

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Economics of Transportation

journal homepage: www.elsevier.com/locate/ecotra

The impact of carbon pricing on tourist destinations: Shifts in demand, supply and emissions in the European aviation market

Xavier Fageda ^a, Katrin Oesingmann ^{b,*}

^a Department of Econometrics, Statistics and Applied Economics, University of Barcelona, Avinguda Diagonal, Edifici 690, 08034, Barcelona, Spain

^b Institute of Air Transport - Department of Air Transport Economics, German Aerospace Center (DLR), Linder Hoehe, 51147, Cologne, Germany

ARTICLE INFO

Keywords:

Carbon pricing
Aviation
Tourism
Difference-in-Differences
EU ETS

ABSTRACT

This paper provides novel evidence of the impact of the European Union Emissions Trading System (EU ETS) as applied to the aviation sector on tourist destinations. We use annual data at the route level for the period 2010–2022 and consider a sample comprising a large set of European cities of origin, on the one hand, and tourist destinations in Europe, North and West Africa and the Middle East, on the other. We apply a difference-in-differences analysis to a matched sample and find that the EU ETS has led to less emissions, less flights and to a lower extent less seats. In contrast, we do not find a negative impact of the EU ETS on passenger numbers. While the attractiveness of tourist destinations in Europe does not seem to have been affected by the EU ETS, our results suggest that it has promoted greater efficiency in airline operations.

1. Introduction

The European Union Emissions Trading System (EU ETS), established in 2005, is the main market-based instrument for reducing greenhouse gas (GHG) emissions in the EU, Norway, Liechtenstein and Iceland, which together make up the European Economic Area (EEA). The EU ETS covers GHG emissions within the EEA produced by energy-intensive activities, including cement, aluminum and steel production, the power generating sector and aviation. As of 2012, it was to include carbon dioxide (CO₂) emissions from domestic and international aviation originating or terminating in the EEA; however, due to international pressure and to give the International Civil Aviation Organization (ICAO) time to develop a global framework for aviation emissions, its scope was temporarily reduced in 2013 to cover just intra-EEA flights. However, emissions from the aviation sector continue to represent a considerable challenge. Indeed, emissions under the EU ETS actually grew by 44 % between 2013 and 2019, driven by increased passenger numbers, while they were only temporarily reduced as a result of the COVID-19 pandemic (EEA, 2024).

All in all, this places the aviation sector under considerable pressure, especially as other sectors in the EU have managed to reduce their emissions since 1990 and are well in line with the Kyoto Protocol

emission reduction targets. Globally, aviation accounts for about 2–3 % of CO₂ emissions (IPCC, 2018), while in the EU this figure had risen to about 4.4 % in 2019. In addition to CO₂ emissions, aviation contributes to global warming through the formation of heat-trapping contrails and cirrus clouds, which, in conjunction with other factors, increase the climate impact three-fold (Lee et al., 2021). International tourism, in particular, is affected by these negative environmental effects, since it can typically involve energy-intensive cross-border transportation. Indeed, a significant proportion of the climate-relevant emissions associated with tourism come from transport, above all from aviation which is responsible for 40 % of total CO₂ emissions in the tourism sector. While tourism represents a major industry in many countries, accounting for 10 % of global GDP and 10 % of global employment, and providing numerous opportunities for socio-economic development, it also has negative impacts, including GHG emissions, other forms of pollution, noise exposure and associated negative socio-economic impacts due to over-tourism (World Tourism Organization & OECD, 2019).

From an economic perspective, emissions can be considered external production and consumption costs that cause environmental and climate damage, as well as being detrimental to individuals. This damage generates costs that are not reflected in market prices. Market-based instruments, such as ETSs and carbon taxes, are designed to internalize

* Corresponding author.

E-mail address: katrin.oesingmann@dlr.de (K. Oesingmann).

<https://doi.org/10.1016/j.ecotra.2025.100414>

Received 7 October 2024; Received in revised form 20 February 2025; Accepted 4 April 2025

Available online 17 April 2025

2212-0122/© 2025 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

these externalities by assigning a price to the damage caused. Such price adjustments lead to higher costs, which should reduce supply and demand and, thus, emissions. They should also incentivize a shift towards technologies that reduce or mitigate these externalities, thereby promoting more sustainable development.

This paper provides novel evidence of the impact of the EU ETS as applied to the aviation sector on tourist destinations. We consider a comprehensive set of output indicators: Passenger numbers, CO₂ emissions, flights and seats. Our specific research goals include an analysis of the effectiveness of the policy and its effects on the tourist attractiveness of EEA destinations. To address these concerns, we use annual data at the route level for 2010–2022, considering a sample made up of a large set of European cities of origin, on the one hand, and tourist destinations in Europe, North and West Africa and the Middle East, on the other. By means of a difference-in-differences analysis applied to a matched sample, we find that the EU ETS has led to less emissions, less flights and to a lower extent less seats as compared to the contrafactual. In contrast, we do not find a negative impact of the policy on passenger numbers. Overall, we provide evidence that airlines are offsetting the scheme through greater efficiency as they operate with bigger and fuller planes. Furthermore, the attractiveness of tourist destinations in Europe does not seem to have been affected by the policy.

The rest of the paper is structured as follows: Section 2 outlines the features of the EU ETS, while Section 3 reviews the extant literature on the impact of carbon instruments on tourism and the aviation sector. Section 4 describes the data used, while Section 5 outlines in detail the empirical strategy. Section 6 presents the main results of the empirical analysis, and Section 7 concludes.

2. The EU ETS and aviation

The aviation sector was first included within the EU ETS in 2012. However, in the following year, a temporary deferral was introduced in the original scope of the EU ETS. This adjustment was made in response to steps taken by the ICAO to implement a global policy measure. As a result, the EU ETS only applies to flights within the EEA. Since 2021, the EU ETS is linked to the Swiss and UK ETS. Flights from the EEA to Switzerland (CH) or the United Kingdom (UK) are subject to the EU ETS, while flights from CH or the UK to the EEA are subject to the respective national ETS.

In addition to this change in scope (i.e. intra-EEA/CH/UK flights only), the EU ETS is affected by several other important (temporary) exceptions. European Directive 2003/87/EC establishes the legal framework for the EU ETS, and not all regions, airports or routes officially included within the EEA are covered by the EU ETS (European Union, 2024). Exempt from the EU ETS and, thus, from the obligation to surrender allowances for the emissions associated with flights to these airports are the so-called outermost regions of the EU. The EU recognizes nine such regions, which are geographically distant from the European continent. They include the Canary Islands (Spain), the Azores and Madeira (Portugal) and various French overseas territories, including Guadeloupe and La Réunion.¹ Until the end of 2023, flights from any EEA-member airport to one of these outermost regions were exempt from the EU ETS, and thus heavy traffic flows from the EEA to popular tourist destinations such as Tenerife and Gran Canaria were excluded. Since 2024, these exemptions were restricted and applied solely to flights within or between these outermost regions and to flights from/to the corresponding national mainland airport, such as flights from

¹ The nine outermost regions of the EU are French Guiana, Guadeloupe, Martinique, Mayotte, Réunion and Saint-Martin (France); Azores, Madeira (Portugal); Canary Islands (Spain). Specific measures and provisions in EU legislation are aimed to help these regions tackle the challenges they face due to their remoteness, insularity, small size, difficult topography, climate, and economic dependence. See: European Commission (2024).

Madrid to Tenerife (European Union, 2024).²

Since the inclusion of aviation in the EU ETS, 82 % of allowances allocated to the aviation sector have been provided for free. Aviation emissions have consistently exceeded the sector's cap (except during the COVID-19 years of 2020 and 2021), requiring the aviation sector to purchase additional allowances from other sectors. Approximately 55 % of all allowances had to be purchased, resulting in aviation becoming a net-buyer of allowances within the EU ETS (EEA, 2024). To address the dangers of carbon leakage, the EU ETS provides free allowances to sectors deemed to be at particular risk. Such a risk arises because the EU ETS concerns itself with production as opposed to consumption, which means entities are required to either purchase allowances or reduce their direct emissions through changes in their production processes. The allocation of free allowances seeks to mitigate the competitive disadvantage that might result from these carbon costs and to prevent the shifting of production to regions with less stringent emissions regulations (Clò, 2010).

Unlike other sectors in the EU ETS, aviation has struggled to achieve emission reductions. In response, the EU has opted to reform the system of allowances in this sector. Thus, free allowances are to be gradually reduced, cutting the current total by 25 % in 2024 and phasing them out altogether by 2026. Additionally, the annual linear reduction factor for the total number of allowances permitted under the EU ETS is set to increase from 2.2 to 4.3 % in 2024, and to 4.4 % as of 2028 (European Union, 2024). This adjustment is likely to intensify pressure on the cap-and-trade system and potentially raise the market price of allowances. These changes are designed to enforce more effectively the "polluter pays" principle and ensure that it is the companies that bear the greatest share of the costs attributable to their emissions. Moreover, there is evidence that companies have been taking advantage of the system by way of so-called "windfall profits" and that free allowances are discouraging advances in emission-reducing technologies (Müller and Teixidó, 2021).

3. Literature

The extant literature addressing the specific issue studied here is rooted in the impact of carbon policies and taxes on both tourism and aviation, given that air transport accounts for around 40 % of tourism-related emissions. The impact of environmental policies on tourism demand and tourism-related emissions has, to date, focused on the effects of various forms of carbon taxes, tourism taxes and (air) passenger taxes. A number of studies have also looked at the impact of ETSs. However, most of this literature exploits simulation studies, while only a few address the question empirically. Among the latter, empirical analyses have examined the impact of both taxes and the EU ETS on air transport demand, supply and emissions. Their findings indicate that passenger taxes reduce air transport demand; yet, the impact of the EU ETS on these demand levels are found to be limited, albeit that emission reductions have been recorded.

3.1. Tourism literature

Early simulation studies of the impact of air passenger charges and carbon taxes in the United Kingdom (UK) on international air traffic found that these measures had relatively small effects on total tourism numbers (Mayor and Tol, 2007; Tol, 2007). The impact of the possible

² Note, moreover, that overseas countries and territories associated with the European Union – e.g. Greenland and Aruba – are permanently excluded from the EU ETS. Additionally, special rules apply to specific airports: e.g. flights to/from the Basel-Mulhouse-Freiburg Euro Airport are subject to the EU ETS because the airport is situated in French territory, while Ercan airport in Cyprus is treated as a non-EU airport, as it is located in the Turkish Cypriot north of the island.

inclusion of aviation in the EU ETS and of taxes restricted to European air travel were found to have a larger effect on total tourism numbers (Mayor and Tol, 2010). However, the studies also find that such measures tend to distort passenger behavior, resulting in a shift of emissions to regions that are less affected or not subject to the same regulations. Seetaram et al. (2014) empirically examine the impact of the UK air passenger duty on outbound tourism demand for different international destinations using an autoregressive distributed lag model. The authors conclude that the effectiveness of the measure has been limited, as travelers are generally willing to pay more to maintain their travel plans. This finding is in line with Denstadli and Veisten (2020), who study the willingness of Norwegian leisure air travelers to pay higher carbon taxes than those included in their ticket price. Their results indicate that Norwegian outbound tourists are willing to accept higher additional charges.

