil society (Neumayer & Perkins, 2004). Airports in countries that make huge progress in achieving sustainability goals are more likely to operate under strong environmental pressure and thus also participate in emission reduction programmes. Green electricity, for instance, is a necessity for the certificate but is more readily available in countries with a high share of renewable energy sources. This leads to the sixth hypothesis:

H6:. The probability of airports entering emission reduction programmes increases by economy-wide progress in emission reduction.

According to the so-called "Porter hypothesis," stricter environmental regulations promote technologies that reduce pollution and emissions of production activities and thus decrease the costs of complying with the regulations (Doran & Ryan, 2016; Porter & Van der Linde, 1995). Therefore, environmental regulations are likely to encourage the use of clean inputs and emission reductions. However, Frondel, Horbach, and Rennings (2007) find no empirical evidence that market-based instruments such as environmental taxes lead to the introduction of clean technologies for selected Organisation for Economic Co-operation and Development (OECD) countries on the basis of production data for manufacturing firms. Given the specifics of airports, careful compliance with regulations is expected, guiding the formulation of the seventh hypothesis:

H7:. The probability of airports entering emission reduction programmes is higher if a carbon tax exists in the country.

Simplified, the duration model approach that captures the determinants of the probability and timing of participation in the airport emission reduction programmes can be illustrated by the airport status in years t_1 to t_n, where t_0 is the year before the certification programme was introduced (Figure 1) and t_1 is the first possible

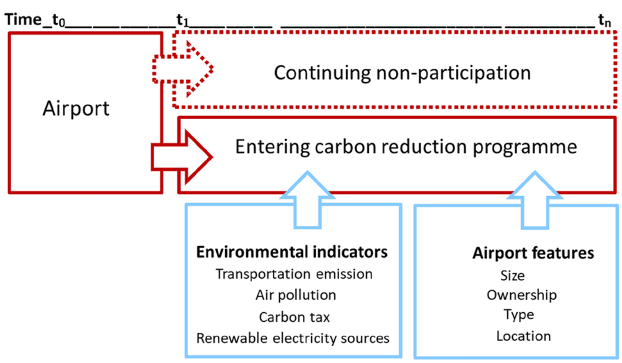


FIGURE 1 Illustration of duration model: Determinants of participation in carbon emission reduction programmes
Source: Own illustration [Colour figure can be viewed at wileyonlinelibrary.com]

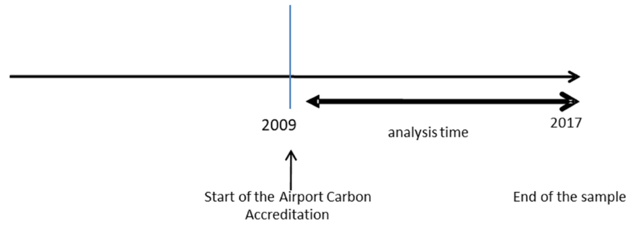


FIGURE 2 Window of analysis
Source: Own illustration [Colour figure can be viewed at wileyonlinelibrary.com]

opportunity to enter. In accordance with the hypotheses formulated, this decision is expected to depend on internal as well as external factors to the airport.

3 | EMPIRICAL MODEL

The duration model describes the probability of entering the carbon emission reduction programme at a certain point in time after t_0, conditional on the status until that year. In this case, the dependent variable is the number of years an airport has refrained from entering the emission reduction programmes after 2008. For the estimations, the Cox proportional hazard model is employed, which evaluates simultaneously the effect of several factors (covariates) on the probability to enter the programme at a certain point in time (Cox, 1972). This hazard ratio $h(t)$ is specified as

$$h(t,\mathbf{X}_i,\mathbf{Y}_{it},\mathbf{Z}_{ct},) = h_0(t)exp(\mathbf{X}_i\alpha,\mathbf{Y}_{it}\beta_1,\mathbf{Z}_{ct}\beta_2),$$

and depends on three vectors of covariates: time-invariant $\boldsymbol{X}_i$ and time-varying variables $\mathbf{Y}_{it}$ at the airport level as well as time-varying factors at the country level $\mathbf{Z}_{ct}$, including a time trend. The baseline hazard is with T = 0 in 2008 and T = 9 in 2017, whereas α, β_1, and β_2 are vectors of coefficients to be estimated. Vector $\boldsymbol{X}$ includes airports that are part of a group and airports close to a capital city, whereas vector $\boldsymbol{Y}$ encompasses (a) the size of the airport, measured as number of passengers, (b) airport growth, measured as the percentage change in number of passengers, and (c) dummy variables for airports serving as hubs for low-cost airlines. Environmental progress at the country level and the time trend are encompassed in vector $\boldsymbol{Z}$.

Right censoring is accounted for. It occurs because the majority of airports still have not entered the emission reduction programmes at the end of the period studied (Figure 2).

4 | DATA AND DESCRIPTIVE STATISTICS

Data for the analysis on participation in the emission reduction programmes originate from the annual reports of the Airport Carbon Accreditation.[3] Information is available on involvement and at

[3]https://www.airportcarbonaccreditation.org/, retrieved October 10, 2019.

