I Z A Institute
of Labor Economics
Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 16783

Tax Incidence in Heterogeneous Markets: The Pass-through of Air Passenger Taxes on Airfares

Florian Wozny

FEBRUARY 2024

DISCUSSION PAPER SERIES

IZA DP No. 16783

Tax Incidence in Heterogeneous Markets: The Pass-through of Air Passenger Taxes on Airfares

Florian Wozny
DLR and IZA

FEBRUARY 2024

ISSN: 2365-9793

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Tax Incidence in Heterogeneous Markets: The Pass-through of Air Passenger Taxes on Airfares*

The tax incidence is central to the effectiveness of taxation. In this paper, I examine the pass-through rate of an air passenger tax to airfares. Additionally, I analyse its impact on passenger numbers, air transport capacity, and the interaction with supply and demand elasticity. For identification, I exploit the implementation of an air passenger tax on worldwide departures from Sweden and compare them with similar departures from Denmark and Finland with no such air passenger tax implementation. For the analysis, I use a unique data set of the universe of worldwide airline bookings. On average, airlines choose an immediate and nearly full pass-through of taxes. Consistent with theoretical priors for oligopolistic markets, tax incidence increases with competition but decreases with lower demand elasticity. Furthermore, the air passenger tax reduces passenger numbers and air transport capacity significantly.

JEL Classification: H22, L13, Q52

Keywords: tax incidence, competition, air passenger tax, environmental policy

Corresponding author:
Florian Wozny
German Aerospace Center (DLR)
Linder Hoehe
D-51147 Köln
Germany

E-mail: Florian.Wozny@dlr.de

* I would like to thank Benjamin Elsner, Andreas Lichter, Sven Maertens, Karsten Müller, Ariane Kehlbacher, Katrin Oesingmann, Janina Scheelhaase as well as seminar and conference participants at the North American Meeting of the Urban Economics Association 2023, LV-Institutskolloquium and Ökonver-Halbjahrestreffen for their feedback.

1 Introduction

Global air transport accounts for 3.5% of anthropogenic climate warming (Lee et al., 2021). However, air transport has been one of the fastest rising sources of greenhouse gas emissions (Pörtner et al., 2022) and without intervention, emissions of international air transport could triple by 2050 compared to 2018 (ICAO, 2022). Many countries have implemented air passenger taxes to reduce air transport emissions. Air passenger taxes – also known as departure taxes – aim to internalize the environmental impact of air transport by levying a tax on departing passengers (Larsson et al., 2019).[1] Increasing airfares are expected to reduce demand and, in turn, supply, thereby reducing air transport emissions. The size of the reduction in passenger numbers depends on the pass-through rate of the tax, which in turn depends on the elasticities of demand and supply in a given market (Ganapati et al., 2020). Passengers are expected to show a demand response only if the tax is passed on to them.

Little is known about the pass-through of environmental policies on consumer prices and the underlying mechanisms. It is commonly assumed that firms can fully pass on costs to consumer prices (Ganapati et al., 2020). Economic theory identifies supply elasticity in terms of competition as a key determinant of pass-through. In competitive markets, taxes are predicted to be fully passed through to prices, although in imperfect markets a one percent increase in taxes may increase prices by less than or more than one percent. Driven by the curvature of demand, it is assumed that pass-through rates exceed one under convex demand. In other words, the additional markup on inelastic demand offsets the losses of elastic demand. On the contrary, pass-through rates are below one under concave demand (Weyl and Fabinger, 2013). Understanding pass-through of taxes in imperfect markets is crucial, as numerous significant industries are characterized as oligopolies (Adachi and Fabinger, 2022).

However, there is little empirical evidence on the relation between competition and pass-through (Genakos and Pagliero, 2022). Furthermore, the empirical understanding how the tax incidence depends on demand elasticity is limited (see Kosonen (2015); Harju et al. (2018)). Usually, higher pass-through rates can be observed in industries with inelastic demand and higher profits (Ganapati et al., 2020). In the context of the airline industry, a few papers have analysed the impact of air passenger taxes on air transport supply and demand (e.g. Falk and Hagsten (2019); Borbely (2019); Oesingmann (2022)). However, causally

[1] Besides, it is a revenue raising duty, which makes an important contribution to the public finances (see, for example, HM Treasury 2011: Reform of Air Passenger Duty: Response to consultation)

identified tax incidence of air passenger taxes remains a gap in the literature (Bradley and Feldman, 2020).

This paper analyses the tax incidence of the Swedish air passenger tax and its impact on passenger numbers and how this translates to the number of departures and available seats. Since April 2018, an air passenger tax has been levied on passengers starting their journeys from Swedish airports. The neighboring countries, Denmark and Finland, have not introduced comparable measures. I exploit the tax variation within origin-destination airport-pairs over time in a difference-in-difference framework. Tax rates increase with the distance between origin and destination airports and apply to all passengers on commercial flights of aircraft registered for carrying 10 passengers or more. The average statutory tax rate corresponds to around 5.7% of mean total airfare of departures from Sweden. Airlines are responsible for transferring the tax to the fiscal office and thus have the authority to decide the proportion of the tax that is ultimately borne by their customers. Using variation in the market structure, this paper also studies the impact of supply and demand elasticity on the tax incidence. In Europe, airlines serve heterogeneous markets with varying degrees of competition. Some airline markets – defined as origin and destination city-pairs – can be considered as competitive, but most markets are best classified as either oligopolistic or monopolistic (Obermeyer et al., 2013). This variation is key to study tax incidences in imperfect markets under heterogeneous competitive circumstances.

This study is based on the unique Sabre Market Intelligence data set (Sabre-MI), providing the universe of airline bookings on a monthly basis. Sabre-MI offers three features that are key to the analysis. First, unlike other data sets used in the corresponding literature, it includes reliable worldwide transaction measures of airfares, passenger numbers, number of departures and available seats. Second, the panel structure of the data set allows to identify the causal impact of the Swedish air tax using Finland and Denmark as a control group. Third, the data set provides monthly observations of origin and destination airport-pairs, separated by airlines and booking classes, thus allowing for heterogeneous analysis under different market conditions. For example, I use variation in passenger number concentration among airlines operating on the same city-pair routes to examine the impact of supply elasticity on tax incidence.

The results show that airlines choose an immediate and nearly full pass-through of air passenger taxes. The pass-through increases linearly with the tax rate. In addition, the air passenger tax significantly reduces passenger numbers by an average of 9.2%, which translates into a similar supply reduction. Effect sizes for passenger numbers and air transport capacity are in line with findings of other studies analysing the impact of similar air passenger taxes (e.g. Falk and Hagsten (2019); Borbely (2019)) and corresponds to the average demand elasticity of air transport in the literature (Intervistas, 2008). Pass-through rates decrease with market concentration at city-pair level. Factors constraining consumers' price elasticity such as business travel increase the pass-through of taxes, both consistent with the theory of tax incidence under oligopoly.

With this paper, I contribute to three strands of literature. First, this paper contributes to the literature on the transmission of varying economic conditions to prices. This has been studied across many economic fields such as exchange rates (Campa and Goldberg, 2005; Goldberg and Hellerstein, 2008; Gopinath et al., 2011), health-care subsidies (Cabral et al., 2018; Duggan et al., 2016), commodity inputs (Nakamura and Zerom, 2010; Bonnet et al., 2013; Fabra and Reguant, 2014; Ganapati et al., 2020) or minimum wages (Harasztosi and Lindner, 2019). More closely related papers in the empirical literature have focused on commodity tax incidences, revealing a large variation. For example, Kenkel (2005) analyses the tax incidence of an alcohol tax suggesting that taxes are more than fully passed through to prices. Carbonnier (2007) studies the tax incidence of a French VAT-reform and points out that the consumer share of the tax burden is between 57% and 77%. Similar to Kenkel (2005), tax incidence varies substantially between product categories. Kosonen (2015) utilizes a Finnish VAT cut for hairdressers and estimates a pass-through of 50%. Benzarti and Carloni (2019) shows that VAT cuts have different incidences for workers, firm owners, consumers, and suppliers. Others have focused on the tax incidence on fuel taxes (Marion and Muehlegger, 2011; Genakos and Pagliero, 2022).

Second, this paper adds new evidence on the impact of supply and demand elasticity on pass-through of costs, subsidies and taxes. Existing evidence regarding the impact of competition on pass-through is mixed. Miller et al. (2017) find that competition reduces pass-through of fuel cost changes to prices in a market in which the pass-through is above one. Similar, Stolper (2018) finds that higher market concentration in the gasoline market is associated with higher pass-through rates of up to 120%. In contrast, Cabral et al. (2018) study the pass-through of government subsidies to health care services. Their results reveal pass-through estimates ranging from 13% to 74%, which increase with competition. Similarly, Genakos and Pagliero (2022) show that pass-through of fuel taxes increases from 40% in monopoly markets to 100% in competitive markets, with price adjustments occurring significantly faster in more competitive markets. Consequently, by analysing the impact of both demand and supply elasticity on tax incidence, I closes a gap in the literature.

Third, this paper contributes to the literature on environmental and air transport policies and their impact on consumer prices or demand and supply responses. Hintermann (2016) shows that emission costs are completely passed on to electricity prices. Similar, Alexeeva-Talebi (2011) finds that European refineries fully pass-through costs of the introduction of the EU Emissions Trading Scheme to fuel prices. Little research has been done on the effect of air passenger taxes on airfares. Several papers have shown that air passenger taxes reduced demand for air transport in Europe. However, these papers omit the analysis of tax incidence due to the absence of comprehensive airfare data (Falk and Hagsten, 2019; Borbely, 2019; Oesingmann, 2022). Huang and Kanafani (2010) analyse the incidence of a passenger facility charge using data from 1993 to 1995. Their findings suggest that the burden on passengers exceeds 200%. Bradley and Feldman (2020) studies the effect of a full-fare disclosure rule on tax incidence, concluding that displaying tax-inclusive airfares is associated with a reduced tax burden for passengers, with the extent of this reduction depending on market concentration. The pass-through rates are lower in highly concentrated markets. Chuang (2021) analyses the incidence of the September 11 Security Fee but without a control group. The most related study, conducted by Bernardo et al. (2024), focuses on the tax incidence of air passenger taxes across Europe, particularly on Low Cost Carrier connections within the European Economic Area and the United Kingdom, using advertised airfares. They estimate pass-through rates from 20% to 56%. However, according to the authors, these estimates are not causally identified.

The remainder of this paper is structured as follows. Section 2 shows background information about the airline industry and ties it with the theoretical framework. In section 3, the Swedish air passenger tax and the data used for the identification strategy are shown. This is followed by Section 4 presenting the empirical strategy and Section 5 presenting the results, before concluding in Section 6.

2 Airline Industry and Theoretical Background

2.1 Airline Industry

The market for air travel is usually described as oligopolistic dominated by a small group of companies due to high start-up costs, infrastructure constraints, and incumbents' large economies of scale. Such barriers may prevent new entrants from increasing competition. Air transport markets are often defined as airport-pairs. Airports belonging to a multi-airport system are assumed to serve the same market. For example, the market between London and New York is usually understood to consists of all connections between London airports and New York airports. Therefore, all airlines operating from airports within a multi-airport system are regarded as competitors (Brueckner et al., 2013). Most of the air transport markets are in fact monopolies. However, many of these markets are rather small in size, with only a minority of passengers traveling in these monopolized markets. Most passengers travel in markets that appear to be oligopolies, with two to four competing airlines (Koopmans and Lieshout, 2016).

Airlines pursue different business models which can be characterized as the traditional full service carrier, low cost carrier, charter/holiday carrier and regional carrier. Holiday carriers usually provide unscheduled services through contracts with tour operators to tourists. Regional carriers operating as feeders on behalf of the full service carriers often do not ticket passengers themselves. Low-cost carriers have a relatively low-cost structure and offer low fares. They provide point-to-point services, often using less congested secondary airports. Full service carriers often referred to as network carriers or legacy carriers provide frequent service using hub and spoke networks. They usually provide passengers with amenities that are included in the ticket price such as meals, blankets, and checked baggage at different service levels such as first class, business class and economy class (Bitzan and Peoples, 2016). Markets can be further divided into leisure and business travelers as business travelers are less price sensitive (Brons et al., 2002). On the contrary, low cost carrier customers are considered more price sensitive (Murakami, 2011). This results in a convex demand curve, indicating that business travelers, who pay higher airfares, exhibit lower price elasticity compared to leisure travelers, who pay lower prices and demonstrate higher price elasticity.