Dwyer et al. (2013) predict that a carbon tax imposed on the Australian industry will reduce GDP, consumption, and employment, with most tourism sectors experiencing a small but notable decline in output. Similarly, Meng and Pham (2017) find a significant drop in both inbound and domestic tourism demand when simulating the impact of a carbon tax, highlighting that such a tax is highly effective in reducing emissions. Zhang and Zhang (2018) use a computable general equilibrium model to simulate the effects of a carbon tax policy on carbon emissions and economic welfare in China's tourism industry. The results indicate that a carbon tax policy could significantly impact tourism-related carbon emissions and economic welfare, with varying effects over time and across different sectors. Zhang and Zhang (2020) empirically analyze the effects of the ETS on tourism-related CO₂ emissions and carbon intensity using a difference-in-differences model. Their findings indicate that the ETS reduces both tourism-related CO₂ emissions and tourism carbon intensity, with these impacts expected to grow over time. Meng et al. (2021) also simulate the short-run effects of an ETS on the Chinese tourism industry. The results indicate that an ETS alone increases energy prices and has a significant adverse impact on China's economy, with the energy sectors experiencing stronger negative impacts than tourism.

Wang and Xi (2023) analyze whether the EU ETS impacts tourism by regulating energy-generating industries. Findings indicate that the EU ETS leads to a significant decline in visitor arrivals from Member States, primarily due to increased transportation expenditures from rising energy prices. The system's effects on international tourism vary by distance, with travelers opting for shorter international trips to mitigate higher travel costs. Boto-García et al. (2024), drawing on data from 26 European countries between 2005 and 2019, investigate how carbon prices within the EU ETS affect tourism demand. Their study finds a 'V'-shaped pattern: tourism arrivals drop by 2.5 percentage points within the first three months after a carbon price shock but rebound to the trend after six months. These results highlight the dynamic response of tourism to carbon pricing policies.

3.2. Aviation literature

Empirical evidence of the impact of passenger or flight ticket taxes on aviation demand is well-documented. Falk and Hagsten (2019) find that the flight departure tax introduced in Germany and Austria in 2011 reduced passenger numbers by 9 % in the first year and 5 % in the following year, based on dynamic panel difference-in-differences estimations. Markham et al. (2018) assess a carbon tax implemented in Australia between 2012 and 2014 and find no evidence that it reduced domestic aviation levels, suggesting that higher carbon pricing might be needed to effect behavioral change. Oesingmann (2022) finds that the German and Austrian passenger ticket tax decreased demand on intra-EEA routes by 4–12 %, depending on whether a dummy variable or the actual price was used as the policy variable. Finally, Bernardo et al. (2024) show that flight ticket taxes significantly impact low-cost airlines, reducing the number of flights per route by 12 % and leading to a

14 % reduction in carbon emissions.

Only a few studies have provided ex post econometric evidence of the EU ETS's impact on the aviation sector. Using standard impact evaluation techniques such as difference-in-differences and synthetic control, these studies report expected airline supply responses, including reduced flight frequencies and higher fares as compared to the counterfactual (Fageda and Teixidó, 2022; Kang et al., 2022; Santonja et al., 2023). For instance, Fageda and Teixidó (2022) note a 5 % emission reduction on ETS routes compared to counterfactuals, while Kang et al. (2022) find a 20 % reduction in total seat numbers, primarily due to fewer flights. Fageda and Teixidó (2023) observe a reduction in emission intensity due to more efficient aircraft and retrofit actions. Similarly, De Jong (2022) finds that the EU ETS has promoted a faster renewal of narrowbody aircraft. Zhang and Wang (2024) report a strong supply effect in domestic markets, and Santonja et al. (2023) find full cost pass-through in airline pricing. However, any direct impact on passenger numbers remains unclear; for example, Oesingmann (2022), when applying gravity modelling techniques, finds no significant effect of the EU ETS on intra-EEA total passenger numbers.

4. Data

4.1. Sample

The EU ETS has effectively been applied to flights within the EEA from 2013 onwards. However, as discussed, there are geographical exceptions in its application that we exploit in the analysis reported here. Air services from continental EEA to the EU's outermost regions and between, but not within, the outermost regions are excluded in the period considered. This means that highly relevant tourist destinations within the EU – most notably the Azores, the Canary Islands and Madeira – are not included in the EU ETS.³

Here, we use annual data for the period 2010–2022 at the route level, i.e. the city-pair market; thus, multi-airport cities are considered as a single origin and/or destination. For example, the city-pair market Rome-Alicante includes flights from the airports of Rome-Ciampino and Rome-Fiumicino to Alicante. Our sample includes a high number of both cities of origin and destination. The cities of origin are made up of 635 cities in the EEA (plus the UK), all of which are cities that operated passenger flights in at least one year during the study period.

The destination cities are made up of 114 leading tourist destinations in Europe, North and West Africa and the Middle East (see Table A1 in the Appendix for the list of these cities). Fig. 1 shows the tourist destinations making up our sample, divided between treatment and control group destinations. Only seven of these cities are not located close to a beach area (that is, Cairo, Fez, Istanbul, Luxor, Marrakech, Samsun and Trabzon). Countries with cities considered as being major tourist destinations are assigned to the following regions: 1) Western Europe (Croatia, France, Greece, Italy, Malta, Portugal and Spain); 2) Eastern Europe (Albania, Bulgaria, Cyprus, Montenegro and Turkey); 3) North Africa (Egypt, Morocco and Tunisia); 4) West Africa (Cape Verde), and 5) Middle East (Israel, Jordan and Lebanon). It should also be noted that 68 cities among the EEA countries are covered by the EU ETS, while 46 cities in Africa, the Middle East, Eastern Europe (along with the cities of the Azores, Canary Islands, Madeira and the Turkish part of Cyprus) are not covered by the EU ETS in our timeframe of analysis.

Treated routes are, therefore, all routes within the EEA, i.e. routes where both endpoints lie in EEA countries. However, as discussed, routes for which the destination lies in the Azores, Canary Islands or Madeira are exceptions and, hence, they form part of the control group. Control routes also include those that link an EEA city with a non-EEA city. We then apply the logic of the difference-in-differences estimator

³ Furthermore, the territories of certain Member States, including Greenland, the Faroe Islands, French Polynesia and Svalbard, are also excluded.

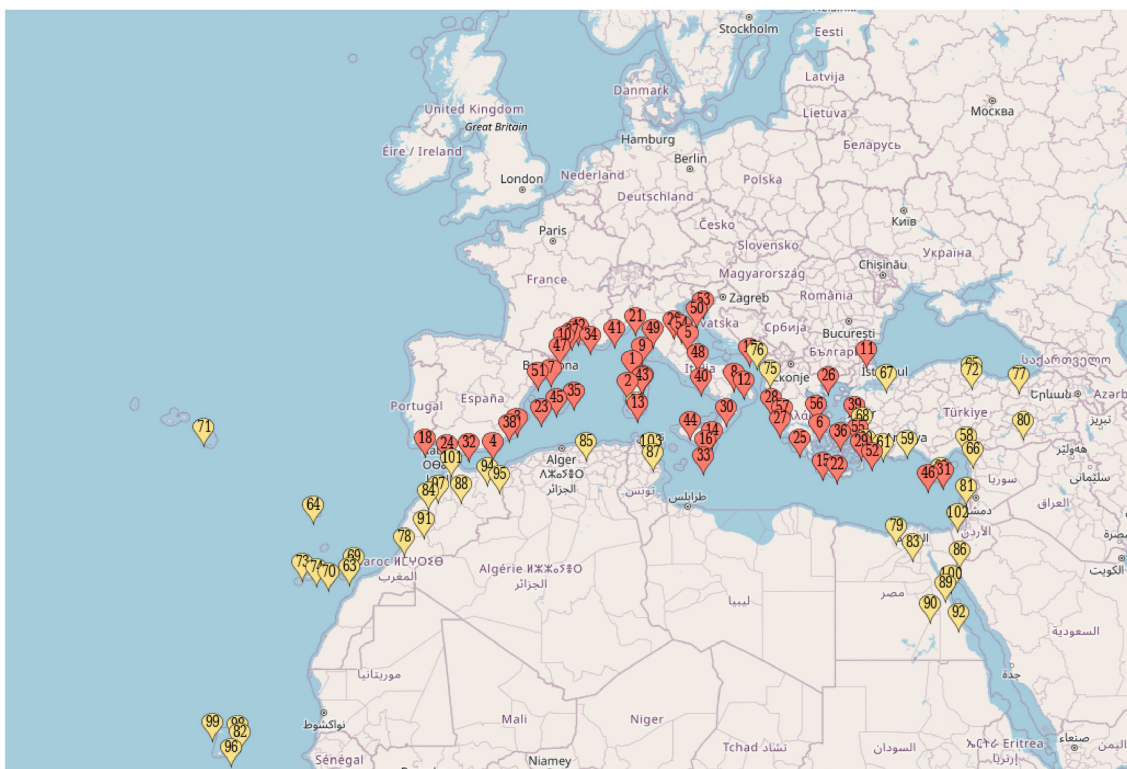


Fig. 1. Tourist destination cities as assigned to the treatment and control groups
 Notes: The red destinations form part of the treated group; the yellow destinations form part of the control group. Source: Created using MapCustomizer. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

to compare changes in treated and control routes before and after the treatment year (that is 2013).

Our primary sample includes 207,861 observations, which includes routes with non-stop services and those with at least one stopover. However, our main regressions restrict the sample to routes with at least 1,000 passengers per month (equivalent to 32/33 passengers per day) to minimize distortions attributable to very thin routes with poor air connections. In this regard, our passenger data is based on estimations based on bookings made through global distribution systems. Such estimates are expected to be less reliable for thin routes. Note also that the full sample includes a high proportion of observations without non-stop services, so that the supply variables have a high number of observations with zero values, potentially distorting the effect of the policy. Thus, the sample used in the main regressions includes 22,056 observations. However, as a robustness check, we also report the results of regressions using the primary sample. Furthermore, we also report the results of regressions that restrict the analysis to non-stop routes without imposing any traffic threshold. The subsample based on non-stop routes have 46,040 observations.

4.2. Sources and description of variables

The dependent variables in our analysis combine demand and supply indicators at the route-year level. Data regarding passengers has been obtained from Sabre Market Intelligence (Sabre, 2024). Sabre provides origin-destination data that includes information for passengers on both non-stop flights and connecting passengers that require at least one stop to reach their destination. As we mention above, demand data is based on estimations made by the provider. It should be noted here that the best available demand data for flights from Europe, including those from Sabre and Official Airlines Guide are based in part on estimates, and not actual data as is the case for supply.