TABLE 1 Descriptive statistics (mean values or per cent)

	Time-varying airport characteristics		
	Low-cost hub (%)	Size, passengers	Growth, Δln passengers, (%)
2009	7.4	2,876,991	−13.7
2010	9.2	3,207,472	6.8
2011	11.3	3,826,508	5.7
2012	12.3	3,835,805	0.6
2013	11.7	3,596,388	3.4
2014	13.1	3,712,534	0.9
2015	14.2	3,899,126	3.7
2016	16.0	4,078,010	6.0
2017	17.6	4,516,026	4.4
Mean	12.3	3,520,775	1.8
Median		580,000	3.0

	Country-level environmental indicators			
	Air pollution (PM2.5) Micrograms per cubic metre	Share of renewable electricity (%)	Transport emissions (NO_2) 2000 = 100	Airports in countries with carbon tax (%)
2009	13.2	24.9	68.0	32.3
2010	14.5	27.3	66.4	33.8
2011	15.1	27.6	65.2	35.1
2012	14.1	30.1	61.9	35.0
2013	13.5	33.8	59.2	32.5
2014	13.0	35.4	58.5	48.9
2015	13.1	37.3	57.2	52.2
2016	12.2	38.2	56.0	53.0
2017	12.0	37.5	55.5	55.6

Time-invariant airport characteristics	
Capital city, %	11.0
Private ownership, %	14.9
Part of group, %	27.2
Distance from the nearest city, km	13.5

Proportion of time-airport pairs across countries, %			
AL	0.2	LU	0.2
AT	1.3	LV	1.0
BA	0.2	MD	0.1
BE	1.1	ME	0.3
BG	0.7	MK	0.1
CH	1.6	MT	0.4
CY	0.4	NL	1.1
CZ	1.1	NO	5.1
DE	7.9	PL	2.3
DK	2.2	PT	3.3
EE	0.2	RO	1.5
ES	7.5	RS	0.2
FI	4.9	RU	1.6
FR	9.0	SE	4.6
GE	0.4	SI	0.2

(Continues)

TABLE 1 (Continued)

Proportion of time-airport pairs across countries, %			
GR	8.6	SK	0.4
HR	1.1	TY	7.3
HU	0.3	UA	0.6
IE	1.4	UK	11.2
IS	0.2	XK	0.1
IT	7.7		

Note. The number of observations is 4,064 for the period 2009–2017. Sources: see text in Data section.

what level for the years 2009 to 2017. The certification is based on several pillars: (a) renewable energy use, (b) energy savings and energy efficiency, fuel switching (airside electric vehicles, alternative fuels), (c) environmentally friendly passenger access to the airport, (d) waste management, and (e) reduction of emissions from aircraft arrivals and departures. Based on these pillars, four levels of participation can be distinguished (Airport Carbon Accreditation Agency):

Level 1 mapping: This level confirms that an airport has quantified and independently verified its CO_2 footprints and that its top management has initiated a process to reduce CO_2 emissions through its direct control from year to year by establishing appropriate policies and targets.

Level 2 reduction: This level confirms that an airport has developed and implemented a CO_2 management plan and timetables to achieve its chosen targets and that it has reduced the CO_2 emissions it directly controls in accordance with its general policy.

Level 3 optimisation: This level confirms that the airport has involved its stakeholders working at the airport in the mapping process and encouraged them to reduce their emissions, thereby promoting a broader airport-related emission reduction.

Level 3+ neutrality: This level is designed for airports that have reduced their direct emissions as much as possible and offset residual emissions that cannot be reduced by other means.

Three of the four levels are used to construct the dependent variables for the estimations. Dependent variable A includes levels 2, 3, and 3+; dependent variable B encompasses levels 3 and 3+; and finally, dependent variable C relates solely to level 3+. The mapping level of the programme (1) will not lead to a reduction in CO_2 emissions and is thus excluded from the analysis.

Information about European airports and their number of passengers originates from the Eurostat Avia Database including 597 commercial airports on the European continent during the period 2009–2017 (see Table 1 for a list of countries).[4] An airport serving as a hub for low-cost airlines is defined as one where Ryanair has a base (source: Ryanair Annual reports 2009–2017). Data on ownership and groups stem from the Airport Ownership Yearbook and from the Amadeus database, whereas the country-level indicators on environmental progress are available either at Eurostat or at the OECD (OECD, 2019).[5] Geographical distance between the airport and the nearest city is calculated as road kilometres using Google maps.

Three major environmental performance indicators are selected for this study: (a) air pollution measured as the mean population exposure to particulate matter (PM)2.5 (micrograms per cubic metre), (b) share of renewable electricity in total electricity generation, and (c) pollutant emissions from transport (nitrogen oxides) index (2000 = 100). In addition, information on the existence of a carbon tax is used as an example of market-based environmental regulations and policy awareness at the country level.[6]

The dataset consists of 4,060 year-airport observations in 41 countries during the period 2009–2017. Once the airports enter the emission reduction programme, it automatically disappears from the estimation set. Information on transportation emissions is only available for the European Union 28 (except Greece), and thus, estimations with this variable reduce the size of the dataset considerably.

Descriptive statistics show that in 2017, almost one fifth of European airports participate in carbon reduction programmes (Table 1). However, only 8% of the airports are certified at the highest level possible as carbon neutral (Figure 3).

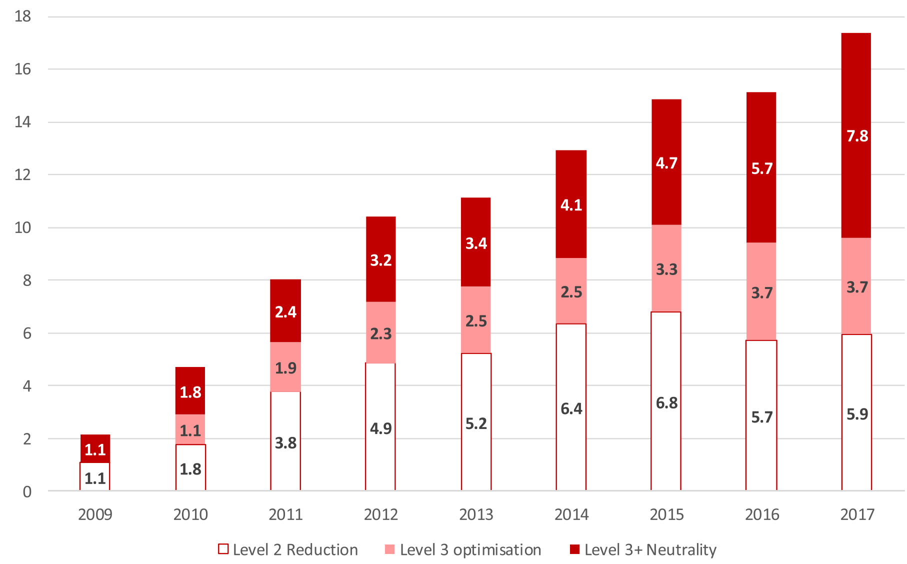
The majority of airports are publicly owned (85%) and approximately one out of four belongs to a group, independent of ownership. Almost every fifth airport serves as a low-cost hub in 2017 as compared with 7% in 2009. The average number of passengers is 3.7 million across airports and over time, whereas the median is 580,000. United Kingdom, France (excluding overseas territories), and Greece account for approximately one tenth each of the time-airport pair observations. The average growth in number of passengers is 2% per year during the period of time studied (Table 1).