Airlines are bounded to the flight schedule at least in the short-term where they have chosen their quantities first and adapt their fares to demand. In the long run, unprofitable routes can be closed (Koopmans and Lieshout, 2016). Typically, flight schedules are planned for 6-month periods although airlines can adjust their scheduling decisions by reducing operating routes and frequencies. However, airlines are subject to the use it or lose it rule in airports with capacity restrictions. If airlines do not use 80% of the allocated slots, they may lose them (ICAO, 2020).

Many airlines have implemented a pricing policy that splits airfares into base fares charged for basic air transport and total fares adding complementary services such as baggage fees. Additional, total fares include carrier-imposed fees like fuel surcharges but also government taxes and compulsory airport charges, for example. Airlines may use the difference between base and total fares for strategic price setting (Bradley and Feldman, 2020).

2.2 Theoretical Background

Economic theory has shown that the pass-through rate of profit-maximizing firms depends on the interaction of market structures and firm characteristics. Most aviation markets are best described as oligopolies providing a relatively homogeneous service. Following Weyl and Fabinger (2013), the pass-through of symmetrically differentiated firms in oligopolistic markets is described by

$$\rho = \frac{1}{1 + \frac{\Theta}{\epsilon_\Theta} + \frac{\epsilon_D - \Theta}{\epsilon_S} + \frac{\Theta}{\epsilon_{ms}}} \tag{1}$$

The conduct parameter Θ captures the degree of the competition among firms ($\Theta = 0$ in a competitive market and $\Theta = 1$ in a monopolistic market). The solution to the firm maximization problem is represented by $\frac{p - mc(q)}{p}\epsilon_D = \Theta$ where $mc(q)$ is the marginal cost and $\epsilon_D = -\frac{p}{qp'}$ the elasticity of demand. The pass-through ρ depends on the variation of the conduct parameter Θ as the quantity produced changes ($\epsilon_\Theta = \frac{\Theta}{q\frac{d\Theta}{dq}}$), the determinants of the elasticity of demand ϵ_D, the elasticity of supply as the inverse marginal cost curve ϵ_s, and the the demand functions' curvature $\epsilon_m s$. As a result, the sign and magnitude of the pass-through is ambiguous. The sign of the effect of an increase in the conduct parameter on the pass-through can be either positive or negative.

To highlight the role of the different elements in the denominator of Equation (1) the expression of ρ can be simplified by specific cases. The ratio $\frac{\epsilon_D - \Theta}{\epsilon_s}$ links demand and supply elasticity and pass-through. This ratio is equal to zero if the marginal cost is constant. It is reasonable to argue that the marginal costs of airlines are constant – at least in the short-run – as they depend on the predefined and fixed flight schedule and on long-term fuel contracts between airlines and trade companies. This suggests that demand heterogeneity probably does not significantly influence the outcome via the ratio $\frac{\epsilon_D - \Theta}{\epsilon_S}$.

The expression $\frac{\Theta}{\epsilon_\Theta}$ is also equal to 0 if Θ is constant. The conduct parameter Θ is a constant in a number of models. For example, Θ is equal to 1 in monopoly, equal to 0 in perfect competition and in the oligopolistic models such as the Bertrand model and equal to $\frac{1}{n}$ in the Cournot model.

A remaining important determinant of the pass-through is the demand curvature ϵ_{ms}. Using a linear demand specification, directly implies that $\epsilon_{ms} = 1$, if demand is concave $\epsilon_{ms} < 1$, if demand is convex $\epsilon_{ms} > 1$. A convex demand specification, as stated in Section 2.1, under constant marginal cost $mc(q)$ and a constant conduct parameter Θ implies $\rho = \frac{1}{1+\frac{\Theta}{\epsilon_{ms}}}$. Consequently, less competition (indicated by an increase in the conduct parameter) results in a lower rate of pass-through to air passengers. In turn, business travelers expire higher pass-through rates than economy class travelers.

3 Institutional Background and Data

3.1 The Swedish Air Passenger Tax

Taxing fuel consumption is a common policy to reduce emissions from transport. It is, however, uncommon in air transport as the 1944 Chicago Convention on International Civil Aviation, article 24, prohibits taxing fuel on international flights. As international air transport generally takes place outside any tax jurisdiction, the International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA) argued that a zero VAT rate should be applied, which is common practice. Air passenger taxes can be seen as a reaction to this practice (Faber and Huigen, 2018).

The Swedish aviation tax was proposed by the government to the Swedish parliament as part of the 2018 budget proposition and accepted on 22 November 2017 (Finansutskottets betänkande 2017/18:FiU1 Statens budget 2018 Rambeslutet). The tax aims to reduce the climate impact of aviation and is regulated in the Swedish act SFS 2017:1200 regarding tax on air travel. It was decided to be implemented on 1 April 2018 as an excise duty concerning commercial air travels. The tax rate is distance dependent[2] – following a polluter-pays-principle – and categorized into three country groups. The tax is applied to all commercial passengers starting their journey from Swedish airports using airplanes registered for carrying 10 passengers or more. All passengers are included except children younger than 2 years, transfer passengers from flights from outside of Sweden, and the cabin crew. The responsibility for paying the tax is put on the operating airline. According to EU-legislation, the tax has to be communicated to the customers by the airline in the price specification before the booking is made.

The amount to be paid differs between destination zones (Figure 1). The tax amount is 60 SEK per air passenger traveling within Sweden and to Europe (1. tax zone). These are short and medium-haul flights. Further, the tax amount per passenger traveling to countries outside Europe is either 250 SEK (2. tax zone 2) or 400 SEK (3. tax zone), depending on the travel distance. The 2. tax zone encompasses medium and long-haul flights, while long-haul flights fall under the 3. tax zone. Given the average exchange rate in 2017, tax rates are equivalent to $7.2 in the 1. tax zone, $30 in the 2. tax zone and $47.6 in the 3. tax

[2] See Table A4a for the average distance per tax group of the estimation sample

zone (Table A1). After the reform, a flight from Stockholm to Berlin that used to cost $100 would now cost $107.2 – everything else equal. A flight from Stockholm to Beijing that used to cost $400 would now cost $447.6.

The tax rate that applies to a certain country also applies to its associated territories that are geographically separated from it. For a detailed list of countries within each tax level, see Table A2. The amount to be paid is adjusted to the annual price level (SFS 2017:1200). From January 2019 onward, taxes have been adjusted to 61/255/416 SEK. Denmark and Finland have not introduced air passenger taxes yet.[3] In Finland and Sweden, the VAT on domestic flights is 10% and 6%, respectively. In both cases no change have occurred at least since 2014. Denmark does not have a VAT on domestic flights[4].

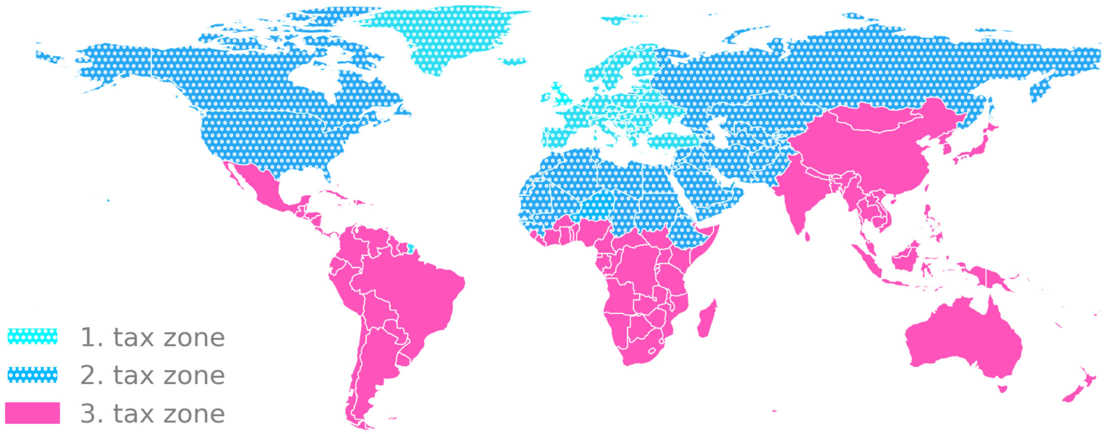


Figure 1: Tax zones of the Swedish air passenger tax

Notes: This figure shows the spatial distribution of the Swedish air passenger tax rates. The tax amount is 60/61 SEK per air passenger traveling within Sweden and to Europe (1. tax zone). Further, the tax amount per passenger traveling to countries outside Europe is either 250/255 SEK (2. tax zone) or 400/416 SEK (3. tax zone), depending on the travel distance.

3.2 Airfare and Passenger Data from the Universe of Airline Bookings

To identify the impact of the air passenger tax, this paper uses confidential airfare and passenger panel-data from the universe of airline bookings provided by Sabre Market Intelligence. This data set provides validated raw bookings from global distribution systems, such as Sabre, Travelport and Amadeus aggregated on a monthly level. Global distribution systems are computer networks operating as an intermediary between travel agents

[3] Besides other policy measures targeted on air transport Norway has implemented an air passenger tax in the observation period and is therefore not considered in the analysis

[4] According to Taxes in Europe Database v3 and European Comission (2014)

and airlines. Sabre Market Intelligence includes sales data from traditional travel agencies and online travel agencies (Sabre, 2015b). The unit of observation are aggregated monthly itineraries within the air travel network. For example, an itinerary from Heathrow Airport to John F. Kennedy Airport may consist of a direct or multiple connecting flights operated by different airlines and different cabin classes. The full data set includes 918,048 mutually exclusive itineraries separated by airline, cabin-class, airport-pairs and connecting airports departing from Sweden, Finland and Denmark over the period from 2015 to 2019. For those itineraries, average airfares and the number of passengers are provided.

The global flight network provides a very large variety of possible itinerary choices. Uncommon itineraries with less than 10 bookings per month and with total airfares above or below the top and bottom 5th percentile of the booking classes per tax zone country group are excluded. This restriction offers the advantage of filtering out less substantial markets, where idiosyncratic variation in passenger demand may be especially prevalent and contribute to statistical imprecision. Moreover, it reduces unobserved heterogeneity, as extreme airfares might express uncommon demand fluctuation due to major events, natural disaster or strikes, for example. This reduces the number of itineraries to 126,013. The majority of itineraries consist of less than 10 bookings per month. However, these itineraries only account for 3% of the overall passenger volume. Furthermore, itineraries between the control and the treatment group are excluded to account for potential spillovers which reduces the number of itineraries to 122,717. Finally, a balanced sample is employed of itineraries that are offered by throughout the period of investigation. This includes non-seasonal itineraries, available every month throughout the observation period, or seasonal itineraries, but only if they are offered in the same months each year. Again, this reduces the number of itineraries significantly to 42,773. In the end, a sample of of 257,550 itinerary-month observations is employed. In a robustness check, a full set of itineraries is employed.

Figure A1 shows that most of the observations stem from the three major airports Arlanda (Stockholm), Copenhagen Airport and Helsinki Airport and 33% from other airports. The locations of the origin airports are shown in Figure A2. The spatial proximity of certain airports potentially gives rise to spillover effects, challenging the non-interference assumption between the control and treatment groups. Consequently, a specification curve analysis is conducted in Section 5.4, involving the random exclusion of NUTS-3 regions from the estimation sample. To further account for potential spillovers, the Netherlands, Latvia, Estonia and Lithuania have been randomly included in the control group of the sample while randomly leaving out Denmark and Finland. These are the nearest neighboring countries without a direct border and without an air passenger tax. Compared to airports, the concentration of airlines and especially destination airports is much lower (Figure A1).

Airfares are divided into total fares, including taxes, surcharges, and additional fees, and base fares, which exclude taxes, surcharges, and other fees. Ancillary fees charged by airlines, such as baggage and preferred seating, are not included in total fares. Airfares are transaction fares, not necessarily offered fares (Sabre, 2015a). Airfares are always quoted in the national currency of the place of departure. Sabre-MI converts airfares into US dollar. Consequently, varying exchange rates affect airfares across countries – increasing time-varying unobserved heterogeneity. To address this, I standardize exchange rates by dividing airfares by the corresponding monthly exchange rates for each country [5] and multiply them by the average exchange rate of 2017. Figure A5 shows the correlation between exchange rates and airfares before converting the airfare (Panel (a)) and after (Panel (b)). Fixing exchange rates reduces time-varying unobserved heterogeneity between countries. Airfares are weighted by average passengers numbers per tax-zone over the sample period.