Supply data includes number of seats, flight frequencies, distances

and the type of aircraft used. These data are drawn from RDC Aviation (2024) and refer to non-stop flights. Thus, routes without direct flights but with a relevant number of connecting passengers will have zero values for the supply variables but positive values for passengers.

To estimate CO₂ emissions, we employ Eurocontrol’s small emitter tool (SET) (Eurocontrol, 2024), designed to assist aircraft operators in their monitoring and reporting obligations under the EU ETS. The SET is based on fuel burn samples of real flight operations and provides accurate estimates of emissions for any given distance and aircraft type. With the aircraft type, the route distance and the number of flights, we can estimate the CO₂ emissions at the route level.

As controls, we consider the population of the urban areas at the point of origin (United Nations Population Division, 2024). Note that population at the destination is also usually considered in studies of demand and/or supply in air routes. However, in our context, the tourist attractiveness of the destination does not necessarily correlate with its population. This is clearly the case of beach areas, which represent a large proportion of the destinations in the sample employed here. Note also that there is not a homogeneous dataset that provides population data for the small beach destinations considered in our sample. However, we also consider a subsample that restricts the control routes to EEA destinations. In such a sample, we include the population at the destination as covariate using the regional statistics from Eurostat (at the NUTS 3 level).

We also consider income per capita at both endpoints of the routes at the country level. In this regard, income at destination is included as a control factor because it can be correlated with variables that influence the tourist attractiveness like the quality of infrastructures, tourism development or the perception that the traveler may have of comfort and safety. Data have been obtained from the World Bank Development Indicators database (World Bank Group, 2024a).

Furthermore, we include a dummy variable for routes with non-stop services and some regressions use a restricted sample comprising these

non-stop routes. In these regressions, we also include a dummy variable that takes a value of one for monopoly routes, i.e. routes on which one single airline controls at least 99 % of the total number of seats offered.

Another variable that is included as covariate is based on Google Trends data. In particular, we consider the global web searches from 2010 to 2022 in the category trips by country of destination. This variable is an index that ranges from 0 to 100 that captures the variability over the period considered for the specific search term (in our case the destination country). So, it is not useful to identify differences across countries but the evolution of the popularity over the period considered for each country. In this regard, we estimate a fixed effect model that only exploits the within variation of the data.

We also consider two additional variables for the destination countries using data that comes from the World Bank Governance Indicators database (World Bank Group, 2024b). First, we include as covariate the official exchange rate determined by national authorities. It is calculated as an annual average of the local currency units relative to the U.S. dollar. This variable may capture the variability in the purchasing power in euros and it can be a proxy of global macroeconomic trends. Second, we add as covariate a political stability index that measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism. It is based on a percentile rank that indicates the country's rank among all countries covered by the aggregate indicator, with 0 corresponding to lowest rank, and 100 to highest rank.

5. Research strategy

5.1. Empirical model

We apply the logic of difference-in-differences (DID), a common methodology adopted within the treatment evaluation framework (Angrist and Pischke, 2009; Gertler et al., 2016). To do so, we estimate the following equation (1) for route i in year t :

$$Y_{it} = \alpha + \beta EU_ETS_{it} + \lambda X_{it} + \gamma_i + \eta_t + \varepsilon_{it} \quad (1)$$

where the dependent variable (Y) may be the number of passengers, the total volume of CO₂ emissions, and the total number of flights and seats. The main explanatory variable is EU_ETS , a dummy variable indicating whether the route is affected by the EU ETS in year t . We expect the EU_ETS variable to present a negative sign regardless of the output indicator considered. Indeed, we may expect that airlines offering flights on treated routes might react to the higher costs that the scheme implies by reducing supply and increasing fares. Less frequencies and higher fares should lead to less demand, while airlines may also react to the EU_ETS by reducing the emissions-intensity of their flights.

X_{it} denotes the set of control variables: income at both the origin and destination country level, city population at the origin, a dummy variable for non-stop services, global web searches, the exchange rate and the political stability index. As discussed, when the sample is restricted to non-stop routes, we also include a dummy for monopoly routes. While when the sample is restricted to EEA destinations, we also consider the regional population at the destination. All continuous variables without zero values are transformed using logarithms. Note, however, that the passenger number variable does not have zero values because connecting passengers are also identified. In contrast, the supply variables (CO₂ emissions, flights and seats) may have zero values if the route does not operate non-stop services.

We also implement an augmented estimator to evaluate the impact of the policy over time by interacting a dummy variable for treated routes with each year of the period under consideration. This allows us to test whether the parallel trend assumption holds, a critical assumption in DID analyses. D_i in equation (2) is a time-invariant dummy variable indicating whether the route is affected by the EU_ETS and t indicates the year. The coefficient β represents the impact of the EU_ETS in each year. The parallel trend assumption implies that the coefficient would be

insignificant before the treatment period starts.

$$Y_{it} = \alpha + \beta (D_i \times t) + \lambda X_{it} + \gamma_i + \eta_t + \varepsilon_{it} \quad (2)$$

The data used present a panel structure and so we employ the techniques typically applied within the framework of panel data models. Hence, the specification includes route fixed effects, as well as year fixed effects. A clear advantage of the route fixed effects model is that it allows us to control for omitted variables that are correlated with the variables of interest, and which do not change over time. The route fixed effects model focuses on the within variation in the data so that it controls the effect of time-invariant variables, such as, the distance covered or historical links between countries. Furthermore, we add year dummies to control for yearly effects that are common to all routes. Standard errors are robust to heteroscedasticity and clustered at the route level.

5.2. Descriptive statistics and entropy balance

Fig. 2 shows the evolution of the output indicators (mean values per year at the route level) in the treated and control groups during the period analyzed. For both treatment and control routes, there is a general trend towards growth in all variables, a trend that was only reversed in 2020 and 2021 due to the major shock to aviation caused by the Covid-19 pandemic. In the comparison between the two groups, the descriptive evidence suggests a relative increase in the number of passengers on the treatment routes compared to the control routes. In contrast, a relative decrease in emissions and supply is observed on the treatment routes compared to the control routes. Furthermore, we do not detect a clear different trend between the control and treatment routes before 2013, the year in which the EU ETS first affected aviation. It should be noted that the highest volume of emissions on the control routes is due to the relevant weight of the long routes from/to the Canary Islands.

The differences between demand and supply could be associated with changes in the load factor of flights. The evolution of the average aircraft size is also relevant. In this regard, Fig. 3 shows both a tendency towards an increase in the load factor and in the average aircraft size on treatment routes compared to control routes.⁴

Table 1 provides a summary of the descriptive statistics of the variables used in the empirical analysis for both the treated and control routes. As expected, the most notable difference lies in the income per capita at the destination, being almost three times higher in the cities of destination on the treated than in those on the control routes. In the context of our analysis, this may distort any identification of the effects of the EU_ETS , as the control and treatment routes may have tourist destinations that are not comparable. Indeed, as we mention above, income at the destination may be related to relevant aspects of tourist attractiveness such as the quality of infrastructures, tourism development or the perception that the traveler may have of comfort and safety.

This means that to identify the effect of the EU_ETS on passengers and emissions, we should compare comparable routes. To ensure comparability, we use entropy balancing (Hainmueller, 2012), a non-parametric matching technique that consists in a reweighting scheme applied to the sample units so that the covariate distributions of the control group are an exact match of those observed in the treated group.

More specifically, the control group is reweighted so that the first and second moments of a set of covariates considered relevant match exactly with those observed in the treated group. We apply the procedure considering those covariates capturing socio-economic characteristics for which we have variability at the city level: i.e. income per capita at

⁴ Numbers in Fig. 3 should be taken with some caution. Data of load factors cross data of two different sources, while aircraft size is strongly determined by route distance.

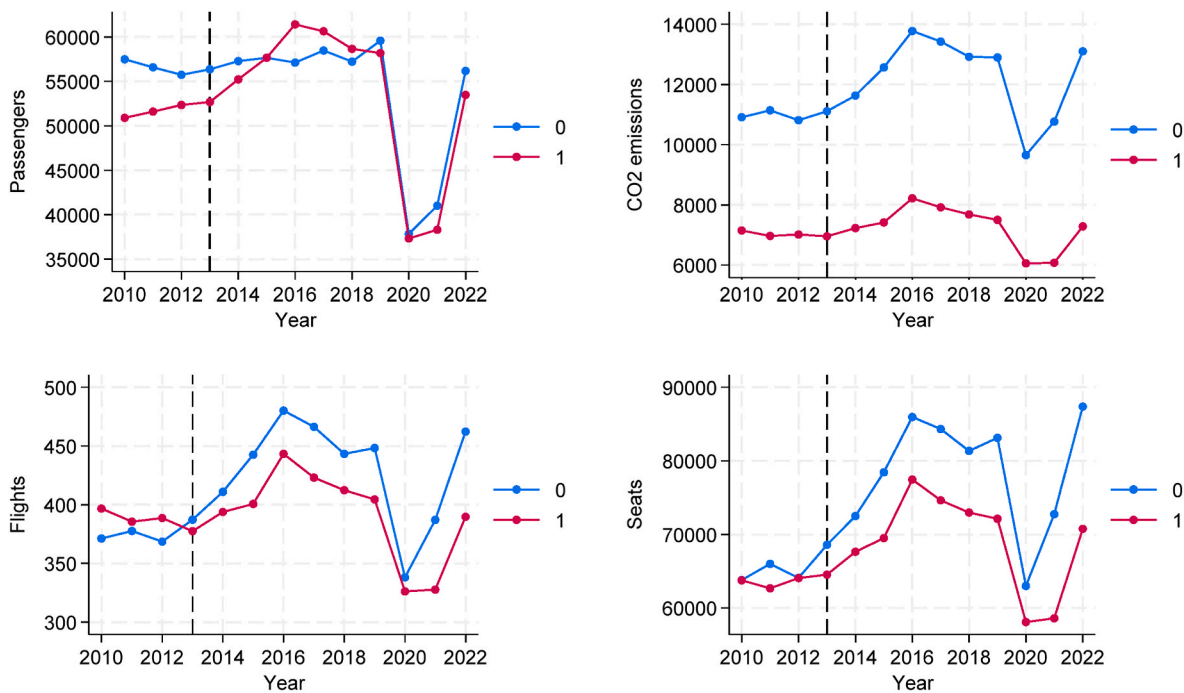


Fig. 2. Evolution of output variables on treated and control routes.

Note: For all graphs, the trend is shown for the treatment group which is affected by the EU ETS (line 1) and for the control group (line 0).