Generally, the environmental performance measures reveal improvements over time: Air pollution and transportation emissions

[4]http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=avia_tf_aca&lang=en, retrieved October 10, 2019.

[5]Source: The ownership of Europe's Airports, 2010 and 2016 (www.aci-europe.org), Eurostat https://ec.europa.eu/eurostat/databrowser/view/T2020_RK300/default/table and OECD STAT Exposure to PM2.5 in countries and regions.

[6]Source: World Bank, www.carbontax.org, retrieved October 10, 2019 (World Bank, Ecofys and Vivid Economics, 2018).



Source: Airport Carbon Accreditation Agency; Eurostat, own calculations.

FIGURE 3 Airports participation in emission reduction programmes (percent) Source: Airport Carbon Accreditation Agency; Eurostat, own calculations [Colour figure can be viewed at wileyonlinelibrary.com]

diminish and the share of renewable electricity increases and is close to 40%.

In 2017, 15 European countries have a carbon tax (CH, DK, EE, ES, FI, FR, IE, IS, LV, NO, PL, PT, SE, SI, and UK), which affects almost three out of five airports in the dataset (World Bank, www.carbontax.org). Fisher's tests for the dummy variables and *t* tests for the continuous variables show that certified and noncertified airports differ significantly in characteristics. Participants in the carbon emission programmes are larger, more often part of an airport group, exhibit higher average growth rates, are located close to the capital city, and are found in countries with higher than average progress in environmental performance (Table 2).

To get a preliminary sense of the relationship over time between the different levels of participation and the selected covariates, a set of Kaplan–Meier bivariate survival estimates may be used (Figures A1, A2, and A3). These estimates show how the probability of resisting the programmes (*y*-axis) relates to each variable and segments within it over time (*x*-axis). For instance, the less steep curves in the size graph indicate that large airports have a lower potential for staying outside the programmes than smaller ones. Further, the estimates suggest that airports belonging to a group have higher likelihood of participation. In addition, the graphs also point to the importance of measures to decrease air pollution as well as to increase the share of renewable electricity generation.

TABLE 2 Characteristics of participating and non-participating airports (mean values)

	Geographical distance (km)	Size, passengers	Growth, Δln passengers (%)	Share of renewable electricity (%)	ln air pollution (PM2.5)	ln transport emissions (NO_2) Index 2000 = 100
No certification	13	3,550,943	2.0	32.5	13.4	61.1
Certification levels 2, 3, & 3+	17	12,500,000	3.1	37.6	12.1	59.4
Certification level 3 & 3+	20	17,100,000	6.3	39.0	11.9	55.3
Certification level 3+	20	11,900,000	5.3	45.0	10.9	54.9
t test 2, 3, & 3+ vs. no certification (*p* value)	0.00	0.00	0.11	0.00	0.00	0.00
	Low-cost hub (%)	Part of group (%)	Capital city (%)	Privately owned (%)	Carbon tax (%)	
No certification	12.6	26.3	10.4	14.5	42.1	
Certification levels 2, 3, & 3+	19.8	58.0	33.3	30.9	53.1	
Certification level 3 & 3+	12.0	60.0	!38.0	26.0	52.0	
Certification level 3+	20.6	76.5	32.4	17.6	61.8	
Fisher-test Levels 2, 3 & 3+ vs. no certification (*p* value)	0.06	0.00	0.00	0.00	0.05	

Note. The Fisher's exact test assesses the independence between two dummy variables and the *t* test is controlling for equal mean of the continuous variables. The number of observations is 4,064 for the period 2009–2017 Sources: See text in Data section.

TABLE 3 Determinants of introducing emission reduction programmes at European airports, Cox proportional hazard model