Panel A of Table 1 shows that the mean statutory tax incidence is \$19.49. It is assigned as 100% pass-through of the air passenger tax on an itinerary departing from Swedish airports according to the tax rate of the destination country between April 2018 and December 2019. Accordingly, 60% of the Swedish itineraries are grouped in tax-zone 1, 23% in tax-zone 2 and 17% in tax-zone 3.[6]

Panel B of Table 1 shows substantial variation in the characteristics of the 257,550 itinerary-month observations. The main variable of interest, weighted total airfares, range from only \$1.88 to \$31,025 with a mean of \$343.08 and a much larger standard deviation of \$1092.59. Passenger numbers per itinerary range from 10 to 28,038 with a mean of 385.68 passengers. Measured in kilometers of the great circle distance, the distance indicates that, on average, itineraries tend to be medium or long-haul. Revenue passenger kilometers (RPK)[7] – used to estimate the tax impact on emissions – show substantial variation as well.

Business class and economy class account for 5% and 95% of the observations in the data set, respectively. About 90% of the itineraries in the data set are carried out by full service or regional carrier whereas 10% are operated by low-cost carrier.[8] The Herfindahl-

[5] Finland: Euro/USD, Denmark: Danish Krone/USD, Sweden: Swedish Krone/USD

[6] The number of observations refer to monthly itineraries departing from Sweden from April 2018 onward and thus differ from the number of observations of Panel B and Panel C which are based on the full estimation sample

[7] RPK = Number of passenger per itinerary × great circular distance between airport-pairs

[8] The ICAO provides a list of low-cost airlines that is used to establish the category of low-cost airlines.

Index (HHI) relies on the distribution of carried persons at the city-pair[9] level in the year 2017. Note that the HHI is potentially endogenous and may respond to the tax rate. For this reason, I fix the characteristics to the values of 2017, i.e., the year prior tax implementation. With an average value of 0.51, the HHI points to an oligopolistic level of competition. Based on findings of Bresnahan and Reiss (1991); Genakos and Pagliero (2022), which indicates that the impacts of competition are predominantly observed in monopolistic and duopolistic markets, I create dummy variables. These variables are assigned a value of 1 for routes characterized as either monopolies (HHI > 0.99) or duopolies (HHI between 0.50 and 0.99). 13$\%$ and 34$\%$ of itineraries are monopolies or duopolies, respectively.

Panel C of Table 1 shows regional characteristics at the NUTS-2 level for origin airport locations, which are used as additional control variables in the regression analysis. The Regional data is provided by Eurostat at a yearly basis.

[9] Airports are assigned to the area of a city

Table 1: Descriptive statistics

	Mean	Std	Min	Max	Observations
Panel A					
Statutory tax incidence (USD)	19.46	16.09	7.12	49.35	40181
1. tax zone	0.60	0.49	0.00	1.00	40181
2. tax zone	0.23	0.42	0.00	1.00	40181
3. tax zone	0.17	0.37	0.00	1.00	40181
Panel B					
Base airfare (USD)	236.18	862.12	0.06	26803.33	257550
Total airfare (USD)	343.08	1092.59	1.88	31025.03	257550
Passengers	385.68	1378.04	10.00	28038.00	257550
Distance (km)	4464.72	3613.75	45.00	20263.00	257550
RPK/1000	850.31	2427.31	1.61	60330.41	257550
Business Class	0.05	0.22	0.00	1.00	257550
Economy Class	0.95	0.22	0.00	1.00	257550
Low Cost Carrier	0.10	0.30	0.00	1.00	257550
Full service or regional carrier	0.90	0.30	0.00	1.00	257550
Herfindahl Index	0.53	0.26	0.13	1.00	257550
Monopoly	0.13	0.33	0.00	1.00	257550
Duopoly	0.34	0.47	0.00	1.00	257550
Panel C					
Population/km^2	336.22	268.32	3.40	756.00	257550
GDP per capita (USD)	42928.19	7634.57	24900.00	51700.00	257550

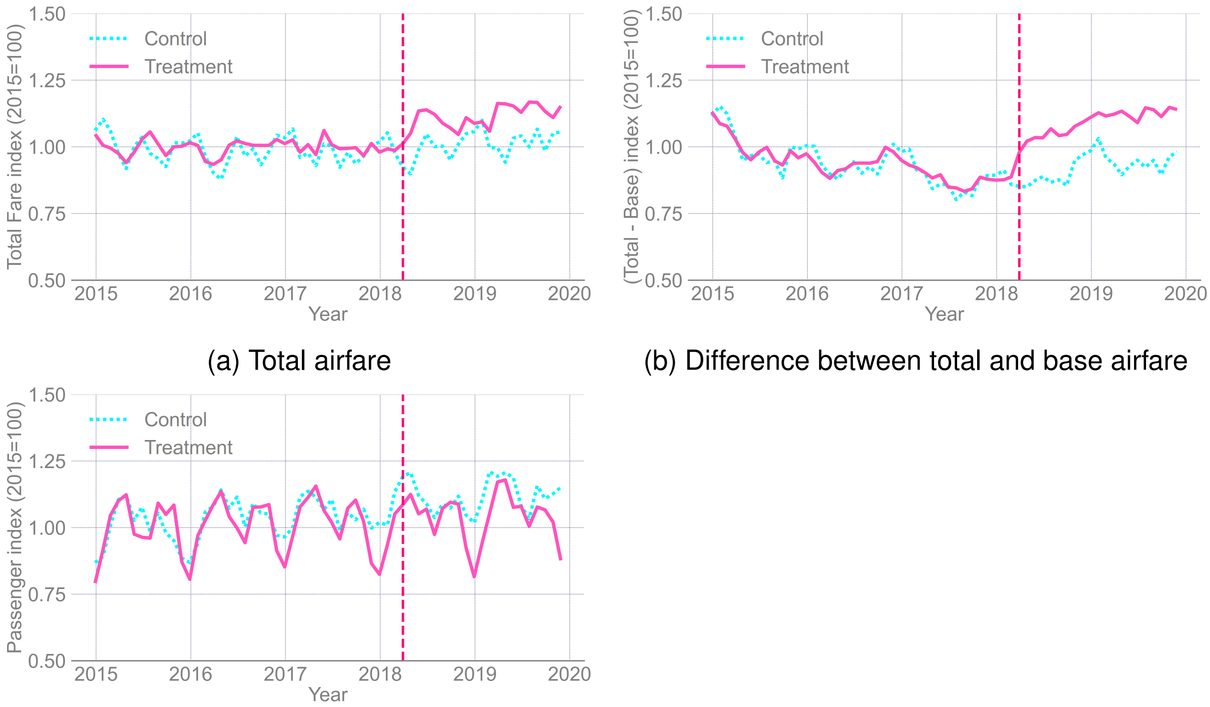
Notes: This table shows descriptive statistics for the variables used in the analysis. The variables presented in Panel A refer to the taxation of departures from Sweden between 01.04.2018-31.12.2019. Panel B shows information about departures from Sweden, Finland and Denmark between 01.01.2015-31.12.2019. The data underlying the statistics in Panel C are obtained from Eurostat and measured at NUTS2 at origin airport locations, although the statistics themselves are computed at the itinerary level.

In order to reveal the reliability of Sabre-MI, airfares and passenger numbers are compared with the publicly accessible Origin Destination Survey (DB1B) provided by the United States Bureau of Transport Statistics. The DB1B survey is conducted by all certified US carriers and covers a stratified 10% sample of domestic air travel in the United States. DB1B is structured on a quarterly basis, which is why I aggregate Sabre data to quarterly values for comparison. Similar to Sabre, it provides origin and destination passenger numbers, transfers, booking classes and airfares paid. It hast been used in several economic studies (Dai et al. (2014); Ciliberto and Williams (2014); Gerardi and Shapiro (2009)). Figure A3a and Figure A3b reveal a strong correlation in the quarterly average airfare and the passenger numbers between the DB1B and Sabre data set. For example, in the first quarter of 2018, the average airfare of a flight from John F. Kennedy International Airport to Hartsfield-Jackson Atlanta International Airport operated by American Airlines is $205 in the DB1B dataset and $215 in the Sabre-MI data set.

To assess the impact on supply quantity, another data set is used, as Sabre-MI does not provide capacity information throughout itineraries. Instead, it provides detailed flight schedule data of the global air passenger transport. It allows to analyse the monthly number of planned departures and the average number of seats per flight of non-stop connections between airports, separated by operating airline, between 2015 and 2019. I restrict the sample to those airport-pairs used to study the airfare and passenger numbers. These are flights of non-stop itineraries – for example from Arlanda Airport to Heathrow Airport – but also flights which are the first leg of an itinerary – for example from Arlanda Airport to Heathrow Airport of an itinerary from Arlanda Airport to John F. Kennedy Airport via Heathrow Airport. Descriptive statistics of the flight schedule data are shown in Table A5.

3.3 Trends Before the Swedish Air Passenger Tax Reform

The validity of the empirical approach's assumption of causal inference relies on the belief that, without the passenger tax reform, the development of airfares and passenger numbers would have been the same in both the treatment and control group. A common trend in the outcome variable before the treatment can be used to support this assumption. To assess whether there are similar trends between the treatment and control group prior to the passenger tax reform, indexed airfares and passenger numbers of both groups are compared over time. Figure 2 shows the average monthly indexes for the total airfare, the difference in total airfare and base airfare and the number of passengers of the control and treatment group. In all cases, the base period is the corresponding average of 2015. The development of these indices demonstrate that before the passenger tax reform, prices and passenger numbers in the control and treatment group have developed very similar. Any differences between the control and treatment group before the passenger tax reform were only of minor size. This is also true for the months immediately before the reform, indicating that air transport in Sweden did not adjust in anticipation of the tax introduction. Consequently, airfares in Finland and Denmark represent a credible counterfactual.



(a) Total airfare

(b) Difference between total and base airfare

(c) Number of passengers

Figure 2: Trends in the control and treatment group

Notes: The figure shows the average monthly indexes for the control and the treatment group (2015 = 1). The dotted vertical line indicates the month of the passenger tax introductions (April 2018).

4 Empirical Strategy

This paper estimates the causal impact of the introduction of an air passenger tax on airfares, passenger numbers and air transport capacities. The introduction of an air passenger tax in Sweden but not in Denmark and Finland motivates a difference-in-differences estimation strategy with the following empirical model, which is applied to itineraries departing from Sweden, Denmark and Finland over the period 2015-2019. The basic model reads:

$$y_{it} = \alpha + \beta Taxrate_it + X_{it}'\gamma + \delta_i + \delta_t + \delta_y d(i) + \delta_m c(i) + \epsilon_{it}, \tag{2}$$

where y_{it} indicates the outcome of interest for itinerary i which are total airfares, the difference between total and base airfares, passenger numbers, revenue passenger kilometers, available seats and number of departures at time t. The main variable of interest is $Taxrate_{it}$ and captures the continuous treatment of itinerary i at time t by an air passenger tax rate. The vector X_{it} accounts for time-varying regional characteristics at the departing airports, specifically addressing population density and GDP per capita. Unit or itinerary fixed effects δ_i capture any time-invariant itinerary characteristics such as the travel distance, historical links between countries, booking class and airline heterogeneity. Time fixed effects δ_t control for any time-specific effects that are uniform across all observation units i. Distance-year fixed effects $\delta_y d(i)$ control for any time-specific effects for observation units i at distance d in year y. Destination-month fixed effects $\delta_m c(i)$ control for any month-specific effects that are uniform across all observation units i within a destination country group c, according to tax zone one two and three (see Table A2) in month m. In order to reduce unobserved heterogeneity, Bradley and Feldman (2020), for example, applied multiple sample restrictions such as excluding business class passengers. Instead, I interact the three different tax rate categories with a binary indicator that equals unity if a business itinerary is being taxed. Consequently, point estimates of $Taxrate_{it}$ represent the results for the economy class, while the results for business class are shown in the heterogeneity analysis later on. To account for cross-sectional correlation in the error terms, I cluster the standard errors at the city-pair level of origin and destination airports.