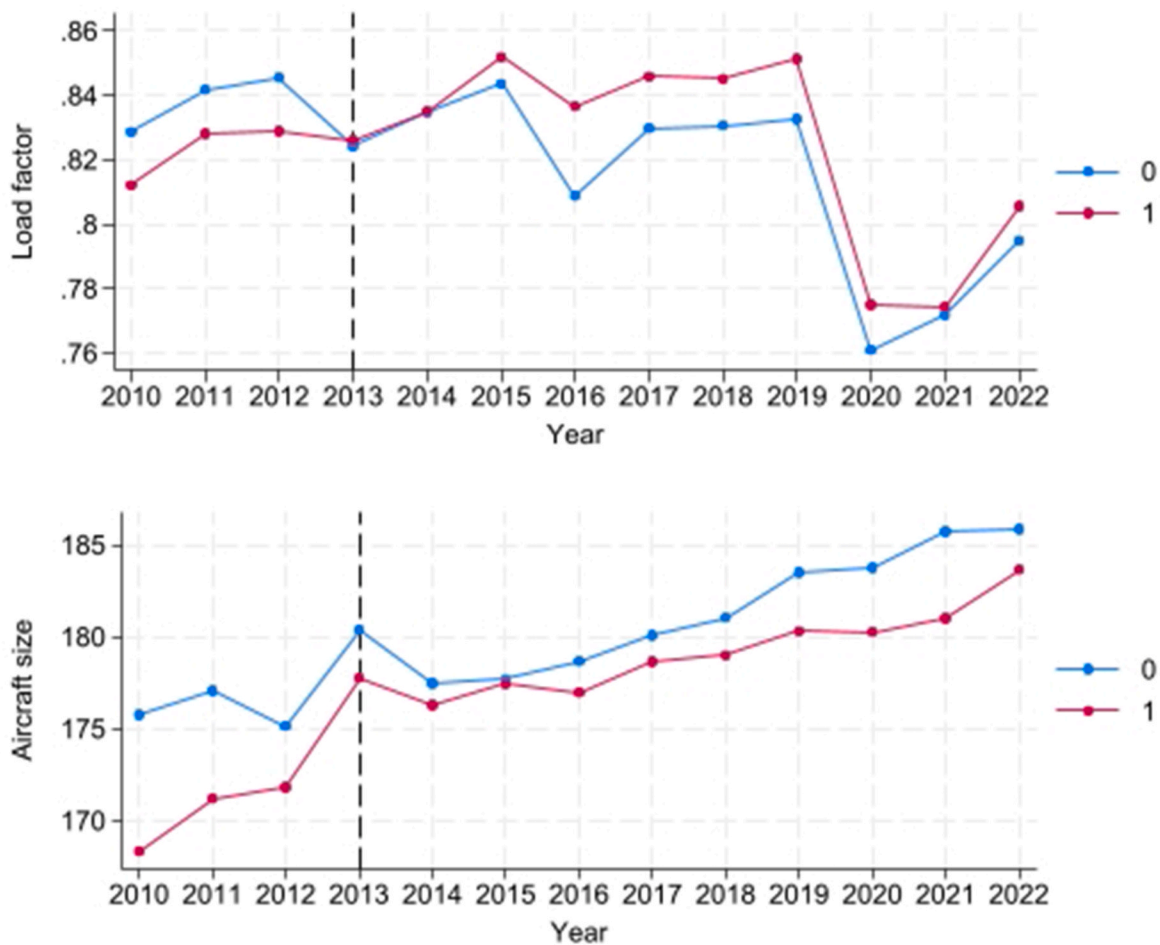


Fig. 3. Evolution of load factors and aircraft size on treated and control routes.

Note: For all graphs, the trend is shown for the treatment group which is affected by the EU ETS (line 1) and for the control group (line 0).

Table 1
Differences between treated and control routes.

	Unit	Treated			Control		
		Obs.	Mean	S.D.	Obs.	Mean	S.D.
CO ₂ emissions	in tons	138,113	841	4,471	91,030	1,213	6,718
Flight frequency	in numbers	138,113	45	249	91,030	42	217
Seats	in numbers	138,113	7,851	43,112	91,030	7,582	40,135
Passengers	in numbers	138,113	6,350	31,402	91,030	5,741	25,728
Income per capita (origin)	in current US dollar	127,266	40,510	21,387	83,349	39,975	20,209
Income per capita (destination)	in current US dollar	127,266	29,822	8,539	83,349	11,624	10,583
Population (origin)	in numbers	125,700	893,917	1,339,553	82,356	980,068	1,427,407
Exchange rate (destination)	in local currency units relative to the U.S. dollar	138,113	1.271	1.448	91,030	64.671	272.948
Web searches (destination)	index (0–100)	138,113	39.820	15.379	91,030	37.276	16.447
Political stability	index (0–100)	138,113	68.832	11.021	91,030	40.760	25.994
Non-stop	dummy	138,113	0.22	0.41	91,030	0.18	0.38
Monopoly	dummy	138,113	0.13	0.33	91,030	0.09	0.29

Notes: For all variables, data are at the year level. S.D. = standard deviation.

both the origin and destination, and the population at origin.⁵ We use the mean values of the variables in the years 2010–2012, the period before EU ETS implementation in the aviation sector.

Fig. 4 shows the covariate balance obtained as measured by the standardized difference in means between the treated and the control group. All standardized differences are minimal after the entropy balancing procedure, the small difference in the income at destination variable between treated and control routes in the matched sample being especially notable. Thus, most regressions use this reweighted sample, which eliminates the confounding factor related to the higher per capita income at the destination on treated routes.

Given the strong income heterogeneity between treated and control routes, our preferred specification is based on the matched sample. Some previous studies on the causal effects of the EU ETS have also considered entropy balancing as essential in their identification strategy (Fageda and Teixidó, 2022; Zhang and Wang, 2024). However, we also report the results of regressions that use the unmatched sample, considering a regression with all control routes and regressions that restrict the sample to EEA and non-EEA destinations. In this regard, income heterogeneity is much smaller when the analysis focuses on EEA destinations.

6. Results

6.1. Effect on passenger numbers and CO₂ emissions

Table 2 shows the main results from the DID estimator when the dependent variable is passenger numbers. The effect of our treatment variable can be read as the percentage change in passenger numbers due to the EU ETS, given that the dependent variable does not have zero values and it can be log-transformed.

Regressions in columns (1) to (4) use the reweighted sample after applying the entropy balance procedure as this ensures a comparable sample of treated and control routes, particularly with regards to the income at destination variable. Columns (5) to (7) use the unmatched sample. As we mention above, our preferred specifications are those that use the matched sample.

Columns (1) and (4) use the full sample, while the rest of the regressions restrict the sample to routes with at least 12,000 passengers per year. As discussed, thin routes can distort the identification of the EU ETS effect; hence, our preferred regressions are those that exclude such routes. Column (3) excludes the years 2020 and 2021, the two years severely affected by the Covid-19 pandemic and which may distort the main effect. The regressions shown in columns (4) refine the

⁵ The entropy balancing procedure does not converge to any value if we add the variables for which the variability is at the country destination level.

comparability between treated and control routes by restricting the sample to routes with non-stop services. Finally, columns (6) and (7) restrict the control routes to EEA and non-EEA destinations.

It should be noted that in Tables 3–5, where we show the results in terms of emissions and supply, we consider the same specifications as in Table 2. In Table A2 in the appendix, we also show the results of the control variables for each of the output indicators analyzed in the regressions that are based on both the matched sample (column 2) and the unmatched sample (column 5).

We do not find a significant negative impact of the EU ETS on passenger numbers, regardless of the regression considered. Indeed, these results are consistent with those reported by Oesingmann (2022).

When using the full sample and the sample for non-stop routes, the coefficient of the EU ETS variable is positive although not statistically significant. In the rest of the regressions that use the matched sample, the impact of the EU ETS on passenger numbers is around -1% / -2% but is never statistically significant. For the unmatched sample, we find a positive and statistically significant effect of the EU ETS on passenger numbers although it becomes non-significant when we restrict the control routes to EEA destinations. Therefore, some unobservable factors not related to the EU ETS may have been driving demand on treatment routes compared to non-EEA destinations. This could lead to an underestimation of the expected negative effect of this policy both in terms of demand and supply, especially when we consider the unmatched sample. In any case, with the caution required by the difficulty of finding control variables that can capture such relative growth in traffic on treatment routes, it does not seem that the EU ETS is harming the tourist attractiveness of treated destinations as compared to control destinations.

Note also that flight frequency and fares are two relevant drivers of passenger numbers that we do not consider as covariates. This is because both variables are correlated with our main explanatory variable, the EU ETS variable, and they are clearly affected by endogeneity bias. Taking this into account, Table A3 in the appendix shows the results of regressions with the matched and unmatched samples that include flights and fares as covariates. Results are very similar to those reported in Table 2 regardless of whether we include these variables as regressors.

Fig. 5 shows the evolution of passenger numbers on treated routes relative to those on control routes. The top panel plots equation (2) coefficients β' for the column (2) specification in Table 2, while the bottom panel provides the results for the column (5) specification in Table 2. Compared to 2012 (the baseline year), the differences between the treated and control routes remain non-significantly different before and after treatment when we use the matched sample (except for 2021 that suggests that the pandemic have favored destinations affected by the EU ETS). When we look at the unmatched sample, there is a clear relative increase in passenger numbers in treated routes, especially since 2016.

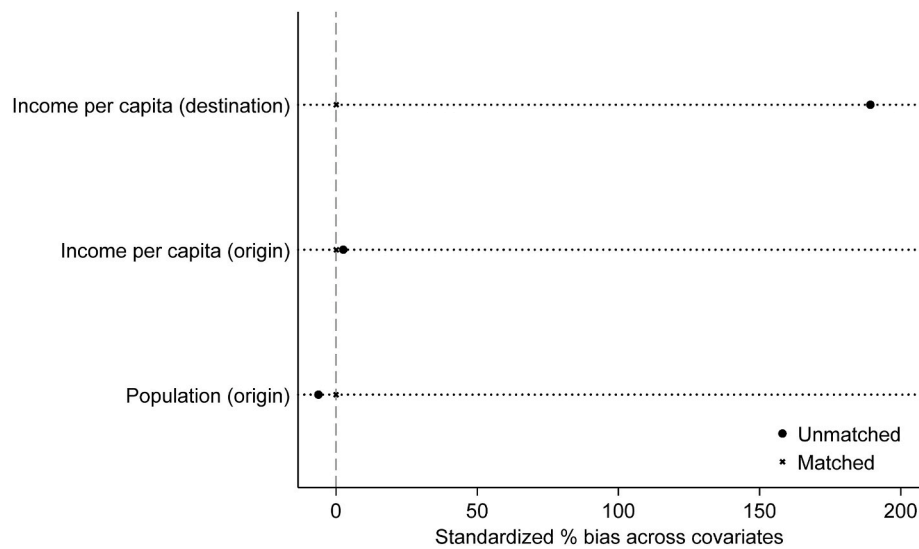


Fig. 4. Standardized mean difference for covariates in treated and control routes before and after entropy balance
 Notes: This graph plots the standardized differences in % between treated and control routes before 2013. x report balance with maximum-entropy reweighting of the control group (Hainmueller, 2012) and dots without balancing. The grey dashed vertical lines mark the 10 % difference, below which differences in means are considered negligible.