	(i)		(ii)		(iii)		(iv)	
	Estimation A: Certification levels 2, 3, and 3+							
Specification	**H-ratio**	***z*-stat**	**H-ratio**	***z*-stat**	**H-ratio**	***z*-stat**	**H-ratio**	***z*-stat**
Low-cost hub	0.600*	−1.90	0.510**	−2.51	0.521**	−2.13	0.528**	−2.37
Privately owned	1.459	1.17	1.515	1.23	1.303	0.59	1.353	0.84
Size, ln passengers	2.021***	3.80	2.097***	4.59	1.890***	3.05	2.025***	4.05
Growth, Δln passengers	0.571	−0.57	0.708	−0.24	1.202	0.13	0.696	−0.28
Part of group	2.513**	2.13	1.724	1.21	2.338	1.59	2.590**	2.22
Share of renewable electricity	1.014***	2.87						
ln air pollution (PM2.5)			0.174***	−2.71				
ln transport emissions (NO_2)					0.279	−1.50		
Countries with carbon tax							2.160**	2.21
Log pseudolikelihood	−411		−384		−334		−410	
Airports, number	577		521		415		578	
Participating airports, number	80		76		67		60	
Observations, number	3,683		3,397		2,667		3,689	
	Estimation B: Certification levels 3 and 3+							
	H-ratio	***z*-stat**	**H-ratio**	***z*-stat**	**H-ratio**	***z*-stat**	**H-ratio**	***z*-stat**
Low-cost hub	0.208***	−3.17	0.196***	−3.55	0.224***	−4.07	0.179***	−3.57
Privately owned	1.200	0.42	1.208	0.41	1.173	0.30	1.086	0.15
Size, ln passengers	2.822***	3.97	2.718***	4.98	2.411***	3.18	2.676***	4.31
Growth, Δln passengers	4.108***	2.60	4.082***	3.62	3.971***	3.16	3.675***	2.88
Part of group	2.685**	2.13	1.879	1.20	2.837*	1.69	2.901**	2.32
Share of renewable electricity	1.018***	4.13						
ln air pollution (PM2.5)			0.176	−1.44				
ln transport emissions (NO_2)					0.046**	−2.01		
Countries with carbon tax							1.981	1.16
Log pseudolikelihood	−231		−211		−173		−232	
Airports, number	577		521		415		578	
Participating airports, number	50		46		39		50	
Observations, number	3855		3565		2815		3861	
	Estimation C: Certification levels 3+							
	H-ratio	***z*-stat**	**H-ratio**	***z*-stat**	**H-ratio**	***z*-stat**	**H-ratio**	***z*-stat**
Low-cost hub	0.563	−1.31	0.503*	−1.67	0.548	−1.63	0.458	−1.52
Privately owned	0.720	−0.49	0.851	−0.24	0.900	−0.14	0.688	−0.51
Size, ln passengers	1.946***	3.54	1.942***	5.50	1.645***	3.12	1.832***	4.25
Growth, Δln passengers	3.114***	6.64	2.624***	8.20	2.519***	8.54	2.685***	6.69
Part of group	5.510***	2.62	3.599**	1.96	7.141**	2.26	6.068***	2.98
Share of renewable electricity	1.020***	3.48						
ln air pollution (PM2.5)			0.138	−1.19				
ln transport emissions (NO_2)					0.025	−1.63		
Countries with carbon tax							1.929	0.78
Log pseudolikelihood	−166		−151		−119		−169	
Airports, number	577		521		415		578	

(Continues)

TABLE 3 (Continued)

	Estimation C: Certification levels 3+							
	H-ratio	z-stat	H-ratio	z-stat	H-ratio	z-stat	H-ratio	z-stat
Participating airports, number	34		31		25		34	
Observations, number	3,933		3,640		2,877		3,939	

Note. H-ratio means hazard ratio. LR-tests of the proportionality assumption show that the null hypothesis, which states that the hazard rates are proportional over time, cannot be rejected at the 5% level. Estimated by Maximum-Likelihood with standard errors cluster-adjusted at the country level (ranging between 26 and 41 countries depending on the estimation sample).
***significance at 1%.
**significance at 5%.
*significance at 10%.[a]Sources: See data section and own calculations.

5 | ESTIMATION RESULTS

The Cox proportional hazard model estimations show that factors both internal (characteristics) and external (country-level progress in environmental protection) to airports are of importance for the likelihood of introducing emission reduction programmes during the period 2009–2017.[7] Just like in the literature on adoption of environmental and carbon saving programmes in firms (Frondel et al., 2008), size of the airport (large) is an important driver of taking part (Table 3). This is valid for the different levels of participation in the emission reduction programmes. Over time, airports belonging to a group are more likely to enter the programme, as suggested by Darnall and Edwards (2006) as well as by Morrow and Rondinelli (2002) for firms in general. A similar behaviour is valid for growing airports (measured as the change in number of passengers), although only in relation to the advanced programme levels. Airports serving as hubs for low-cost airlines demonstrate a lower likelihood of participating in the certification programmes, possibly partly related to their cost structure, as suggested by Darnall et al. (2010), for instance. Country-level increases in renewal electricity is another prominent variable for all levels of participation.

Because of the possible interdependence among the country-level environmental variables, four different specifications are estimated, one for each of the variables: (i) share of renewable electricity, (ii) air pollution, (iii) transport emissions, and (iv) existence of a carbon tax.

The hazard ratio indicates whether the variable in question affects the probability of entering the emission reduction programmes. A ratio higher (lower) than 1 implies an increased (decreased) hazard. The *z*- statistics are based on standard errors clustered across countries and report the significance level of the estimate. Size of the airport is an important factor for participation in the emission reduction programme independent of level and specification. The larger the airport, the higher the probability of entering. The estimates show that the likelihood to participate in any level of the carbon emission programme is two to three times as high for airports one unit larger than the sample median of 580,000 passengers (Specification i). A growth in the number of passengers at the airport by one unit (say from the mean of 1.8% to 2.8%), all other variables held constant, means that the rate of participation in the two higher levels of certification increases by a factor of 3.1 or 4.1, respectively (Specification i).

Being part of a group is also crucial for involvement. The dummy variable is significant at the 5% level in two thirds of the estimations and reaches the largest magnitude for the highest level of the programme. For specification (i), the hazard ratio ranges between 2.5 and 5.5, implying that these airports have a probability between 2.5 and 5.5 times higher to participate in the programmes as compared with the group of independent airports at any point in time. This pattern is plausible, because belonging to a group normally means that there are more financial resources available than for independent firms (airports). A similar pattern is valid for the growth rate, although only for the more advanced certification levels (3 and 3+, 3+).

There is a lower likelihood of participation in carbon emission programmes for airports serving as hubs for low-cost airlines. The hazard ratio for the dummy variable ranges between 0.18 and 0.60 indicating that the probability of involvement is between 40% and 62% lower for low-cost hubs. However, separate estimations of the highest level of participation (carbon neutral airports) show that the effect of the low-cost hub dummy variable is no longer significant at conventional levels (Estimation C: Certification level 3+).