In order to capture dynamic effects of the air passenger tax introduction, event studies are conducted to test whether tax effects differ over the post-treatment periods. In addition, this allows to test whether the identifying assumption of common pre-trends is violated. The introduction of an air passenger tax should not have any impact during pre-treatment periods. The extended model is:

$$y_{it} = \alpha + \sum_{k=-12,k\neq-1}^{k=+12} \beta^k Taxrate_{ik} + X_{it}'\gamma + \delta_i + \delta_t + \delta_y d(i) + \delta_m c(i) + \epsilon_{it}, \tag{3}$$

where the continuous variables $Taxrate_{ik}$ indicate monthly leads and lags of up to 12 months before and after the enactment of the air passengers tax. The reference category is $k = -1$, hence the post treatment effects are relative to the month immediately before the policy change and are interpreted as the effect of the air passenger tax rate k periods before or after its introduction. Controls are the same as before.[10]

[10] Event dummies are binned up at the endpoints of the event window (i.e., $k = -12$ and $k = 12$)

5 Results

5.1 The Impact of the Swedish Air Passenger Tax on Airfares

This section presents the estimation results for the impact of the air passenger tax introduction on airfares. Estimates of the β coefficient measure the total effect of the air passenger tax rate on airfares, which includes demand and supply responses. Therefore, results are reduced-form effects. Table 2 reports the main OLS results for the air passenger tax on total airfares. Each cell in this table represents an estimate for β according to Equation 2 from a separate regression of airfares on air passenger tax rates. All regressions include itinerary (unit) and time fixed effects to capture any time-invariant itinerary characteristics (e.g., willingness to pay) as well as any time-variant changes that are uniform across itineraries (e.g., business cycle, policy or fuel price changes). Further controls included are indicated at the bottom of each column. Controls for relevant time-variant regional characteristics are included by GDP per capita and population density at NUTS2-level of the origin airport. Distance-year fixed effects control for any time-varying differences in flight distance such as operational costs or travel behavior, while destination-month fixed effects control for any seasonal differences between destination country groups.

Table 2 starts with a two-way fixed effect regression in Column (1) controlling for itinerary and time fixed effects.[11] The tax incidence for total airfares is 1.032 and significantly different from zero at conventional levels. In Column (2), including distance-year fixed effects increases point estimates, indicating higher price increases for longer-distance itineraries over time in Finland and Denmark compared to Sweden. Column (3) maintains stable point estimates with the inclusion of destination-month fixed effects. In Column (4), controlling of regional characteristics slightly reduces the point estimate but it continues to be statistically significant different from zero. Despite including numerous control variables, point estimates remain highly stable. Including the business class interaction term in Column (5), reveals a tax incidence of 0.99. This applies to economy class itineraries only. A $300 economy class ticket, subject to a $47 air passenger tax, amounts to $346.53. On the contrary, the point estimate in Column (4) reflects the average joint effect for both business class and economy class itineraries. According to theoretical priors, including the business class interaction reduces the point estimate, as low price elasticity is susceptible to over-shifting.

Statutorily, the air passenger tax is included in the total airfare, not in the base airfare. Thus, if base fares have remained time-invariant, and no further surcharges have been

[11] I do not apply the proposed estimator of De Chaisemartin and d'Haultfoeuille (2020) as it is motivated by group fixed effect. Instead, I apply unit fixed effects.

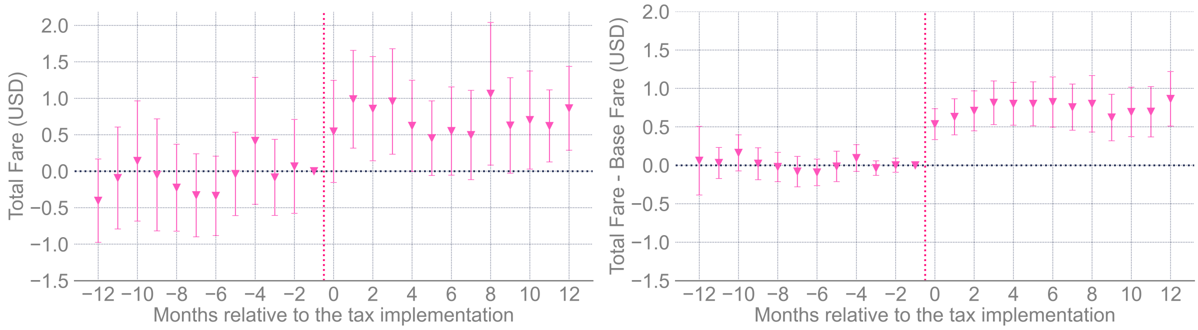
implemented, the difference between total and base airfare should increase by one. Airlines can influence the difference between base and total airfare by reducing fuel surcharges, for example. Table A3 shows the results for the difference between the total and base airfare, using the same methodology as in Table 2. The difference between total and base fares does not increase by the same magnitude as total fares, indicating that certain airline-imposed fees, such as fuel surcharges, have been transferred to the base airfare due to the reform. Despite including numerous control variables, point estimates remain highly stable.

Table 2: Effect of the air passenger tax on total airfares

	(1)	(2)	(3)	(4)	(5)
Tax rate	1.032***	1.307***	1.282***	1.180***	0.993***
	(0.198)	(0.224)	(0.222)	(0.222)	(0.171)
Controls:					
Itinarary FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Distance (Km) $\times$ Year	No	Yes	Yes	Yes	Yes
Destination $\times$ Month	No	No	Yes	Yes	Yes
Region characteristics	No	No	No	Yes	Yes
Tax zone $\times$ Business	No	No	No	No	Yes
Adjusted R^2	0.97	0.97	0.97	0.97	0.97
Observations	257550	257550	257550	257550	257550

Notes: This table displays the main estimation results from OLS regressions. Each coefficient is the result of a separate regression of monthly-level airfares on a continuous variable for itineraries being levied by an air passenger tax rate, controlling for the variables indicated below. Standard errors, clustered at the city-pair level, are displayed in parentheses. Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

Figure 3 presents the results for the tax incidence in an event study framework. Panel (a) illustrates the impact of air passenger tax rates on total airfares, while Panel (b) displays the impact on the difference between the base and total airfare. In both panels, the effects start to appear already in the first month and remain relatively constant over time. Coefficients in both panels vary between one half and one. Pre-reform trends are flat and not statistically different from zero.



(a) Total airfare

(b) Difference between total and base airfare

Figure 3: Event study estimates: Tax incidence

Notes: This figure illustrates the estimated treatment effect from OLS regressions of air passenger tax rates on total fares and the difference between total and base fares relative to the pre-reform month. The underlying econometric model is described in Equation 3. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the city-pair level.

Table 3 shows different functional forms between the air passenger tax and the tax incidence. For comparison, Column (1) reproduces the estimate reported in Column (5) of Table 2. The estimates in Columns (2) and (3) provide evidence in favor of a linear relationship. In Column (2), a non-linear relationship is imposed using a binary indicator for tax rates, revealing a pass-through rate of one at the mean[12]. In Column (3), the three different tax rate categories are interacted with a binary indicator that equals unity if an itinerary is taxed. The point estimate of the 1. tax zone is \$6.45 and it is statistically significant different from zero. This corresponds to a tax incidence of 0.9. The significant point estimates of the 2. and 3. tax zone are \$35.85 and \$44.12, respectively. Consequently, the tax incidence is 1.19 in the 2. tax zone and 0.91 in the 3. zone three. According to Weyl and Fabinger (2013), pass-through rates depend solely on market conduct, supply elasticity, and demand elasticity, which are analysed in the following sections.

[12] $19.43/19.46 = 1$

Table 3: Functional form of the passenger tax on total airfares

	(1)	(2)	(3)
Tax rate	0.993***		
	(0.171)		
Tax		19.431***	
		(3.886)	
1. tax zone			6.451**
			(3.189)
2. tax zone			35.845***
			(10.255)
3. tax zone			44.121***
			(7.449)
Controls:			
Itinarary FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Distance (Km) $\times$ Year	Yes	Yes	Yes
Destination $\times$ Month	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes
Tax zone $\times$ Business	Yes	Yes	Yes
Adjusted R^2	0.97	0.97	0.97
Observations	257550	257550	257550

Notes: In this table, various functional forms of the estimated treatment effect are presented, derived from OLS regressions of total fares on air passenger tax rates. Control variables are listed at the bottom. Standard errors, clustered at the city-pair level, are displayed in parentheses. Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

Table 4 explores whether the impact of the air passenger tax on total airfares differs between market structures. For each set of groups, the air passenger tax rate is interacted with indicators listed on the left-hand side.

Column (1) presents tax incidences categorized by duopoly and monopoly relative to all other remaining itineraries. Under non-monopolistic and non-duopolistic competition, the tax incidence is 1.028. In case of duopolisitic competition, pass-through remains unchanged, whereas it decreases to 0.213 under monopolistic competition. This aligns with the economic theory on tax incidence presented in Section 2.2 and corroborates the findings of Bresnahan and Reiss (1991) or Genakos and Pagliero (2022), indicating supply effects on pass-through only in the context of high market concentration.

In theory, the price elasticity of business class travel is presumed to be lower compared to that of economy class travel. In Column (2), the tax rate is interacted with a business class indicator, revealing a tax incidence of 0.973 for economy class travel and four for business class travel. Once again, over-shifting aligns with the theory due to convex demand curvature. Inelastic business class travelers compensate for revenue losses caused by elastic economy travelers. Column (3) investigates whether low pass-through rates on monopoly itineraries differ between economy and business class travelers, using a triple interaction term of the tax rate and two indicator variables that equal unity for monopolistic and business class itineraries, respectively. In a monopolistic setting, airlines may argue against reducing pass-through rates for business class similarly to economy class due to the inelastic demand for business class. However, according to Column (3), no such difference exists.

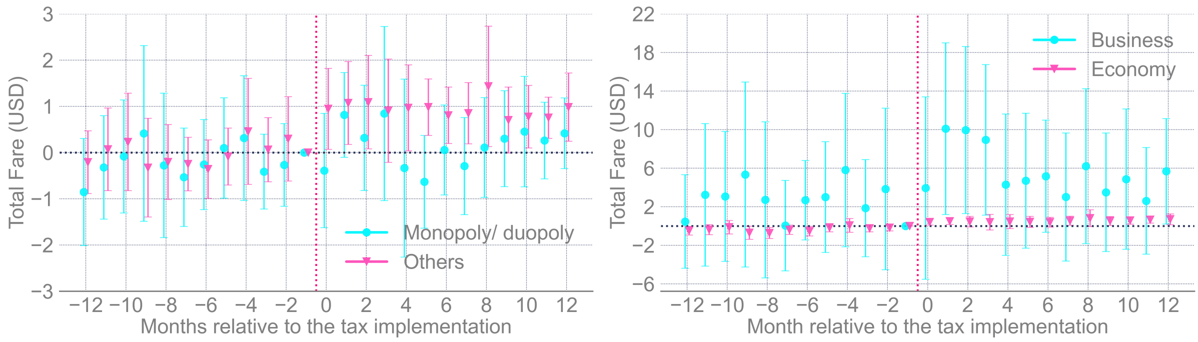
Costumers of low cost carrier are expected to have higher price elasticity. Therefore, a low cost carrier indicator is interacted with the tax rate in Column (5). The estimator implies that low cost carrier do not pass through taxes differently than other carriers. Nevertheless, demand elasticity as well as supply elasticity are both important determinants of tax incidence.