Table 2
 Effect of EU ETS on passenger numbers. Diff-in-Diff estimates.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ln(Passengers)	ln(Passengers)	ln(Passengers)	ln(Passengers)	ln(Passengers)	ln(Passengers)	ln(Passengers)
EU ETS	0.0500 (0.0340)	-0.0265 (0.0231)	-0.0165 (0.0221)	0.0238 (0.0432)	0.110*** (0.0163)	0.0318 (0.0226)	0.131*** (0.0202)
Observations	207,861	22,056	20,021	46,040	22,276	16,557	19,796
R-squared	0.201	0.410	0.234	0.222	0.371	0.416	0.360
Number routes	22,093	3,020	3,008	6,544	3,106	2,246	2,809
Routes	All	All	All	Non-stop	All	Control (EEA destinations)	Control (Non-EEA destinations)
Sample	All	>12,000 pax	>12,000 pax	All	>12,000 pax	>12,000 pax	>12,000 pax
Period	2010–2022	2010–2022	2010–2019 & 2022	2010–2022	2010–2022	2010–2022	2010–2022
Matching	EB	EB	EB	EB	NONE	NONE	NONE

Notes: This table reports the regression of passenger numbers on the EU ETS indicator. Columns (1) to (4) use the reweighted sample after applying the entropy balance procedure, while columns (5) to (7) use the unmatched sample. Columns (1) and (4) estimate the effect of the EU ETS for the full sample, and columns (2), and (3), (5), (6) and (7) restrict the sample to routes with at least 12,000 passengers per year. Column (3) excludes the years 2020–2021, while column (4) restricts the analysis to non-stop routes. Column (6) and (7) restrict the control routes to EEA and non-EEA destinations, respectively. All regressions include as controls income at origin and destination, population at origin, a dummy for non-stop services, the popularity of the destination country based on Google Trends, the exchange rate of the destination country (USD/national currency), the political stability index of the destination country, and route and year fixed effects. Column (4) also includes as a covariate a dummy for monopoly routes, while column (6) include as covariate the population at destination. Robust standard errors (in parentheses) are clustered at the route level. ***p < 0.01, **p < 0.05, *p < 0.1. Pax = passengers. EEA = European Economic Area.

Table 3 shows the results from the DID estimator when the dependent variable is CO₂ emissions. As we mention above, the dependent variable may have zero values because some routes do not operate non-stop services; hence, the log-transformation of the CO₂ emissions variable is only possible when the sample is restricted to routes with non-stop services. Recall also that the regressions reported in Table (3) replicate those reported in Table (2) but considering CO₂ emissions rather than passenger numbers as the dependent variable.

We find a significant negative impact of the EU ETS on CO₂ emissions. This result holds for all regressions, except for the regression with the unmatched sample restricted to non-EEA destinations. This result is consistent with findings reported by Fageda and Teixidó (2022). Compared to the control routes, the scheme has led to a reduction in emissions of around -176 to -1.500 tons. In the regressions that focus on non-stop routes and where the coefficient can be interpreted as a percentage change, the impact of the EU ETS is about -7 %. Thus, we provide evidence of the effectiveness of the EU ETS on a sample based on

tourist destinations, considering that the main goal of the policy is to reduce carbon emissions.

Some caveats must be mentioned here. The descriptive evidence shows a tendency for emissions to increase in both the treatment and control routes. Therefore, the negative effect we found should be interpreted as a smaller increase in emissions in the treatment routes compared to the control routes; total emissions have not stopped increasing.

Results for passenger numbers show that some unobserved factors may have pushed demand in treated routes since 2016. This may underestimate the effect of the EU ETS on carbon emissions, particularly on the regressions based on the unmatched sample. Otherwise, the lower emissions on treated routes could be partially explained by the increase in emissions on control routes given that we focus on nearby tourist destinations that compete to attract travelers. This potential carbon leakage effect could overestimate the effect of the policy on emissions. In any case, the expected negative impact of the EU ETS is clearer in terms

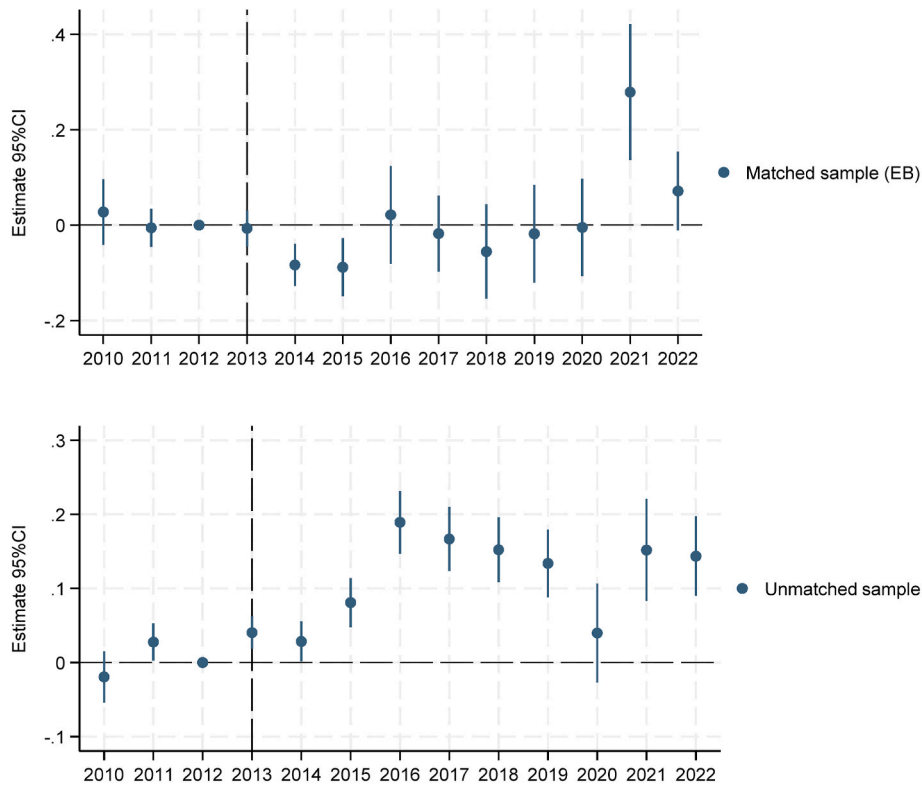


Fig. 5. Year-on-year difference-in-differences estimates (passenger numbers)

Notes: This figure plots results from an event-study analysis of the difference in the passenger numbers at the route level between treated and control routes before and after policy implementation. The coefficients reported are taken from equation (2), in which we interact the treatment variable with year indicators. The top panel reports the results of the specification in column (2) of Table 2, while the bottom panel shows the results of specification (5). The base year is 2012 and the confidence interval is set at 95 % with standard errors clustered at the route level.

Table 3
Effect of EU ETS on CO2 emissions. Diff-in-Diff estimates.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CO ₂ emissions	CO ₂ emissions	CO ₂ emissions	ln(CO ₂ emissions)	CO ₂ emissions	CO ₂ emissions	CO ₂ emissions
EU ETS	-176.9** (79.43)	-1,545** (662.0)	-1,102** (525.2)	-0.0745** (0.0328)	-763.2*** (271.2)	-1,360*** (337.6)	-139.0 (355.0)
Observations	207,861	22,056	20,021	46,038	22,276	16,557	19,796
R-squared	0.039	0.258	0.211	0.306	0.206	0.237	0.197
Number routes	22,093	3,020	3,008	6,542	3,106	2,246	2,809
Routes	All	All	All	Non-stop	All	Control (EEA destinations)	Control (Non-EEA destinations)
Sample	All	>12,000 pax	>12,000 pax	All	>12,000 pax	>12,000 pax	>12,000 pax
Period	2010–2022	2010–2022	2010–2019 & 2022	2010–2022	2010–2022	2010–2022	2010–2022
Matching	EB	EB	EB	EB	NONE	NONE	EB

Notes: This table reports the regression of CO₂ emissions on the EU ETS indicator. Columns (1) to (4) use the reweighted sample after applying the entropy balance procedure, while columns (5) to (7) use the unmatched sample. Columns (1) and (4) estimate the effect of the EU ETS for the full sample, and columns (2), and (3), (5), (6) and (7) restrict the sample to routes with at least 12,000 passengers per year. Column (3) excludes the years 2020–2021, while column (4) restricts the analysis to non-stop routes. Column (6) and (7) restrict the control routes to EEA and non-EEA destinations, respectively. All regressions include as controls income at origin and destination, population at origin, a dummy for non-stop services, the popularity of the destination country based on Google Trends, the exchange rate of the destination country (USD/national currency), the political stability index of the destination country, and route and year fixed effects. Column (4) also includes as a covariate a dummy for monopoly routes, while column (6) includes as covariate the population at destination. Robust standard errors (in parentheses) are clustered at the route level. ***p < 0.01, **p < 0.05, *p < 0.1. Pax = passengers. EEA = European Economic Area.

of supply (to the extent that emissions can be directly related to supply) rather than in terms of demand.