Single country progress in environmental protection is also a major factor affecting the participation in carbon reduction programmes. The share of renewable electricity generation is highly significant for all programme levels (Specification i), with a hazard ratio of 1.01 or 1.02. This indicates that an increase in the share of renewable electricity generation by 1 unit (from the sample mean of 32% to 33%) is associated with a 1.4% rise in the probability to participate in the carbon reduction programmes, independent of level. The magnitude of the relationship changes to 2.0% for the carbon neutrality level (Estimation C: Certification level 3+). The shift towards renewable electricity generation over time is therefore one important explanation behind the increased participation in the carbon reduction programmes. This result coincides with a high level of green electricity production at the beginning of the sample period (such as in Finland, Norway, Sweden, and Switzerland) or with a significantly increased

[7]The stcox command in STATA 15.1 is used to obtain the estimates.

TABLE 4 Determinants of introducing emission reduction programmes at large European airports, Cox proportional hazard model

	(i)		(ii)		(iii)		(iv)	
	Estimation A: Certification levels 2, 3 and 3+							
Specification	H-ratio	z-stat	H-ratio	z-stat	H-ratio	z-stat	H-ratio	z-stat
Low-cost hub	0.594*	−1.87	0.497**	−2.56	0.489**	−2.41	0.520**	−2.44
Privately owned	1.276	0.88	1.287	0.78	1.208	0.51	1.228	0.63
Size, ln passengers	2.768***	7.10	2.715***	7.16	2.881***	5.20	2.692***	6.61
Growth, Δln passengers	0.310	−1.02	0.439	−0.53	0.766	−0.14	0.466	−0.65
Part of group	1.784	1.47	1.474	0.84	1.492	0.77	1.919	1.57
Share of renewable electricity	1.017***	3.76						
ln air pollution (PM2.5)			0.295	−1.43				
ln transport emissions (NO_2)					0.643	−0.58		
Countries with carbon tax							1.804*	1.65
Log pseudolikelihood	−311		−291		−240		−313	
Airports, number	278		252		198		279	
Participating airports, number	68		64		55		68	
Observations, number	1,831		1,688		1,379		1,837	
	Estimation B: Certification levels 3 and 3+							
	H-ratio	z-stat	H-ratio	z-stat	H-ratio	z-stat	H-ratio	z-stat
Low-cost hub	0.200***	−3.19	0.190***	−3.60	0.219***	−3.96	0.180***	−3.48
Privately owned	1.288	0.62	1.257	0.51	1.304	0.54	1.222	0.40
Size, ln passengers		6.45	3.002***	6.46	2.797***	4.33	2.997***	6.34
Growth, Δln passengers	6.793***	2.56	6.544***	3.69	6.491***	3.89	5.829***	3.03
Part of group	2.332**	2.14	1.833	1.12	2.301	1.61	2.549**	2.30
Share of renewable electricity	1.019***	3.62						
ln air pollution (PM2.5)			0.269	−1.10				
ln transport emissions (NO_2)					0.079**	−2.21		
Countries with carbon tax							1.618	0.92
Log pseudolikelihood	−198		−181		−144		−201	
Airports, number	279		253		199		280	
Participating airports, number	46		42		35		46	
Observations, number	1,966		1,819		1,490		1,972	
	Estimation C: Certification levels 3+							
	H-ratio	z-stat	H-ratio	z-stat	H-ratio	z-stat	H-ratio	z-stat
Low-cost hub	0.561	−1.36	0.576*	−1.78	0.503*	−1.69	0.478	−1.51
Privately owned	0.759	−0.42	1.042	0.06	0.876	−0.20	0.756	−0.40
Size, ln passengers	1.995***	4.59	1.629***	2.68	1.888***	5.49	1.824***	4.44
Growth, Δln passengers	5.906***	3.82	4.961***	5.65	4.338***	3.48	4.856***	4.42
Part of group	4.548***	2.64	5.413**	2.20	3.263*	1.77	5.013***	2.89
Share of renewable electricity	1.021***	3.85						
ln air pollution (PM2.5)			0.028*	−1.67				
ln transport emissions (NO_2)					0.218	−0.94		
Countries with carbon tax							1.500	0.55
Log pseudolikelihood	−138		−126		−94		−141	
Airports, number	279		253		199		280	

(Continues)

TABLE 4 (Continued)

	Estimation C: Certification levels 3+							
	H-ratio	z-stat	H-ratio	z-stat	H-ratio	z-stat	H-ratio	z-stat
Participating airports, number	30		27		21		30	
Observations, number	2044		1894		1552		2050	

Note. H-ratio means hazard ratio. Tests of the proportionality assumption show that the null hypothesis, which states that the hazard rates are proportional over time, cannot be rejected at the 5% level. Estimated by Maximum-Likelihood with standard errors cluster-adjusted at the country level (ranging from 26 to 41 countries).
***significance at 1%.
**significance at 5%.
*significance at 10%.[a]Sources: see data section and own calculations.

share (Denmark, Germany, Ireland, and the United Kingdom).[8] The alternative environmental and policy indicators air pollution (Specification ii), transport emissions (Specification iii), and the dummy variable for countries with a carbon tax (Specification iv) are only partly significant. Air pollution measures and the existence of a carbon tax are significant at the 5% level for the initial levels of the programme, but not for the more advanced levels.

In summary, the estimations reveal that airport commitments to change the internal processes and organisation in line with the emission reduction programmes are related, by and large, to similar factors as for firms in general. Although the relationships vary across stages of participation in the carbon emission reduction programmes, only one out of seven hypotheses may have to be rejected. While size of the airport is important for all levels, growth and belonging to a group are more crucial for the advanced stages and some of the environmental variables (except renewable electricity sources), and the carbon tax are mainly relevant for the initial phase. However, private ownership is not related to participation at conventional significance levels, as opposed to the expectations.