Table 4: Heterogeneous effects of the air passenger tax on total airfares

	(1)	(2)	(3)	(4)
Tax rate	1.028***	0.973***	1.042***	1.046***
	(0.187)	(0.164)	(0.175)	(0.163)
Tax rate × duopoly	0.261			
	(0.310)			
Tax rate × monopoly	-0.815***		-0.627***	
	(0.303)		(0.148)	
Tax rate × business class		3.027**	3.349**	
		(1.381)	(1.701)	
Tax rate × monopoly × business class			-1.355	
			(2.202)	
Tax rate × low cost carrier				-2.287
				(1.836)
Controls:				
Itinarary FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes	Yes
Distance (Km) × Year	Yes	Yes	Yes	Yes
Destination × Month	Yes	Yes	Yes	Yes
Tax zone × Business	Yes	No	No	Yes
Adjusted R^2	0.97	0.97	0.97	0.97
Observations	257550	257550	257550	257550

Notes: This table displays the estimates from OLS regressions of airfares on several interactions of the tax rate with market and airline characteristics and the control variables listed at the bottom. Standard errors, clustered at the city-pair level, are displayed in parentheses. Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

Figure 4 displays the tax incidence of total airfares in an event study framework, categorized by monopoly/ duopoly and other remaining itineraries (Panel (a)), and further categorized by business and economy class (Panel (b)). In Panel (a), taxes are passed on immediately in non-monopoly or non-duopoly itineraries and maintain a relatively consistent level. Conversely, in monopoly or duopoly itineraries, pass-through consistently stays lower. In both cases, pre-reform trends are flat and not statistically different from zero. Panel (b) indicates that the point estimates for business class are imprecisely estimated. Nevertheless, they are larger compared to those for economy class, consistent with the findings in Table 4. Again, pre-reform trends are rather flat and not statistically different from zero.



(a) Tax incidence by supply elasticity (b) Tax incidence by demand elasticity

Figure 4: Event study estimates: Tax incidence by market characteristics

Notes: This figure illustrates the estimated treatment effect from OLS regressions of tax rates on total airfares separated by competition and booking class. The underlying econometric model is described in Equation 3. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the city-pair level.

5.2 The Impact of the Swedish Air Passenger Tax on Passenger Numbers and Revenue Passenger Kilometers

The results presented so far have shown that the introduction of the air passenger tax significantly increases airfares. While the air passenger tax directly targets airfares, the key policy motivation for taxing airfares is to reduce the number of passengers or revenue passenger kilometers. Thus, Table 5 shows whether the increase in total airfares translates into reductions in passenger numbers, using the same set of controls as in Table 2. According to Column (1), a one-dollar increase in tax rates reduces passenger numbers by 0.9 per itinerary. Including distance-year fixed effects in Column (2) increases the reduction in passenger numbers, which is consistent with an increase in pass-through rates in Column (2) in Table 2. Destination-month fixed effects diminish the impact of the air passenger tax on passenger numbers, yet the point estimate remains highly significant (Column (3)). Hence, there appears to be a divergence in seasonality concerning destinations between treatment and control countries. Including regional characteristics in Column (2) does not change the point estimate. As expected, including the business class interaction-term in Column (5) slightly increases the point estimate. Column (5) shows that a $1 increase in tax rates reduces economy class passenger numbers by 0.963. This translates into an elasticity of -0.86.[13]. In line with relevant literature on air transport, this suggests a relatively inelastic response. It could be driven by differences in the functional form of tax incidence and demand response. For instance, there is no theoretical basis for the tax incidence to

[13] $(-0.963/385,68)/(0.993/343,08) = -0.86$

vary between a \$7 and \$30 tax, assuming everything else is equal. The expected response in terms of passenger numbers, however, is likely to vary, particularly if there is a difference in the tax rate as a percentage of the average airfare in each tax zone, similar to what is observed with the Swedish passenger tax (Table A4b).

Table 5: Effect of the air passenger tax on passenger numbers

	(1)	(2)	(3)	(4)	(5)
Tax rate	-0.902***	-1.122***	-0.929***	-0.930***	-0.963***
	(0.201)	(0.229)	(0.224)	(0.239)	(0.243)
Controls:					
Itinarary FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Distance (Km) $\times$ Year	No	Yes	Yes	Yes	Yes
Destination $\times$ Month	No	No	Yes	Yes	Yes
Region characteristics	No	No	No	Yes	Yes
Tax zone $\times$ Business	No	No	No	No	Yes
Adjusted R^2	0.90	0.90	0.90	0.90	0.90
Observations	257550	257550	257550	257550	257550

Notes: This table displays the main estimation results from OLS regressions. Each coefficient is the result of a separate regression of monthly-level passenger numbers on a continuous variable for itineraries being levied by air passenger tax rate, controlling for the variables indicated below. Standard errors, clustered at the city-pair level, are displayed in parentheses. Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

Table 6 shows different functional forms between the air passenger tax and the passenger numbers. In each regression, the outcome is the number of passengers. For comparison, Column (1) reproduces the estimate reported in Column (5) of Table 5. In Column (2), a binary indicator is employed that equals unity if an itinerary is taxed, revealing a reduction in passenger numbers of 9.1$\%$ at the mean [14]. Estimates in Column (3) provide evidence in favor of a non-linear relationship when interacting the three different tax rate categories with a binary indicator that equals unity if an itinerary is taxed. The coefficient of the 1. tax zone is statistically different from zero. The tax reduces the number of passengers by 34.14. Furthermore, the passenger numbers in the 2. and 3. tax zone are significantly reduced by 31.536 and 43.25, respectively. There are at least to explanations for larger reductions in passenger numbers in the 1. tax zone compared to the 2. tax zone. First, for domestic travel, taxes are imposed on both the outward and return flight. Additionally,

[14] 35.093/385.68=0.091

the presence of alternative modes of transportation, such as trains, contributes to greater elasticity in demand.

To account for differences in the functional form of airfares and passenger numbers, I use non-parametric estimates when examining the relationship between these variables. According to Table 1, the average total airfare amounts to $343.08. The Swedish air passenger tax results in an average airfare increase of $19.43 (Table 3, Column (2)), equivalent to a 5.7% increase in the average total airfare. Consequently, the observed average decline in passenger numbers of 9.1%, which corresponds to an elasticity of -1.59, is consistent with the anticipated elasticity range found in the literature (Intervistas, 2008).

Revenue passenger kilometers are useful for estimating the tax impact on emissions. The average 9.1% reduction in passenger numbers translates into an 8.4% reduction in revenue passenger kilometers (Table A4). In the full sample, itineraries originating in Sweden account for a total of 75.95 billion revenue passenger kilometers in 2019. Consequently, without the air passenger tax revenue passenger kilometers would have been 6.96 billion higher.

Table 6: Functional form of the air passenger tax on passenger numbers

	(1)	(2)	(3)
Tax rate	-0.963***		
	(0.243)		
Tax		-35.093***	
		(9.250)	
1. tax zone			-34.140**
			(15.263)
2. tax zone			-31.536***
			(8.052)
3. tax zone			-43.250***
			(12.520)
Controls:			
Itinarary FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Distance (Km) $\times$ Year	Yes	Yes	Yes
Destination $\times$ Month	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes
Tax zone $\times$ Business	Yes	Yes	Yes
Adjusted R^2	0.90	0.90	0.90
Observations	257550	257550	257550

Notes: This table displays the estimates from OLS regressions of the monthly passenger numbers on several functional forms of the air passenger tax and the control variables listed at the bottom. Standard errors, clustered at the city-pair level, are displayed in parentheses. Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

Table 7 explores whether the impact of the air passenger tax on passenger numbers differs between market structures, using the same methodology as in Table 5. Column (1) displays tax incidences categorized by duopoly and monopoly in comparison to all other itineraries. In monopolistic and oligopolistic competition, passenger numbers remain unchanged, whereas they decrease by -0.926 in case of other itineraries for a \$1 increase in the air passenger tax. Constant passenger numbers can be attributed to significantly lower pass-through rates in monopolistic competition. However, under duopolistic competition, pass-through rates do not differ from those in other itineraries (see Table 4 Column (1)).

Column (2) examines disparities in how the air passenger tax affects passenger numbers between business and economy class travelers by interacting the tax rate with a business class indicator. Despite a higher pass-through rate (refer to Table 4, Column (2)), a one-dollar increase in the air passenger tax results in only a 0.293 decrease in the number of business class passengers (Column (2)). This can be ascribed to the lower price elasticity observed among business class travelers. In Column (3), I interact the tax rate with indicators that equal unity for monopolistic and business class itineraries, respectively. The interaction term shows, that the difference in the impact of the tax on passenger numbers narrows between economy and business class passengers under monopolistic competition. Lower pass-through rates under monopolistic competition effectively maintain the demand for economy class passengers.

In Column (4) a dummy variable for low cost carrier is interacted with the tax rate. As expected, the coefficient for low cost carrier is insignificant, given that low cost carriers do not pass-through taxes compared to full-service carrier (see Column (4), Table 4).

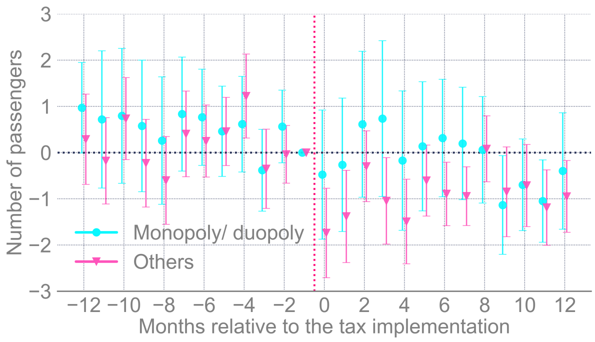
Table 7: Heterogeneous effects of the air passenger tax on passenger numbers

	(1)	(2)	(3)	(4)
Tax rate	-0.926***	-0.977***	-1.005***	-0.967***
	(0.259)	(0.243)	(0.254)	(0.250)
Tax rate $\times$ duopoly	-0.233			
	(0.337)			
Tax rate $\times$ monopoly	0.100		0.254	
	(0.210)		(0.217)	
Tax rate $\times$ business class		0.684***	0.776***	
		(0.198)	(0.235)	
Tax rate $\times$ monopoly $\times$ business class			-0.591**	
			(0.290)	
Tax rate $\times$ low cost carrier				0.185
				(1.589)
Controls:				
Itinarary FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes	Yes
Distance (Km) $\times$ Year	Yes	Yes	Yes	Yes
Destination $\times$ Month	Yes	Yes	Yes	Yes
Tax zone $\times$ Business	Yes	No	No	Yes
Adjusted R^2	0.90	0.90	0.90	0.90
Observations	257550	257550	257550	257550

Notes: This table displays the estimates from OLS regressions of the monthly level passenger numbers on several interactions of the tax rate and market and airlines characteristics and the control variables listed at the bottom. Standard errors, clustered at the city-pair level, are displayed in parentheses. Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

Figure 5 presents the tax effect for the number of passengers in an event study framework. The reduction of passenger numbers (Figure 5a) is in line with reduced airfares in Figure 3. Th decline in passenger numbers is already evident in the initial month following implementation and persists relatively consistently despite some fluctuations. According to Figure 5b, this development is driven by monopolistic and duopolistic competition, thus confirming findings of Column (1) in Table 7.

(a) Overall



(b) By supply elasticity

Figure 5: Event study estimates: Passenger numbers

Notes: This figure illustrates the estimated treatment effect from OLS regressions of the tax rate on the passenger numbers relative to the pre-reform month. The underlying econometric model is described in Equation 3. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the city-pair level.

5.3 The Impact of the Swedish Air Passenger Tax on Air Transport Capacity

The results presented so far have shown that the introduction of the air passenger tax significantly increased airfares and reduced passenger numbers. In order to achieve emission reductions, a decrease in passenger numbers must be accompanied by a reduction in supply, such as the number of departures or the size of the aircraft. Therefore, Table A6 shows how the air passenger tax affects air transport capacities departing from Sweden, while using the same set of controls as in Table 2 and Table 5. According to Table A6, the air passenger tax significantly reduces the air transport capacity. Specifically, given the mean air passenger tax of \$19.46, capacity is reduced by 4.5 departures and 4.51 seats per flight, which accounts for 9% and 2.7% of the mean, respectively (see Table A5). This reduction in capacity is a direct consequence of the air passenger tax, leading to airlines offering fewer flights and utilizing smaller aircraft. The magnitude of the reduction is in line with the reduction in passenger numbers of 9.2% mentioned in Section 5.2. Consequently, the air passenger tax reduces air transport emissions. It is important to note that the impact on departures is immediately apparent after the implementation of the tax, as depicted in Figure A6. This aligns with the immediate onset of decreases in passenger numbers. The onset of reductions in seats appears delayed.