Fig. 6 shows the evolution of CO₂ emissions on treated routes relative to those on control routes. As in Fig. 5, the top panel plots equation (2) coefficients β' for the column (3) specification in Table 3, while the bottom panel provides the results for the column (5) specification in

Table 3. Compared to 2012 (the baseline year), the differences between the treated and control routes are not statistically different before treatment when using the matched sample, confirming that the parallel trends assumption holds. For the unmatched sample, emissions are slightly higher in treated as compared to control routes before treatment. From 2013 onwards, CO₂ emissions on treated routes are

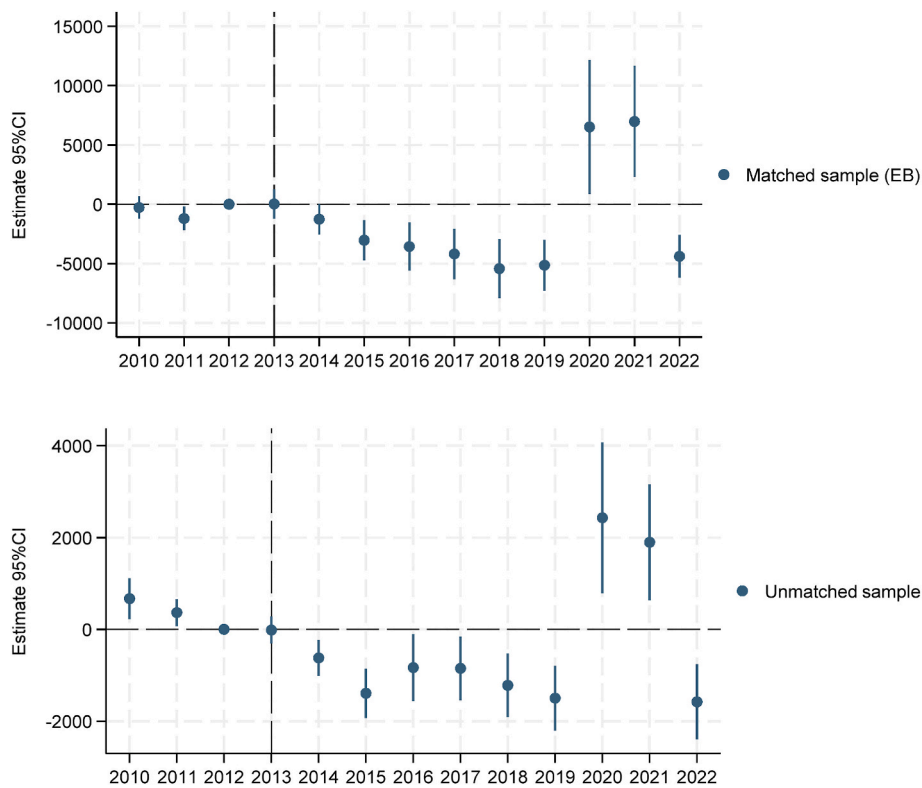


Fig. 6. Year-on-year difference-in-differences estimates (CO₂ emissions)

Notes: This figure plots results from an event-study analysis of the difference in the CO₂ emissions at the route level between treated and control routes before and after policy implementation. The coefficients reported are taken from equation (2), in which we interact the treatment variable with year indicators. The top panel reports the results of the specification in column (2) of Table 2, while the bottom panel shows the results of specification (5). The base year is 2012 and the confidence interval is set at 95 % with standard errors clustered at the route level.

significantly lower than those on control routes, except for the years 2020–2021 that are conditioned by the pandemic. This is the case for both the matched and unmatched sample.

6.2. Effect on flights and seats

In this subsection, we explore the impact of the EU ETS on flights and seats as this might provide insights into the results regarding passenger numbers and CO₂ emissions. Table 4 shows the results from the DID

estimator when the dependent variable is the total number of flights. We find that the EU ETS has significantly reduced the number of flights, regardless of the regression considered. Indeed, the coefficient of the EU ETS variable is negative and statistically significant in all regressions. The impact is about $-6/-85$ (-15% for non-stop routes). For the matched sample, Fig. 7 shows that differences between treated and control routes have increased since 2014 (a trend that is only altered on the covid years). For the unmatched sample, the pattern is less clear with smaller differences between 2016 and 2019.

Table 4
Effect of EU ETS on flights. Diff-in-Diff estimates.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	flights	flights	flights	ln(flights)	flights	flights	flights
EU ETS	-6.756*** (2.401)	-60.70*** (17.30)	-36.51** (16.69)	-0.149*** (0.0438)	-25.26*** (8.989)	-24.99** (11.74)	-85.91*** (30.85)
Observations	207,861	22,056	20,021	46,040	22,276	16,557	19,577
R-squared	0.052	0.303	0.281	0.312	0.216	0.205	0.314
Number routes	22,093	3,020	3,008	6,544	3,106	2,246	2,724
Routes	All	All	All	Non-stop	All	Control (EEA destinations)	Control (Non-EEA destinations)
Sample	All	>12,000 pax	>12,000 pax	All	>12,000 pax	>12,000 pax	>12,000 pax
Period	2010–2022	2010–2022	2010–2019 & 2022	2010–2022	2010–2022	2010–2022	2010–2022
Matching	EB	EB	EB	EB	NONE	NONE	NONE

Notes: This table reports the regression of flights on the EU ETS indicator. Columns (1) to (4) use the reweighted sample after applying the entropy balance procedure, while columns (5) to (7) use the unmatched sample. Columns (1) and (4) estimate the effect of the EU ETS for the full sample, and columns (2), (3), (5), (6) and (7) restrict the sample to routes with at least 12,000 passengers per year. Column (3) excludes the years 2020–2021, while column (4) restricts the analysis to non-stop routes. Column (6) and (7) restrict the control routes to EEA and non-EEA destinations, respectively. All regressions include as controls income at origin and destination, population at origin, a dummy for non-stop services, the popularity of the destination country based on Google Trends, the exchange rate of the destination country (USD/national currency), the political stability index of the destination country, and route and year fixed effects. Column (4) also includes as a covariate a dummy for monopoly routes, while column (6) includes as covariate the population at destination. Robust standard errors (in parentheses) are clustered at the route level. ***p < 0.01, **p < 0.05, *p < 0.1. Pax = passengers. EEA = European Economic Area.

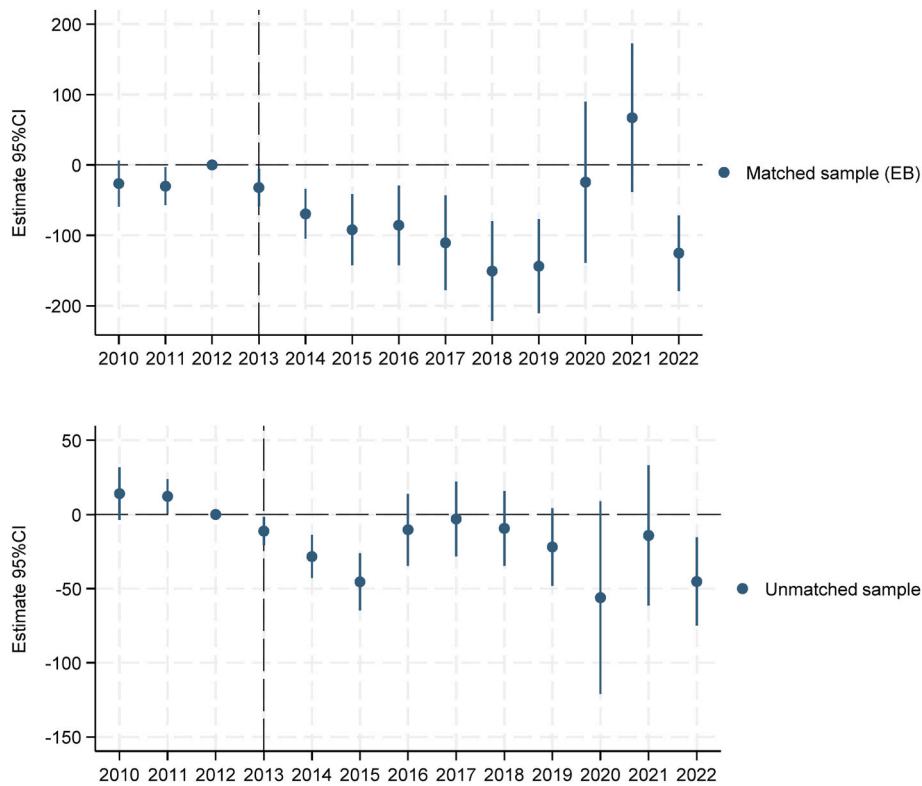


Fig. 7. Year-on-year difference-in-differences estimates (flights)

Notes: This figure plots results from an event-study analysis of the difference in flights at the route level between treated and control routes before and after policy implementation. The coefficients reported are taken from equation (2), in which we interact the treatment variable with year indicators. The top panel reports the results of the specification in column (2) of Table 2, while the bottom panel shows the results of specification (5). The base year is 2012 and the confidence interval is set at 95 % with standard errors clustered at the route level.

Table 5 and Fig. 8 show the results from the DID estimator when the dependent variable is the total number of seats. We find a negative effect of the EU ETS in all regressions, although the effect is only statistically significant in the regressions that use the matched sample and do not exclude the covid years. The impact of the EU ETS varies between $-700/-6,700$ seats (-8% when the sample is restricted to non-stop routes). The evolution over time reported in Fig. 8 is like that mentioned for flights.

Overall, the impact is greater for flights than for seats when

considering the comparable effects for non-stop routes (which can be interpreted as the percentage change) and when bearing in mind that the impact on seats is only statistically significant in some of the regressions. Furthermore, the (negative) impact is greater for seats than for passenger numbers. With the matched sample, the effect of the EU ETS on seats is negative and statistically significant in most regressions, while it is not statistically significant for passenger numbers. In the unmatched sample, the effect of the EU ETS on passenger numbers can be even positive and statistically significant, while it is not statistically

Table 5
Effect of EU ETS on seats. Diff-in-Diff estimates.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	seats	seats	seats	ln (seats)	seats	seats	seats
EU ETS	-707.5* (401.7)	-6,773** (2,826)	-2,508 (2,825)	-0.0825** (0.0433)	-1,905 (1,697)	-1,624 (2,192)	-736.8 (2,083)
Observations	207,861	22,056	20,021	46,040	22,276	16,557	19,796
R-squared	0.053	0.314	0.315	0.315	0.223	0.218	0.222
Number routes	22,093	3,020	3,008	6,544	3,106	2,246	2,809
Routes	All	All	All	Non-stop	All	EEA destinations	Non-EEA destinations
Sample	All	>12,000 pax	>12,000 pax	All	>12,000 pax	>12,000 pax	>12,000 pax
Period	2010–2022	2010–2022	2010–2019 & 2022	2010–2022	2010–2022	2010–2022	2010–2022
EU ETS	EB	EB	EB	EB	NONE	NONE	NONE

Notes: This table reports the regression of seats on the EU ETS indicator. Columns (1) to (4) use the reweighted sample after applying the entropy balance procedure, while columns (5) to (7) use the unmatched sample. Columns (1) and (4) estimate the effect of the EU ETS for the full sample, and columns (2), (3), (5), (6) and (7) restrict the sample to routes with at least 12,000 passengers per year. Column (3) excludes the years 2020–2021, while column (4) restricts the analysis to non-stop routes. Column (6) and (7) restrict the control routes to EEA and non-EEA destinations, respectively. All regressions include as controls income at origin and destination, population at origin, a dummy for non-stop services, the popularity of the destination country based on Google Trends, the exchange rate of the destination country (USD/national currency), the political stability index of the destination country, and route and year fixed effects. Column (4) also includes as a covariate a dummy for monopoly routes, while column (6) includes as covariate the population at destination. Robust standard errors (in parentheses) are clustered at the route level. ***p < 0.01, **p < 0.05, *p < 0.1. Pax = passengers. EEA = European Economic Area.