Whilst overall participation in the carbon emission programme is relatively low, several airports, including also some of those participating in the programme, have expansion plans for both terminals and runways (source: selected annual reports of major airport operators).[9] This could raise the question about the so-called "green washing," that is, whether airports make efforts to reduce ground emissions in an attempt to hide the general increase in air pollution. Literature documents cases of greenwashing activities (Delmas & Burbano, 2011; Testa, Miroshnychenko, Barontini, & Frey, 2018), and symbolic environmental strategies are widespread (Hyatt & Berente, 2017; Testa, Boiral, & Iraldo, 2018). However, an opposite scenario might be valid too, in that airports are not even allowed to apply for permission of expansion until they have cleaned away the ground emissions. Green process innovations, such as carbon emission reduction programmes may also enhance the green image of the airports among stakeholders and clients. A green image, characterised by environmental commitment and awareness, is becoming increasingly important for firms (Xie, Zhu, & Wang, 2019).

Several robustness checks are undertaken to validate the results. Given that size is a main indicator of participation in the certification programme, large airports are estimated separately, singled out as those larger than the median number of passengers (580,000). The estimations based on this subgroup confirm the general findings: Participation in the programmes is significantly higher for airports that are large, are part of a group, and have a growing number of passengers (Table 4) Low-cost hubs are less likely to participate. In contrast to the overall results, the environmental variables predict participation to a lower degree and being part of a group is markedly less important, particularly for the lower levels, possibly because the benefits of affiliation are smaller for already large firms.

Estimations are also performed for the early years of the programme (2009–2012) in order to explore if factors of importance for entering the emission reduction programmes are different for the early movers, but they are not. Instead of the environmental indicators at the country level, an air quality measure at the disaggregated level is tested (Source: the OECD, Exposure to PM2.5 in Functional Urban Areas and in macro and micro regions available for the period 2010–2017). This attempt only renders weakly significant relationships for the total dataset (Estimation A). The results could stem from the fact that the air quality data are highly volatile at a finer geographical level or that this is indeed the wrong level for environmental measures to impact. Non-reported robustness results are available upon request.

Several alternative factors are also considered as control variables, but are not included in the final specification because they are not significantly different from zero at conventional levels. These include the vicinity of a capital city and geographical distance to the airport from the nearest city.

6 | CONCLUSIONS

This study provides first empirical evidence on factors that affect the likelihood of participation in emission reduction programmes for European airports. These programmes started in 2009 and, by 2017, close to every fifth of the 597 commercial airports in Europe

[8]Source: World Bank, www.carbontax.org, retrieved October 10, 2019.
[9]See for instance Finavia annual reports, https://www.finavia.fi/en/about-finavia/financial-information/annual-reports (accessed December 2, 2018) and Swedavia annual reports, https://www.swedavia.com/about-swedavia/financial-information/ https://www.finavia.fi/en/about-finavia/financial-information/annual-reports (accessed December 2, 2018).

participates. Only a few airports are certified at the highest level of participation, as climate neutral (8%). Estimations of a Cox proportional hazard duration model with both time-varying and time-invariant variables show that airport internal (characteristics) as well as external (country-level progress in environmental protection) factors affect the probability of entering the programmes. Large airports, fast growing airports, and those that are part of a group are more likely to take part in the carbon reduction certification programmes. The role of size is robust with respect to different levels of participation, whereas being part of a group and performance is more relevant for the advanced levels. Airports that serve as low-cost hubs exhibit a significantly lower probability of participation in carbon emission reduction programmes. Indicators that measure progress in environmental progress at the country level are also aspects of importance for the decision on participation, most distinctly represented by renewable electricity generation.

Several policy implications can be derived from the study. The participation rate in the programmes is still low, and the speed of adoption is slow compared with country-level progress in environmental protection, for instance. Expressed by innovation terminology, this establishes a participation level of first movers or early adopters. Policymakers might need to find something that triggers the participation rate. Airports put under the highest competitive pressure, that is, small airports or low-cost hubs are less engaged in these standards. Thus, decreased barriers relating to costs as well as tools needed for being allowed entrance to the certification programme are of importance. Less costly certification schemes could be offered for smaller airports and access to green electricity facilitated, for instance.

Carbon neutrality might be seen as a paradox, given that airports provide ground service for an emission enhancing industry. Although research and development has not yet managed to make plane engines cleaner, this should not hinder other related areas or industries from taking such actions.

This study is affected by several limitations. First, the relationship between participation on the one hand and size and performance on the other cannot be interpreted as causal because environmental certification may lead to more customers, and thus, there might be a two-way relationship. Second, the analysis does not include the whole aviation industry, only the airports. There is also a geographical limitation to airports on the European continent, and thus, it is unclear if results can be generalised for other parts of the world. Further, there is limited information on the airport specific characteristics, which future work needs to integrate (for instance, information on shareholders) and possibly also to extend the study beyond Europe. Another interesting avenue for future research would be to model the decision to cease the participation in the programmes. As a methodological novelty, the competing-risks-duration can be used for three types of participation simultaneously.