5.4 Robustness

Definition of the sample The primary findings are drawn from data concerning Swedish, Finnish, and Danish airports adhering to the selection criteria outlined in Section 3.2. Figure A7a illustrates the coefficients from individual regressions based on the econometric model outlined in Equation 2. This involves a systematic exclusion of each NUTS3 region and their associated airport combinations from the estimation sample, with an exception for the collective exclusion of all Swedish regions.[15] The bottom of the figure features a red bar indicating the regions that have been excluded from the sample. Importantly, the coefficient shows a consistent level of stability and remains significantly distinct from zero, even when excluding the SE11 region, which encompasses Arlanda Airport.

Figure A7b presents the variation of coefficients from separate regressions under the econometric framework of Equation 2, executed by randomly assigned combinations of control groups. In an effort to enhance the robustness check and introduce greater variation, additional control countries including the Netherlands, Lithuania, and Latvia, have been incorporated. The countries that have been omitted from the control group are marked with a red bar at the bottom of the figure. The coefficient demonstrates a remarkable consistency and significant deviation from zero across different control group compositions.

Furthermore, Table A7 provides the results when the main sample is not limited to continuous observations, thereby including discontinued or newly opened itineraries, for example. Point estimates for airfares in this expanded sample are significantly higher compared to the main specification in Table 2 and remain significantly different from zero. This could be attributed to the inclusion of unique itineraries with low price elasticity, which have been identified as instrumental in the over-shifting of tax burdens. On the other hand, the impact on passenger numbers, while still significantly different from zero, shows a reduced point estimate.

Inference Hypothesis tests reported in Section 5 are based on conventional p-values and t-tests and their underlying parametric assumptions. These assumptions may not be valid if the error terms are correlated across itineraries, for example. To adjust for cross-sectional dependence of the error term, standard errors have been clustered at the city-pair level. However, clustering at this level could insufficiently adjust standard errors. To gain further confidence in the statistical significance, non-parametric permutation tests are performed. The idea behind these tests is to estimate the sampling distribution of estimates under the assumption that the null hypothesis of no effect is true. This placebo distribution can

[15] The geographical locations of airports and NUTS-3 regions are depicted in Figure A2

be obtained by repeatedly randomizing the treatment across observations while leaving the outcome and all other regressors constant or by repeatedly randomizing the outcome while leaving the treatment and all other regressors constant. The null hypothesis can be rejected if the original point estimate lies in the tails of the placebo distribution and thus is unlikely to emerge by chance. The tests shown in Table A8a provide strong evidence against the null hypothesis of no effect. Randomizing the total airfare or the passenger numbers across all observations and running 10,000 replications, empirical p-values of 0.01 are obtained. Table A8 once again addresses the concern that clustering standard errors at the city-pair level might not adequately capture spatial correlations present in the error terms. Presented standard errors clustered at the country-pair level, which exhibit slight variations when compared to those clustered at the city-pair level.

Spillovers The probability of spillover effects among itineraries is pronounced within the interdependent air transport network. The most apparent spillover would be on return itineraries to Sweden. As the air passenger tax decreases the number of passengers departing from Sweden, there might be a corresponding decrease in passengers returning to Sweden, potentially leading to a reduction in airfares for those itineraries. To test this hypothesis, I employ Equation 3 for symmetrical itineraries to Sweden. Observation numbers are slightly lower as not every itinerary originating in Sweden has a counterpart arriving in Sweden. According to Column (1) of Table A9, the air passenger tax does not translate into a reduction of airfares for return itineraries. However, Column (2) shows that passenger numbers as well as revenue passenger kilometers are reduced on return itineraries by 6.6% or 6.1% of the mean, respectively (see Table A10). This leads to an additional reduction of 4.93 billion revenue passenger kilometers in 2019.

6 Conclusion

Air passenger taxes are expected to reduce emissions by increasing airfares, thus reducing demand and, in turn, supply. Using a difference-in-difference approach and event study techniques, this paper exploits the introduction of a distance-dependent progressive air passenger tax in Sweden and analyses the pass-through on airfares, the impact on passenger numbers, revenue passenger kilometers, and air transport capacity.

The results show an immediate and nearly complete pass-through of air passenger taxes to airfares. A \$1 increase in passenger tax rates increases airfares by \$0.95. Consistent with theoretical priors under oligopolistic and monopolistic competition, the results show that higher market concentration or greater demand elasticity reduces the tax incidence. In monopolistic markets, the tax incidence is 0.366 compared to 1.02 in non-monopolistic markets. Factors amplifying consumers' price elasticity, such as business travel, significantly enhance the pass-through of taxes, thereby causing an over-shift in the tax.

The increase in airfares affects both passenger numbers and air transport capacity. On average, the air passenger tax leads to a 9.1$\%$ reduction in the number of passengers. This decline in passenger numbers consequently reduces supply, as evidenced by fewer departures and available seats. The average reduction in passenger numbers aligns with the findings of Falk and Hagsten (2019); Borbely (2019); Oesingmann (2022) and corresponds with the expected demand elasticity in the related literature.

In 2019, the air passenger tax reduces revenue passenger kilometers originating from Sweden by 6.96 billion and – due to spillovers – by 4.93 billion for inbound flights. With each revenue passenger kilometer emitted by air transport departing from Europe averaging 89 grams of CO_2 in 2019 (EASA, 2022), the tax results in an reduction of 619,440 metric tonnes of CO_2 for departures and 438,770 metric tonnes of CO_2 for arrivals. Consequently, the 38 million passengers departing from Sweden pay a total tax burden of $739.48 million, corresponding to $698.80 per reduced metric tonne of CO_2. For comparison, direct carbon capture – a considerably expensive technical method of CO_2 reduction – is estimated to be feasible on a large scale at around $1000 per metric tonne of CO_2 (National Academies of Sciences and Medicine, 2019). The social cost of CO_2 – measuring the monetized value of the damages to society caused by an incremental metric tonne of CO_2 – is unlikely to exceed $413 (Rennert et al., 2022). The current average price per metric tonne of CO_2 within the EU Emissions Trading System is approximately $90 (European Comission, 2023).

The insights of the paper are crucial for policy-makers, offering a more comprehensive perspective on how taxes can contribute to emission reduction. Air passenger taxes can be successful in achieving a fast and significant passenger reduction, which in turn decreases supply. However, in the longer term, other CO_2 reduction strategies, such as cap and trade systems, likely prove to be more efficient, albeit their implementation is frequently slower owing to political challenges.

References

Adachi, T. and Fabinger, M. (2022). Pass-through, welfare, and incidence under imperfect competition. *Journal of Public Economics* 211: 104589.

Alexeeva-Talebi, V. (2011). Cost pass-through of the eu emissions allowances: Examining the european petroleum markets. *Energy Economics* 33: S75–S83.

Benzarti, Y. and Carloni, D. (2019). Who really benefits from consumption tax cuts? Evidence from a large VAT reform in France. *American Economic Journal: Economic Policy* 11: 38–63.

Bernardo, V., Fageda, X. and Teixidó, J. (2024). Flight ticket taxes in europe: Environmental and economic impact. *Transportation Research Part A: Policy and Practice* 179: 103892.

Bitzan, J. and Peoples, J. (2016). A comparative analysis of cost change for low-cost, full-service, and other carriers in the US airline industry. *Research in Transportation Economics* 56: 25–41.

Bonnet, C., Dubois, P., Villas Boas, S. B. and Klapper, D. (2013). Empirical evidence on the role of nonlinear wholesale pricing and vertical restraints on cost pass-through. *Review of Economics and Statistics* 95: 500–515.

Borbely, D. (2019). A case study on Germany's aviation tax using the synthetic control approach. *Transportation Research Part A: Policy and Practice* 126: 377–395.

Bradley, S. and Feldman, N. E. (2020). Hidden baggage: Behavioral responses to changes in airline ticket tax disclosure. *American Economic Journal: Economic Policy* 12: 58–87.

Bresnahan, T. F. and Reiss, P. C. (1991). Entry and competition in concentrated markets. *Journal of political economy* 99: 977–1009.

Brons, M., Pels, E., Nijkamp, P. and Rietveld, P. (2002). Price elasticities of demand for passenger air travel: a meta-analysis. *Journal of Air Transport Management* 8: 165–175.

Brueckner, J. K., Lee, D. and Singer, E. S. (2013). Airline competition and domestic US airfares: A comprehensive reappraisal. *Economics of Transportation* 2: 1–17.

Cabral, M., Geruso, M. and Mahoney, N. (2018). Do larger health insurance subsidies benefit patients or producers? evidence from medicare advantage. *American Economic Review* 108: 2048–87.

Campa, J. M. and Goldberg, L. S. (2005). Exchange rate pass-through into import prices. *Review of Economics and Statistics* 87: 679–690.

Carbonnier, C. (2007). Who pays sales taxes? Evidence from French VAT reforms, 1987–1999. *Journal of Public Economics* 91: 1219–1229.

Chuang, S.-H. (2021). Aviation taxation and tax incidence. *Applied Economics* 53: 454–468.

Ciliberto, F. and Williams, J. W. (2014). Does multimarket contact facilitate tacit collusion? Inference on conduct parameters in the airline industry. *The RAND Journal of Economics* 45: 764–791.

Dai, M., Liu, Q. and Serfes, K. (2014). Is the effect of competition on price dispersion non-monotonic? Evidence from the US airline industry. *Review of Economics and Statistics* 96: 161–170.

De Chaisemartin, C. and d'Haultfoeuille, X. (2020). Two-way fixed effects estimators with heterogeneous treatment effects. *American Economic Review* 110: 2964–2996.

Duggan, M., Starc, A. and Vabson, B. (2016). Who benefits when the government pays more? Pass-through in the Medicare Advantage program. *Journal of Public Economics* 141: 50–67.

EASA (2022). European Aviation Environmental Report. *European Union Aviation Safety Agency* .

European Comission (2014). Study on the economic effects of the current VAT rules for passenger transport. Final Report .

European Comission (2023). Report from the commission to the european parliament and the council on the functioning of the european carbon market in 2022 pursuant to articles 10(5) and 21(2) of directive 2003/87/ec .

Faber, J. and Huigen, T. (2018). A study on aviation ticket taxes. *CE Delft* .

Fabra, N. and Reguant, M. (2014). Pass-through of emissions costs in electricity markets. *American Economic Review* 104: 2872–99.

Falk, M. and Hagsten, E. (2019). Short-run impact of the flight departure tax on air travel. *International Journal of Tourism Research* 21: 37–44.

Ganapati, S., Shapiro, J. S. and Walker, R. (2020). Energy cost pass-through in US manufacturing: Estimates and implications for carbon taxes. *American Economic Journal: Applied Economics* 12: 303–42.

Genakos, C. and Pagliero, M. (2022). Competition and pass-through: Evidence from isolated markets. *American Economic Journal: Applied Economics* 14: 35–57.

Gerardi, K. S. and Shapiro, A. H. (2009). Does competition reduce price dispersion? New evidence from the airline industry. *Journal of Political Economy* 117: 1–37.

Goldberg, P. K. and Hellerstein, R. (2008). A structural approach to explaining incomplete exchange-rate pass-through and pricing-to-market. *American Economic Review* 98: 423–29.

Gopinath, G., Gourinchas, P.-O., Hsieh, C.-T. and Li, N. (2011). International prices, costs, and markup differences. *American Economic Review* 101: 2450–86.

Harasztosi, P. and Lindner, A. (2019). Who pays for the minimum wage? *American Economic Review* 109: 2693–2727.

Harju, J., Kosonen, T. and Skans, O. N. (2018). Firm types, price-setting strategies, and consumption-tax incidence. *Journal of Public Economics* 165: 48–72.

Hintermann, B. (2016). Pass-through of co2 emission costs to hourly electricity prices in germany. *Journal of the Association of Environmental and Resource Economists* 3: 857–891.

Huang, E. and Kanafani, A. (2010). Taxing for Takeoff: Estimating Airport Tax Incidence through Natural Experiments. *Available at SSRN 1591312* .

ICAO (2020). Worldwide Airport Slot Guidelines (WASG). *International Air Transport Association* .

ICAO (2022). Icao environmental report 2022. *International Civil Aviation Organisation* .

Intervistas (2008). Estimating Air Travel Demand Elasticities .

Kenkel, D. S. (2005). Are alcohol tax hikes fully passed through to prices? Evidence from Alaska. *American Economic Review* 95: 273–277.