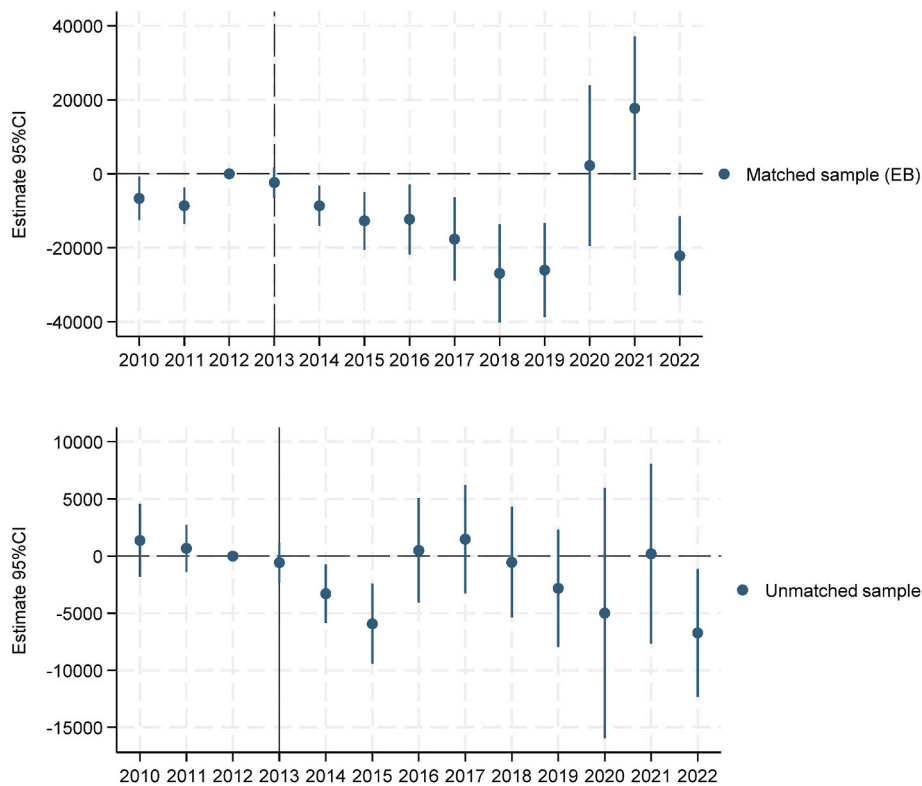


Fig. 8. Year-on-year difference-in-differences estimates (seats)

Notes: This figure plots results from an event-study analysis of the difference in seats at the route level between treated and control routes before and after policy implementation. The coefficients reported are taken from equation (2), in which we interact the treatment variable with year indicators. The top panel reports the results of the specification in column (2) of Table 2, while the bottom panel shows the results of specification (5). The base year is 2012 and the confidence interval is set at 95 % with standard errors clustered at the route level.

significant for seats.

These results suggest that airlines have reacted to the higher costs of the EU ETS by reducing flight frequencies and increasing aircraft size, which is consistent with the findings of Brueckner and Zhang (2010) and Kang et al. (2022). In addition, fewer flights and to a lower extent fewer seats but not fewer passengers can mainly be explained by an increase in the load factor of the planes, a result that is also consistent with the analysis of Brueckner and Zhang (2010). The descriptive evidence shown above is consistent with the increase in the load factors and aircraft size of treated routes as compared to control routes.

Note also that the EU ETS seems to be more clearly effective in terms of emissions than seats. Thus, it can be that the policy has promoted the reduction in the emissions intensity of flights, which would be consistent with the findings of Fageda and Teixidó (2022) and De Jong (2022).

7. Conclusion

In this paper, we have undertaken a comprehensive analysis of the effects the EU ETS has had on tourist destinations by considering its impact on both demand and supply indicators. Indeed, concerns have been expressed about the implementation of this policy, including its potential detrimental impact on tourist outcomes.

We find that the EU ETS has been effective in reducing emissions, at least as compared to the counterfactual. Furthermore, it has led to less flights and to a lower extent to less seats. In contrast, we do not find evidence of a relevant shift of passengers from regulated to unregulated tourist destinations even though carbon pricing has led to fewer flights on regulated routes. Thus, other factors not directly related to flights may be driving the decision as to whether to visit an area affected by the emissions market. Furthermore, our analysis provides evidence that the EU ETS has increased the efficiency of airline operations.

Passengers have not reacted strongly to the lower air supply, particularly to the lower frequency which is considered the main quality attribute in the aviation sector. Although air transport is relevant in explaining tourism outcomes, it seems that passengers originating in a European country (or, at least, many of them) consider other factors that are not directly related to air transport when choosing between one or another nearby tourist destination. This means that tourist destinations in non-EEA countries, North and West Africa (along with the Azores, the Canary Islands and Madeira) are imperfect substitutes for EEA tourist destinations. In this regard, the flight attributes constitute only a part of the choice criteria for the vacation. In any case, the implementation of the EU ETS does not appear to have a negative impact on the competitiveness of the tourist destinations affected by the measure, at least when analyzed in terms of the number of tourists arriving at their destination by plane.

The other main implication of our results is that the EU ETS has led to an increase in the efficiency of airline operations. In this regard, we find that the EU ETS has had a negative impact on emissions and supply but not a negative impact on demand. Airlines in EU ETS routes are using bigger (and likely more fuel-efficient) aircraft and these aircraft are getting fuller so that airlines are offsetting the ETS through greater efficiency.

Our analysis is not without some limitations that need to be highlighted again. The tourist destinations in the treated and control groups are very heterogeneous, especially in terms of income. This entails the need to rebalance the sample to be able to compare comparable routes.

In addition, the availability of data for a sample that includes cities in Europe, North and West Africa and the Middle East is reduced. In this regard, some unobservable factors not related to the EU ETS may have pushed demand in EEA destinations as compared to non-EEA destinations, some years after the implementation of the EU ETS. However, this

distortion is diluted in the matched sample. Note also that both demand and supply variables could simultaneously be affected by those unobservable factors, and results for supply and emissions are as it could be expected. In any case, such unobservable factors could underestimate the supply effects that we find.

Furthermore, it can be that the control routes are also affected by the EU ETS given that we focus on nearby tourist destinations that compete to attract travelers. However, results when passenger numbers is the dependent variable suggest that treated and control tourist destinations are imperfect substitutes.

In short, even considering the previous limitations, our analysis suggests that carbon pricing in aviation has being effective in containing the increase in emissions by improving efficiency in airline operations. This containment of emissions does not seem to have led to a loss of tourists.

APPENDIX

Table A1
List of destination cities in our sample

Europe (included in the EU ETS)	Europe (NOT included in the EU ETS)	North and West Africa, Eastern Europe, Middle East
Ajaccio, Alghero, Alicante, Almeria, Ancona, Athens, Barcelona, Bari, Bastia, Beziers, Bourgas, Brindisi, Cagliari, Catania, Chania, Comiso, Dubrovnik, Faro, Figari, Forli, Genoa, Heraklion, Ibiza, Jerez, Kalamata, Kavala, Kefallinia, Kerkyra, Kos, Lamezia-Terme, Larnaca, Malaga, Malta, Marseille, Menorca, Mikonos, Montpellier, Murcia, Mytilene, Naples, Nice, Nimes, Olbia, Palermo, Palma Mallorca, Paphos, Perpignan, Pescara, Pisa, Preveza/Lefkas, Pula, Reus, Rhodes, Rijeka, Rimini, Samos, Skiathos, Split, Thessaloniki, Thira, Toulon, Trapani, Trieste, Valencia. Varna, Venice, Zadar, Zakynthos	Adana, Antalya, Bodrum, Dalaman, Ercan, Fuerteventura, Funchal, Gazipasa, Hatay, Istanbul, Izmir, Lanzarote, Las Palmas, Ponta Delgada, Samsun, Santa Cruz de la Palma, Tenerife, Tirana, Tivat, Trabzon	Agadir, Alexandria, Amman, Beirut, Boa Vista, Cairo, Casablanca, Djerba, Eilat, Enfidha, Fez, Hurghada, Luxor, Marrakech, Marsa Alam, Monastir, Nador, Oujda, Praia, Rabat, Sal, Sao Vicente, Sharm El Sheikh, Tangier, Tel Aviv, Tunis

Table A2
Effect of EU ETS on outputs. Diff-in-Diff estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln(passengers)	ln(passengers)	CO ₂ emissions	CO ₂ emissions	Flights	Flights	Seats	Seats
EU ETS	-0.0265 (0.0231)	0.110*** (0.0163)	-1,545** (662.0)	-763.2*** (271.2)	-60.70*** (17.30)	-25.26*** (8.989)	-6,773** (2,826)	-1,905 (1,697)
ln (GDP per capita_or.)	0.251 (0.182)	0.245*** (0.0572)	2,754 (2,546)	2,579*** (658.2)	79.07 (100.8)	138.9*** (31.17)	10,066 (17,935)	17,120*** (5,271)
ln (GDP per capita_dest.)	0.105 (0.136)	0.148*** (0.0539)	-12.14 (2 427)	-94.46 (960.9)	188.0** (74.71)	78.70*** (26.25)	37,787*** (14,299)	11,107** (4,670)
ln (population_or.)	-0.775 (0.531)	-0.0447 (0.221)	-15,799 (14,231)	9,384*** (2,825)	-115.1 (320.5)	559.7*** (110.0)	-65,404 (60,890)	72,412*** (20,692)
Nonstop	0.0217 (0.0655)	0.0479* (0.0285)	1,140** (559.9)	1,419*** (274.8)	33.01 (22.19)	42.75*** (9.571)	2,680 (4,132)	5,122*** (1,768)
Web searches	0.00131 (0.00116)	0.000293 (0.000697)	149.8*** (52.05)	36.01*** (12.79)	2.867** (1.230)	0.134 (0.463)	558.5** (232.9)	109.3 (84.56)
Exchange rate	-0.0128*** (0.00486)	-0.00913*** (0.00222)	-143.8 (100.4)	11.41 (41.59)	-7.439*** (2.383)	-0.557 (1.221)	-1,653*** (450.7)	111.3 (222.2)
Political stability	0.00184 (0.00125)	0.00308*** (0.000693)	129.6*** (30.34)	25.34** (10.76)	3.765*** (0.814)	0.859*** (0.388)	538.5*** (135.1)	37.19 (72.59)
Constant	17.26** (7.185)	6.847** (3.170)	184,942 (220,696)	-152,233*** (44,999)	-1,154 (4,741)	-9,673*** (1,670)	413,998 (891,383)	-1.243e+06*** (310,490)
Observations	22,056	22,276	22,056	22,276	22,056	22,276	22,056	22,276
R-squared	0.410	0.371	0.258	0.206	0.303	0.216	0.314	0.223
Number routes	3,020	3,106	3,020	3,106	3,020	3,106	3,020	3,106
Routes	All	All	All	All	All	All	All	All
Sample	>12,000 pax	>12,000 pax	>12,000 pax	>12,000 pax	>12,000 pax	>12,000 pax	>12,000 pax	>12,000 pax
Period	2010–2022	2010–2022	2010–2022	2010–2022	2010–2022	2010–2022	2010–2022	2010–2022
Matching	EB	NONE	EB	NONE	EB	NONE	EB	NONE

CRediT authorship contribution statement

Xavier Fageda: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization, Visualization. **Katrin Oesingmann:** Writing – original draft, Visualization, Methodology, Investigation, Conceptualization, Data curation, Formal analysis, Writing – review & editing.