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APPENDIX A

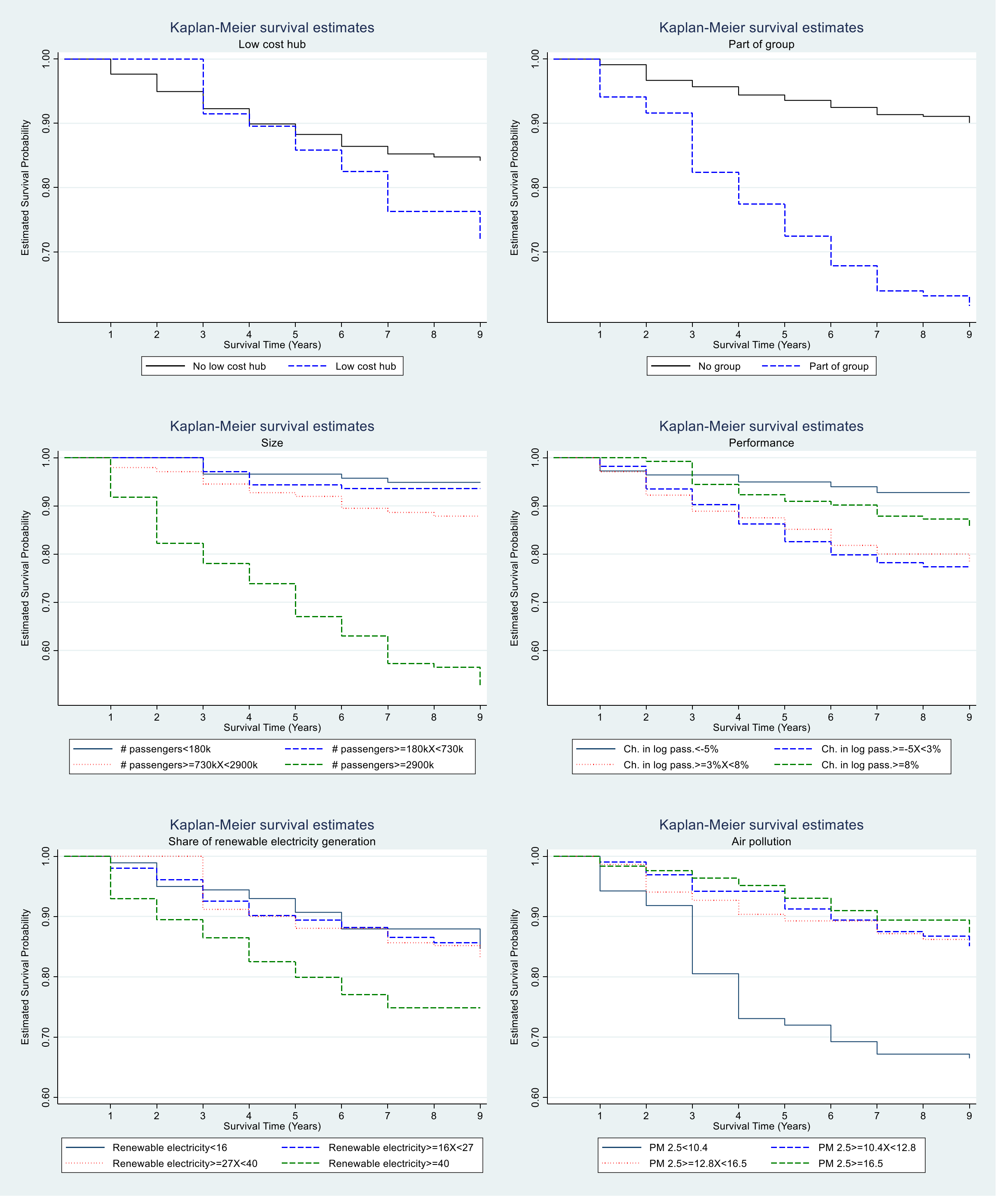

FIGURE A1 Kaplan–Meier estimates (Participation in emission reduction programmes (levels 2, 3, and 3+) [Colour figure can be viewed at wileyonlinelibrary.com]