Koopmans, C. and Lieshout, R. (2016). Airline cost changes: To what extent are they passed through to the passenger? *Journal of Air Transport Management* 53: 1–11.

Kosonen, T. (2015). More and cheaper haircuts after VAT cut? On the efficiency and incidence of service sector consumption taxes. *Journal of Public Economics* 131: 87–100.

Larsson, J., Elofsson, A., Sterner, T. and Åkerman, J. (2019). International and national climate policies for aviation: A review. *Climate Policy* 19: 787–799.

Lee, D. S., Fahey, D. W., Skowron, A., Allen, M. R., Burkhardt, U., Chen, Q., Doherty, S. J., Freeman, S., Forster, P. M., Fuglestvedt, J. et al. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment* 244: 117834.

Marion, J. and Muehlegger, E. (2011). Fuel tax incidence and supply conditions. *Journal of public economics* 95: 1202–1212.

Miller, N. H., Osborne, M. and Sheu, G. (2017). Pass-through in a concentrated industry: Empirical evidence and regulatory implications. *The RAND Journal of Economics* 48: 69–93.

Murakami, H. (2011). Time effect of low-cost carrier entry and social welfare in us large air markets. *Transportation Research Part E: Logistics and Transportation Review* 47: 306–314.

Nakamura, E. and Zerom, D. (2010). Accounting for incomplete pass-through. *The Review of Economic Studies* 77: 1192–1230.

Obermeyer, A., Evangelinos, C. and Püschel, R. (2013). Price dispersion and competition in European airline markets. *Journal of Air Transport Management* 26: 31–34.

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.

Pörtner, H.-O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., Begum, R. A., Betts, R., Kerr, R. B., Biesbroek, R. et al. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. IPCC Geneva, Switzerland:.

Rennert, K., Errickson, F., Prest, B. C., Rennels, L., Newell, R. G., Pizer, W., Kingdon, C., Wingenroth, J., Cooke, R., Parthum, B. et al. (2022). Comprehensive evidence implies a higher social cost of co2. *Nature* 610: 687–692.

Sabre (2015a). Market Intelligence - Glossary and FAQs - Doc. Edition 1.2 .

Sabre (2015b). Market Intelligence v5.7 - User Guide - Doc. Edition 1.0 .

Sciences, E. National Academies of and Medicine (2019). Negative emissions technologies and reliable sequestration: A research agenda .

Stolper, S. (2018). Local pass-through and the regressivity of taxes: Evidence from automotive fuel markets. *Manuscript: University of Michigan* .

Weyl, E. G. and Fabinger, M. (2013). Pass-through as an economic tool: Principles of incidence under imperfect competition. *Journal of Political Economy* 121: 528–583.

Appendices

A The Swedish Air Passenger Tax

Table A1: Air passenger tax rate

(Tax zone)	(04.2018-12.2018)	(01.2019-12.2019)	(In USD)
1.	60 SEK	61 SEK	$\approx$ 7.19 USD
2.	250 SEK	255 SEK	$\approx$ 30.02 USD
3.	400 SEK	416 SEK	$\approx$ 48.59 USD

Notes: This table displays the tax rate based on the SFS 2017:1200. SEK is converted to USD using the average exchange rate of 2017 (8.439 SEK/USD)

Table A2: Tax zone by country

Country	Tax zone
Afghanistan	2
Albania	1
Algeria	2
Andorra	1
Armenia	2
Austria	1
Azerbaijan	2
Bahrain	2
Belarus	1
Belgium	1
Bosnia and Herzegovina	1
Bulgaria	1
Burkina Faso	2
Canada	2
Cape Verde	2
Chad	2
Croatia	1
Cyprus	1
Czech Republic	1
Denmark	1
Djibouti	2
Egypt	2
Eritrea	2
Estonia	1
Ethiopia	2
Finland	1
France	1
Gambia	2
Georgia	2
Germany	1
Greece	1
Guinea	2
Guinea Bissau	2
Hungary	1
Iceland	1
Iran	2
Iraq	2
Ireland	1
Israel	2
Italy	1
Ivory Coast	2
Jordan	2
Kazakhstan	2
Kosovo	1
Kuwait	2
Kyrgyzstan	2
Latvia	1
Lebanon	2
Libya	2
Liechtenstein	1
Lithuania	1
Luxembourg	1
North Macedonia	1
Mali	2
Malta	1
Mauritania	2
Moldova	1
Monaco	1
Montenegro	1
Morocco	2
Netherlands	1
Niger	2
Norway	1
Oman	2
Pakistan	2
Palestine	2
Poland	1
Portugal	1
Qatar	2
Romania	1
Russia	2
San Marino	1
Saudi Arabia	2
Senegal	2
Serbia	1
Slovakia	1
Slovenia	1
Spain	1
Sudan	2
Sweden	1
Switzerland	1
Syria	2
Tajikistan	2
Tunisia	2
Turkey	1
Turkmenistan	2
UK	1
Ukraine	1
United Arab Emirates	2
USA	2
Uzbekistan	2
Vatican	1
Yemen	2

Notes: This table shows in alphabetical order the countries included in the 1. tax zone and the 2. tax zone. All countries not included in the table are included in the 3. tax zone.

B The Sabre Data Set and Additional Results

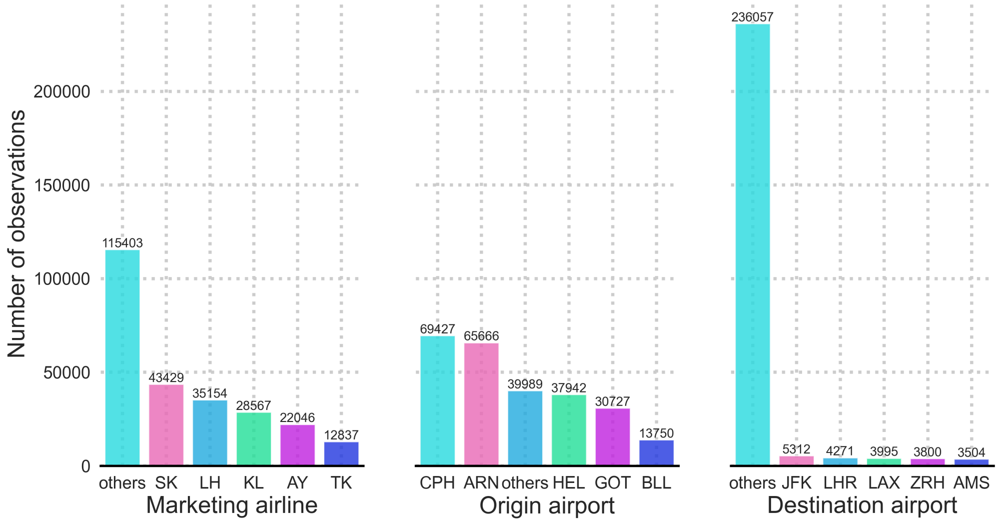


Figure A1: **Observations of the top-5 airports and airlines**

Notes: This figure shows the number of observations for the top-5 origin and destination airports and airlines across the estimation sample.

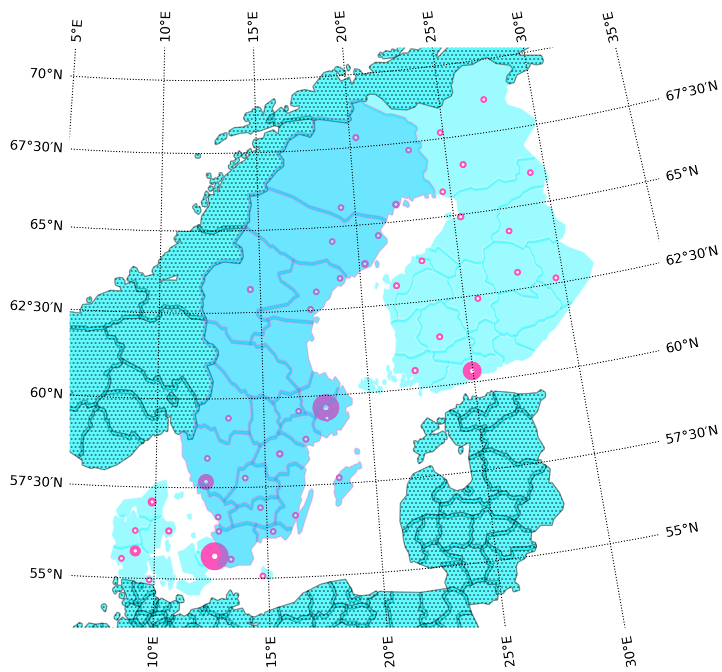
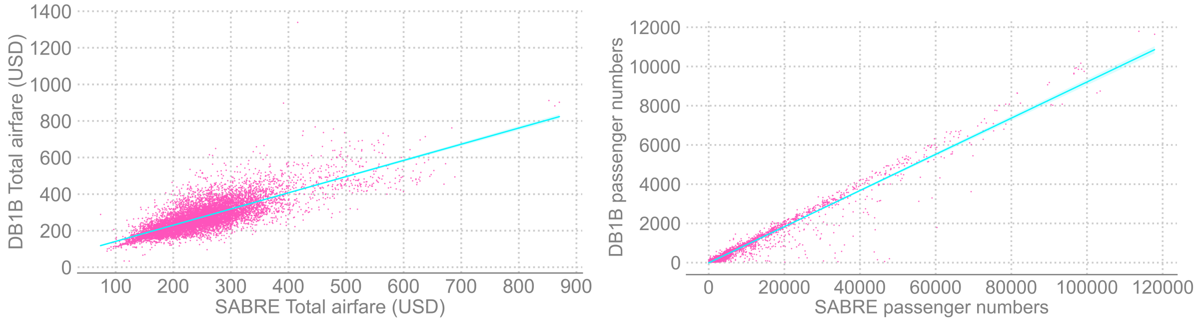


Figure A2: **Airports of departure**

Notes: This map shows the boundaries of the NUTS-3 regions and the airports of departure in Sweden, Finland and Denmark used in the analysis. The size of the dots represents the shares of itineraries per airports over the observation period.

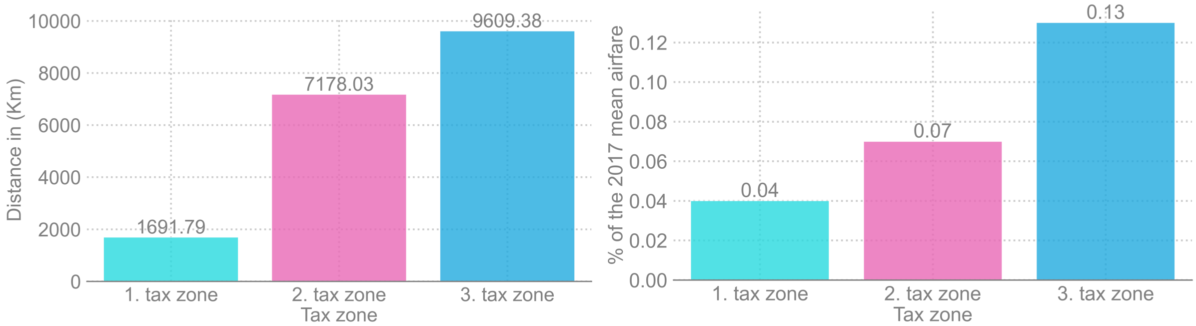


(a) Total airfare

(b) Passenger numbers

Figure A3: Correlation between SABRE and DB1B

Notes: The figure shows the correlation between the DB1B and Sabre data set for quarterly passenger numbers and average airfares at connection level in 2018



(a) Flight distance by tax zone

(b) Tax rate as % of the tax zone mean airfare

Figure A4: Tax zone characteristics

Notes: This figure shows descriptive characteristics of Sabre-MI between 2015 and 2019 for itineraries departing from Sweden, Finland and Denmark separated by the three tax zones of the Swedish air passenger tax.