Acknowledgements

We acknowledge financial support from the Spanish Ministry of Science, Innovation, and Universities (PID2021-128237OB-I00) and from the self-funded project VMO4Orte of the German Aerospace Center (DLR). We thank Sven Maertens and David Plesch for comments on an earlier version of the paper.

Notes: This table reports the regression of output variables on the EU ETS indicator. We restrict the sample to routes with at least 12,000 passengers per year, and we consider both the matched and unmatched samples. All regressions include as controls route and year fixed effects. Robust standard errors (in parentheses) are clustered at the route level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A3
Effect of EU ETS on passenger numbers considering fares and flights as covariates. Diff-in-Diff estimates

	(1)	(2)
	ln(Passengers)	ln(Passengers)
EU ETS	0.0293 (0.0220)	0.124*** (0.0153)
Flights	0.000584*** (6.59e-05)	0.000547*** (6.38e-05)
Fares	-0.116*** (0.0366)	0.000954 (0.0168)
Observations	22,056	22,276
R-squared	0.512	0.462
Number routes	3,020	3,106
Routes	All	All
Sample	>12,000 pax	>12,000 pax
Period	2010–2022	2010–2022
Matching	EB	NONE

Notes: This table reports the regression of passenger numbers on the EU ETS indicator considering fares and flights as covariates. We restrict the sample to routes with at least 12,000 passengers per year, and we consider both the matched and unmatched samples. All regressions include as controls income at origin and destination, population at origin, a dummy for non-stop services, the popularity of the destination country based on Google Trends, the exchange rate of the destination country (USD/national currency), the political stability index of the destination country, and route and year fixed effects. Robust standard errors (in parentheses) are clustered at the route level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Pax = passengers. EEA = European Economic Area.

References

- Angrist, J.D., Pischke, J.S., 2009. Mostly Harmless Econometrics: an Empiricist's Companion. Princeton Univ. Press. <https://ebookcentral.proquest.com/lib/kxp/detail.action?docID=475846>.
- Bernardo, V., Fageda, X., Teixidó, J., 2024. Flight ticket taxes in Europe: environmental and economic impact. *Transport. Res. Pol. Pract.* 179, 103892. <https://doi.org/10.1016/j.tra.2023.103892>.
- Boto-García, D., Albert, J.F., Gómez-Fernández, N., 2024. Carbon price shocks and tourism demand. *Ann. Tourism Res.* 108, 103813. <https://doi.org/10.1016/j.annals.2024.103813>.
- Brueckner, J.K., Zhang, A., 2010. Airline emission charges: effects on airfares, service quality, and aircraft design. *Transp. Res. Part B* 44, 960–971. <https://doi.org/10.1016/j.trb.2010.02.006>.
- Clò, S., 2010. Grandfathering, auctioning and carbon leakage: assessing the inconsistencies of the new ETS directive. *Energy Policy* 38 (5), 2420–2430. <https://doi.org/10.1016/j.enpol.2009.12.035>.
- De Jong, G., 2022. Emission Pricing and Capital Replacement: Evidence from Aircraft Fleet Renewal. Working paper TI 2022-060/VIII at Tinbergen Institute.
- Denstadli, J.M., Veisten, K., 2020. The flight is valuable regardless of the carbon tax scheme: a case study of Norwegian leisure air travelers. *Tour. Manag.* 81, 104150. <https://doi.org/10.1016/j.tourman.2020.104150>.
- Dwyer, L., Forsyth, P., Spurr, R., Hoque, S., 2013. Economic impacts of a carbon tax on the Australian tourism industry. *J. Trav. Res.* 52 (2), 143–155. <https://doi.org/10.1177/0047287512461568>.
- EEA, 2024. EU ETS Data viewer. <https://www.eea.europa.eu/data-and-maps/dashboard/emissions-trading-viewer-1>.
- Eurocontrol, 2024. Smaller emitters tool (SET). <https://www.eurocontrol.int/tool/small-emitters-tool>. (Accessed 20 April 2024).
- European Commission, 2024. The EU and its outermost regions. https://ec.europa.eu/regional_policy/policy/themes/outermost-regions_en.
- European Union, 2024. Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 Establishing a Scheme for Greenhouse Gas Emission Allowance Trading within the Community and Amending Council Directive 96/61/EC: Version 01.03.2024. European Union.
- Fageda, X., Teixidó, J., 2022. Pricing carbon in the aviation sector: evidence from the European emissions trading system. *J. Environ. Econ. Manag.* 111, 102591. <https://doi.org/10.1016/j.jeem.2021.102591>.
- Fageda, X., Teixido, J., 2023. Technology diffusion in carbon markets: evidence from aviation. <https://doi.org/10.2139/ssrn.4621462>.
- Falk, M., Hagsten, E., 2019. Short-run impact of the flight departure tax on air travel. *Int. J. Tourism Res.* 21 (1), 37–44. <https://doi.org/10.1002/jtr.2239>.
- Gertler, P.J., Martinez, S., Premand, P., Rawlings, L.B., Vermeersch, C.M.J., 2016. In: Impact Evaluation in Practice, second ed. Inter-American Development Bank and World Bank, Washington, DC. <https://doi.org/10.1596/978-1-4648-0779-4>.
- Hainmueller, J., 2012. Entropy balancing for causal effects: a multivariate reweighting method to produce balanced samples in observational studies. *Polit. Anal.* 20 (1), 25–46. <https://doi.org/10.1093/pan/mpi025>.
- IPCC, 2018. Global Warming of 1.5 °C - Special Report.
- Kang, Y., Liao, S., Jiang, C., D'Alfonso, T., 2022. Synthetic control methods for policy analysis: evaluating the effect of the European Emission Trading System on aviation supply. *Transport. Res. Pol. Pract.* 162, 236–252. <https://doi.org/10.1016/j.tra.2022.05.015>.
- Lee, D.S., Fahey, D.W., Skowron, A., Allen, M.R., Burkhardt, U., Chen, Q., Doherty, S.J., Freeman, S., Forster, P.M., Fuglested, J., Gettelman, A., León, R. R. de, Lim, L.L., Lund, M.T., Millar, R.J., Owen, B., Penner, J.E., Pitari, G., Prather, M.J., Wilcox, L.J., 2021. The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmos. Environ.* 244, 117834. <https://doi.org/10.1016/j.atmosenv.2020.117834>.
- Markham, F., Young, M., Reis, A., Higham, J., 2018. Does carbon pricing reduce air travel? Evidence from the Australian 'Clean Energy Future' policy, July 2012 to June 2014. *J. Transport Geogr.* 70, 206–214. <https://doi.org/10.1016/j.jtrangeo.2018.06.008>.
- Mayor, K., Tol, R.S., 2007. The impact of the UK aviation tax on carbon dioxide emissions and visitor numbers. *Transp. Policy* 14 (6), 507–513. <https://doi.org/10.1016/j.tranpol.2007.07.002>.
- Mayor, K., Tol, R.S., 2010. The impact of European climate change regulations on international tourist markets. *Transport. Res. Transport Environ.* 15 (1), 26–36. <https://doi.org/10.1016/j.trd.2009.07.002>.
- Meng, S., Pham, T., 2017. The impact of the Australian carbon tax on the tourism industry. *Tour. Econ.* 23 (3), 506–522. <https://doi.org/10.5367/te.2015.0514>.
- Meng, S., Pham, T., Dwyer, L., Grant, B., 2021. Carbon price impacts on the Chinese tourism industry. *J. Trav. Res.* 60 (2), 370–383. <https://doi.org/10.1177/0047287520903111>.
- Müller, N., Teixidó, J.J., 2021. The effect of the EU ETS free allowance allocation on energy mix diversification: the case of Poland's power sector. *Clim. Policy* 21 (6), 804–822. <https://doi.org/10.1080/14693062.2020.1870914>.
- Oesingmann, K., 2022. The effect of the European Emissions Trading System (EU ETS) on aviation demand: an empirical comparison with the impact of ticket taxes. *Energy Policy* 160, 112657. <https://doi.org/10.1016/j.enpol.2021.112657>.
- RDC Aviation, 2024. Apex schedules. <https://rdcaviation.com/>.

- Sabre, 2024. Market intelligence. <https://prod.marketintelligence.sabre.com/mi/MarketIntelligence.html#OD>.
- Santonja, A., Teixidó, J., Zaklan, A., 2023. Carbon Cost Pass-Through in European Aviation (Working paper).
- Seetaram, N., Song, H., Page, S.J., 2014. Air passenger duty and outbound tourism demand from the United Kingdom. *J. Trav. Res.* 53 (4), 476–487. <https://doi.org/10.1177/0047287513500389>.
- Tol, R.S., 2007. The impact of a carbon tax on international tourism. *Transport. Res. Transport Environ.* 12 (2), 129–142. <https://doi.org/10.1016/j.trd.2007.01.004>.
- United Nations Population Division, 2024. World urbanization prospects: 2022 revision. <https://www.un.org/development/desa/pd/world-population-prospects-2024>. (Accessed 10 April 2024).
- Wang, X., Xi, H., 2023. Carbon mitigation policy and international tourism. Does the European Union Emissions Trading System hit international tourism from member states? *Ann. Tourism Res.* 103, 103684. <https://doi.org/10.1016/j.annals.2023.103684>.
- World Bank Group, 2024a. World development indicators. <https://databank.worldbank.org/source/world-development-indicators>. (Accessed 10 April 2024).
- World Bank Group, 2024b. World development indicators. <https://www.worldbank.org/en/publication/worldwide-governance-indicators>. (Accessed 5 February 2025).
- World Tourism Organization; OECD, 2019. Transport-related CO₂ emissions of the tourism sector: modelling results. <https://doi.org/10.18111/9789284416660>.
- Zhang, Y., Wang, K., 2024. Mitigation effect of the European Union emission trading system on aviation emissions. *Transport. Res. Transport Environ.* 130, 104186. <https://doi.org/10.1016/j.trd.2024.104186>.
- Zhang, J., Zhang, Y., 2018. Carbon tax, tourism CO₂ emissions and economic welfare. *Ann. Tourism Res.* 69, 18–30. <https://doi.org/10.1016/j.annals.2017.12.009>.
- Zhang, J., Zhang, Y., 2020. Could the ETS reduce tourism-related CO₂ emissions and carbon intensity? A quasi-natural experiment. *Asia Pac. J. Tourism Res.* 25 (9), 1029–1041. <https://doi.org/10.1080/10941665.2020.1819837>.