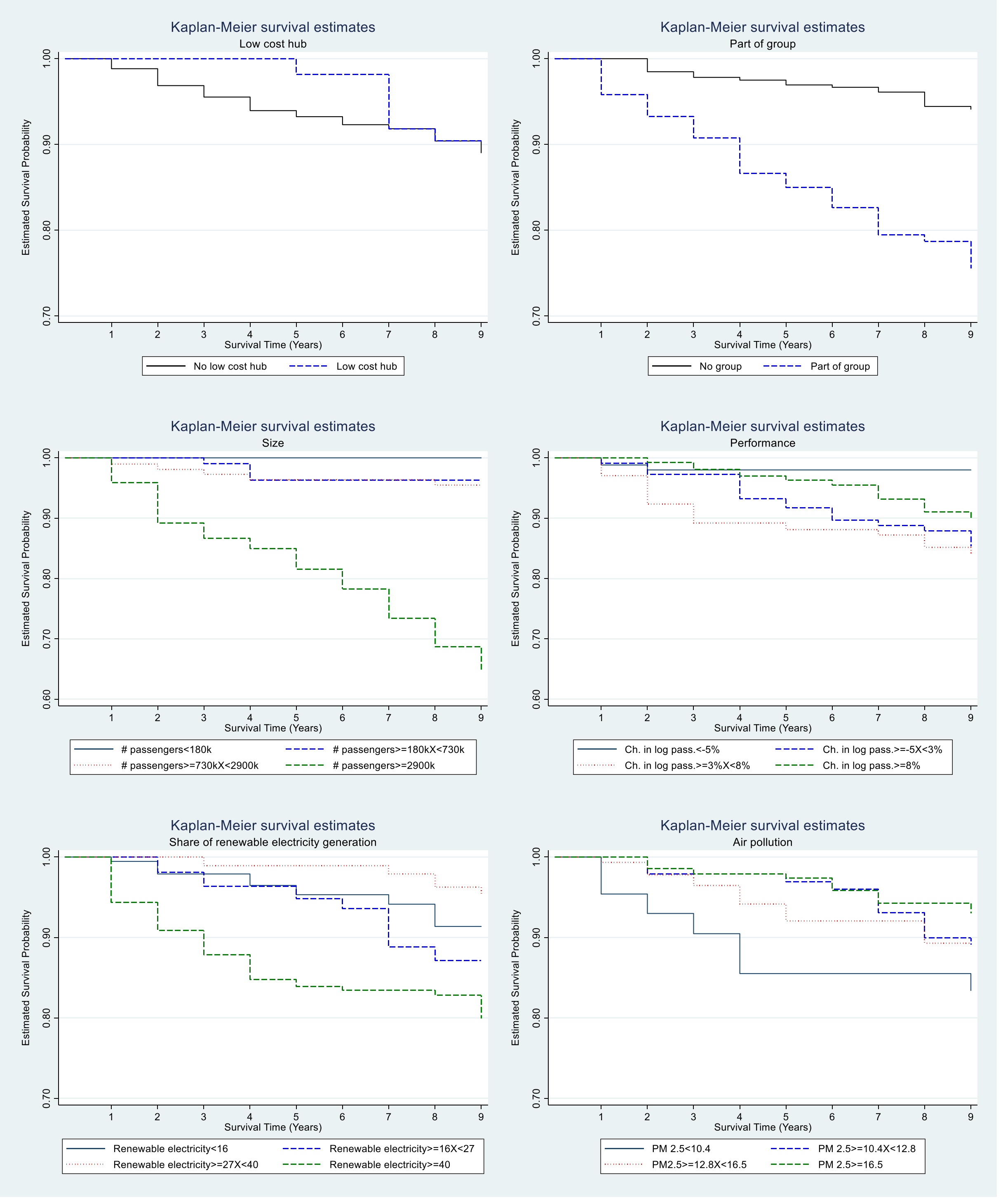

FIGURE A2 Kaplan–Meier estimates (levels 3 and 3+) [Colour figure can be viewed at wileyonlinelibrary.com]

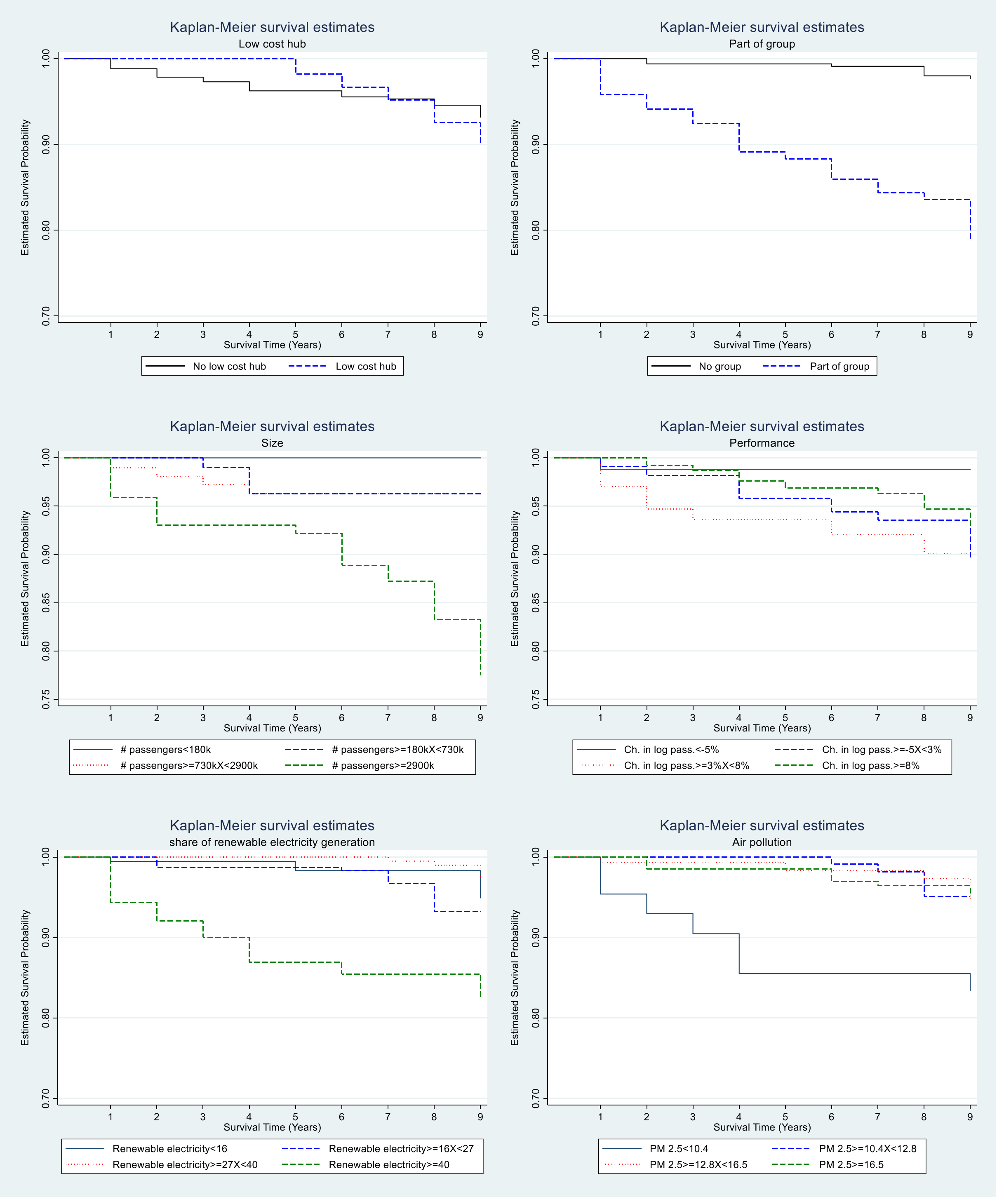

FIGURE A3 Kaplan–Meier estimates (level 3+) [Colour figure can be viewed at wileyonlinelibrary.com]