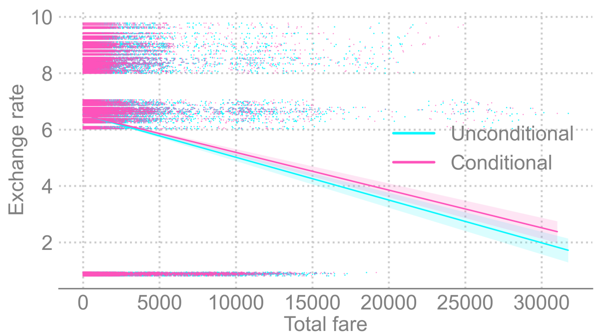


Figure A5: Correlation between exchange rate and total airfare

Notes: This figure illustrates the correlation between the exchange rate of local currencies of departing airports and total airfares. Conditional airfares are divided by the corresponding monthly exchange rates and multiplied by the average 2017 exchange rate

Table A3: Effect of the air passenger tax on the difference between total and base airfares

	(1)	(2)	(3)	(4)	(5)
Tax rate	0.616***	0.799***	0.810***	0.769***	0.735***
	(0.068)	(0.080)	(0.080)	(0.082)	(0.077)
Controls:					
Itinarary FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Distance (Km) $\times$ Year	No	Yes	Yes	Yes	Yes
Destination $\times$ Month	No	No	Yes	Yes	Yes
Region characteristics	No	No	No	Yes	Yes
Tax zone $\times$ Business	No	No	No	No	Yes
Adjusted R^2	0.96	0.96	0.96	0.96	0.96
Observations	257550	257550	257550	257550	257550

Notes: This table displays the estimates from OLS regressions of the monthly level difference between total and base airfares at itinerary level. Each coefficient is the result of a separate regression of monthly-level difference between total and base airfare on a continuous variable for airport-pairs being levied by an air passenger tax rate, controlling for the variables indicated below. Standard errors, clustered at the city-pair level, are displayed in parentheses. Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

Table A4: Effect of the air passenger tax on revenue passenger kilometers

	(1)	(2)	(3)
Tax rate	-3.323***		
	(1.083)		
Tax		-71.176***	
		(21.755)	
1. tax zone			-37.636*
			(22.489)
2. tax zone			-90.856***
			(26.955)
3. tax zone			-165.813**
			(65.172)
Controls:			
Itinarary FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Distance (Km) $\times$ Year	Yes	Yes	Yes
Destination $\times$ Month	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes
Tax zone $\times$ Business	Yes	Yes	Yes
Adjusted R^2	0.86	0.86	0.86
Observations	257550	257550	257550

Notes: This table displays the estimate from OLS regressions of the monthly revenue passenger kilometers at itinerary level. Each coefficient is the result of a separate regression of monthly-level of revenue passenger kilometers on a continuous variable for itineraries being levied by an air passenger tax rate, controlling for the variables indicated below. Standard errors, clustered at the city-pair level, are displayed in parentheses. Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

Table A5: Descriptive statistics of departures and seats

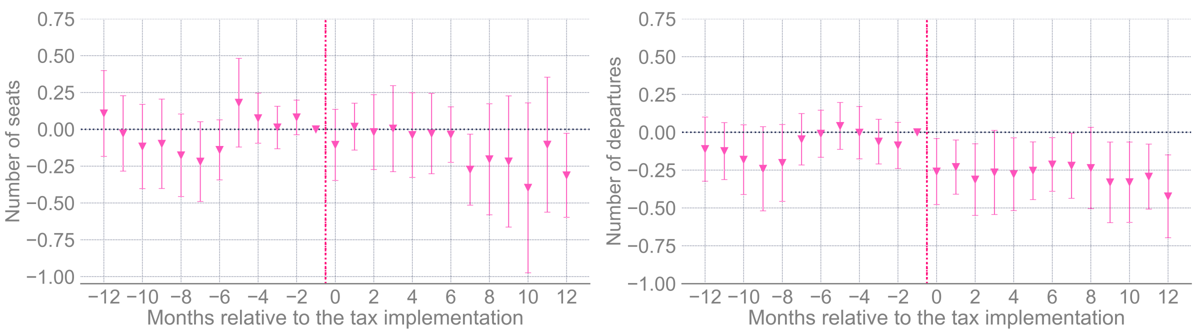
	Mean	Std	Min	Max	Observations
Departures	49.90	54.48	1.0	386.00	28471.0
Seats	184.03	58.28	0.0	523.84	28471.0

Notes: This table shows descriptive statistics for the number of seats and departures used in the supply analysis.

Table A6: Effect of the air passenger tax on non-stop demand and supply

	Seats	Departures
	(1)	(2)
Tax rate	-0.252***	-0.232***
	(0.087)	(0.055)
Controls:		
Itinerary FE	Yes	Yes
Time FE	Yes	Yes
Distance (Km) × Year	Yes	Yes
Destination × Month	Yes	Yes
Region characteristics	Yes	Yes
Tax zone × Business	Yes	Yes
Adjusted R^2	0.96	0.92
Observations	28471	28471

Notes: This table displays the main estimation results from OLS regressions. Each coefficient is the result of a separate regression of monthly-level air transport capacity indicators listed at the top on a continuous variable for itinerants being levied by an air passenger tax rate, controlling for the variables indicated below. Standard errors, clustered at the city-pair level, are displayed in parentheses. Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

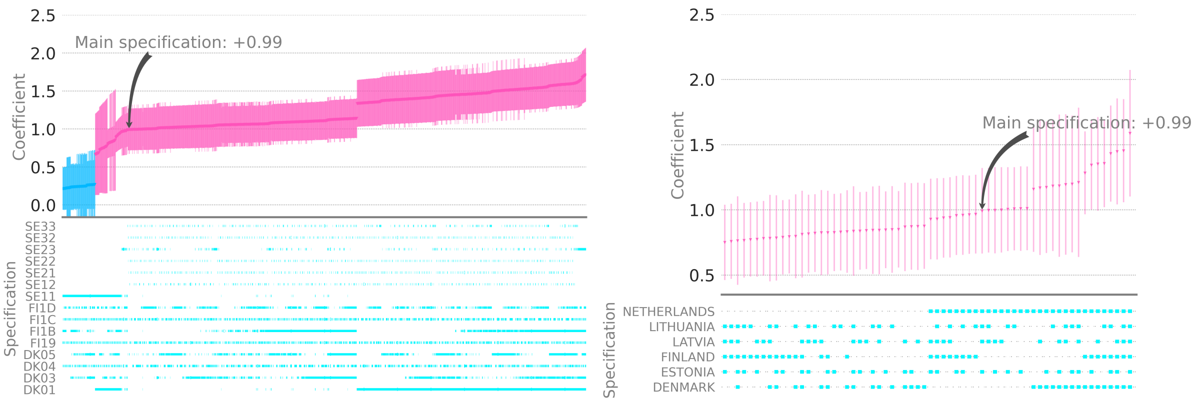


(a) Seats (b) Departures

Figure A6: Event study estimates: Seats and departures

Notes: This figure illustrates the estimated treatment effect from OLS regressions of the air passenger tax rate on the number of seats and departures relative to the pre-reform month. The underlying econometric model is described in Equation 3. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the city-pair level.

C Inference

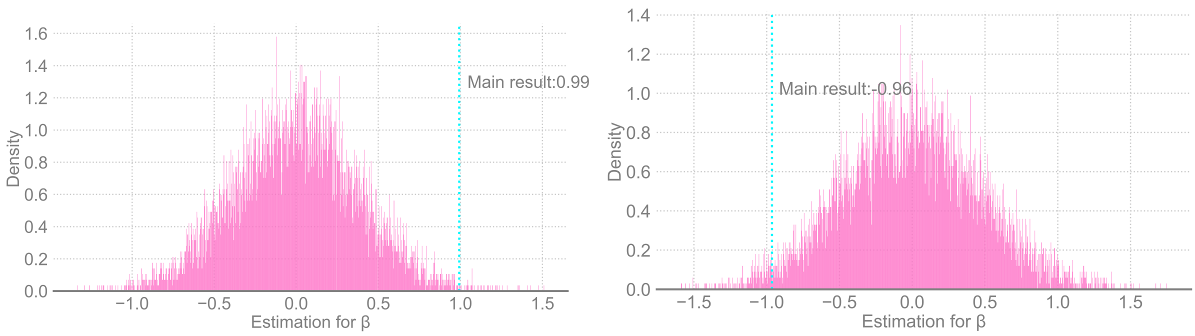


(a) Leave out NUTS-3 regions

(b) Leave out countries

Figure A7: Specification curves

Notes: This specification chart displays the point estimates and confidence intervals for the marginal effect of the tax rate on total airfares. In panel (a) all possible combinations of NUTS-3 regions are randomly excluded from the main estimation sample used in Table 2. In Panel(b) the main estimation sample is extended by similar control group countries. Again, all possible combinations of control group countries are excluded. Each coefficient is the result of a separate OLS regression that includes regional characteristics, time and itinerary fixed effect as well as distance-year and destination-month fixed effects. The estimate of the main specification (Table 2 Column 4) is highlighted. Vertical bars indicate 95% confidence intervals (pink: significant, blue: not significant). The confidence intervals are based on standard errors clustered at the city-pair level.



(a) Total Fare

(b) Passenger numbers

Figure A8: Placebo permutation test

Notes: These figures show histograms of the frequency distribution of estimates from placebo permutation tests for total airfares and passenger numbers based on random allocation of total airfares or passenger numbers, respectively, with 10,000 replications. Controls and fixed effects correspond to the specification in Column (5) of Table 2 and Table 5. The vertical lines indicate the corresponding point estimates.

Table A7: Robustness check based on full-sample

	Total airfare		Passengers	
	(Main)	(Full)	(Main)	(Full)
Tax rate	0.993^{***}	1.442^{***}	-0.963^{***}	-0.766^{***}
	(0.171)	(0.108)	(0.243)	(0.128)
Controls:				
Itinarary FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Distance (Km) $\times$ Year	Yes	Yes	Yes	Yes
Destination $\times$ Month	Yes	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes	Yes
Tax zone $\times$ Business	Yes	Yes	Yes	Yes
Adjusted R^2	0.97	0.97	0.90	0.88
Observations	257550	1516049	257550	1516049

Notes: Column (1) reproduces the point estimates of Column (5) in Table 2. In Column (2) the full sample of observations has been used while applying the same specification as in Column (1). Column (3) reproduces the point estimates of Column (5) in Table 5. In Column (4) the full sample of observations has been used while applying the same specification as in Column (3). Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

Table A8: Alternative clustering of standard errors

	Total airfare		Passengers	
	(City-pair)	(Country-pair)	(City-pair)	(Country-pair)
Tax rate	0.993^{***}	0.993^{***}	-0.963^{***}	-0.963^{*}
	(0.171)	(0.173)	(0.243)	(0.504)
Controls:				
Itinarary FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Distance (Km) $\times$ Year	Yes	Yes	Yes	Yes
Destination $\times$ Month	Yes	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes	Yes
Tax zone $\times$ Business	Yes	Yes	Yes	Yes
Adjusted R^2	0.97	0.97	0.90	0.90
Observations	257550	257550	257550	257550

Notes: Column (1) reproduces the point estimates of Column (5) in Table 2. In Column (2) the standard errors are clustered at the destination and origin country-pair level. Column (3) reproduces the point estimates of Column (5) in Table 5. The standard errors in Column (3) are clustered at the country-pair level. Significance levels: $***: p < 0.01$, $**: p < 0.05$, $*: p < 0.1$.

Table A9: Effect of the air passenger tax on return itineraries

	Total airfare	Passengers	RPK
	(1)	(2)	(3)
Tax	-2.583	-25.282***	-48.553**
	(2.796)	(9.416)	(21.115)
Controls:			
Itinarary FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Distance (Km) $\times$ Year	Yes	Yes	Yes
Destination $\times$ Month	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes
Tax zone $\times$ Business	Yes	Yes	Yes
Adjusted R^2	0.98	0.90	0.83
Observations	242046	242046	242046

Notes: This table displays the estimation results for return itineraries from OLS regressions. Each coefficient is the result of a separate regression of monthly-level airfares on a indicator variable for itineraries being levied by air passenger tax, controlling for the variables indicated below. Standard errors, clustered at the city-pair level, are displayed in parentheses. Significance levels: $*** : p < 0.01, ** : p < 0.05, * : p < 0.1.$

Table A10: Descriptive statistics of return itineraries

	Mean	Std	Min	Max	Observations
Total airfare	355.28	1095.50	2.09	36766.33	242046
Passengers	381.27	1366.73	10.00	28038.00	242046
RPK/ 1000	799.26	2166.78	1.61	58123.06	242046

Notes: This table shows main descriptive statistics for return itineraries.