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## From Tax Incidence to Emission Reduction: The Pass-through of Air Passenger Taxes

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# From Tax Incidence to Emission Reduction: The Pass-through of Air Passenger Taxes

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## Abstract

This paper studies the causal path from incidence to emission reductions of an environmental tax and the influence of competition and demand elasticity within a difference-in-differences framework. For identification, I exploit the implementation of an air passenger tax on worldwide departures from Sweden and compare them with departures from similar airports without an air passenger tax to the same destination. On average, pass-through is immediate and nearly complete. The tax significantly reduces passenger numbers, air transport capacity and global emissions. While tax pass-through increases with competition, demand reductions remain constant across market concentrations. Higher tax pass-through with inelastic demand results in a relatively small reduction in demand. Different price elasticities of demand converge in monopolistic markets.

**JEL:** H22; L13; Q52

**Keywords:** Tax incidence; competition; elasticity; environmental tax

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# 1 Introduction

Global air transport is estimated to account 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 and without intervention, emissions of international air transport could triple by 2050 compared to 2018 (Pörtner et al., 2022; ICAO, 2022). Countries such as Sweden have implemented air passenger taxes to reduce air transport emissions. Other countries, such as Germany<sup>1</sup>, initially introduced air passenger taxes to increase tax revenues, but over time justified taxes by environmental objectives. In this case, 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). Similar to other environmental taxes, increasing fares are expected to reduce demand and, in turn, supply, thereby reducing emissions. The size of the reduction potentially depends on the pass-through rate of the tax, which in turn depends on the market structure. Most air passengers travel in markets that appear to be oligopolies, with two to four competing airlines (Koopmans and Lieshout, 2016). Demand is assumed to be convex due to a mixture of demand with low and high elasticity (Berry et al., 2006).

In recent years, several studies have analyzed cost pass-through (Ritz, 2024). However, there is still a limited understanding of how changes in pass-through affect demand and, in turn, supply responses. This knowledge is crucial for assessing policies such as environmental taxes. Economic theory identifies competition and demand elasticity as key determinants of pass-through. In competitive markets, taxes are expected to be fully passed through to prices. In imperfect markets, a one percent tax increase may lead to a price change that is either less or more than one percent, as market concentration allows firms to engage in more strategic pricing. In oligopolistic markets, driven by the curvature of demand, pass-through rates exceed one under convex demand and constant marginal costs. 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). Therefore, market characteristics can affect the economic benefit of a tax designed to internalize externalities. For example, in highly concentrated markets with concave demand and constant marginal costs, environmental taxes levied as consumption taxes would have a lower economic benefit if lower pass-through reduces intended demand and supply effects. In such cases, companies would bear the additional tax burden, and the tax incentive would not be passed on to the customer. However, even if the tax is fully

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<sup>1</sup> see Drucksache 19/14339

passed on to the customer, low demand or supply elasticity could reduce the economic benefit of an environmental tax. Understanding pass-through of taxes and how this translates into demand and supply responses in imperfect markets is crucial, as numerous significant industries are characterized as oligopolies (Adachi and Fabinger, 2022).

In this paper I analyze the pass-through of the Swedish air passenger tax across different markets and its impact on passenger numbers and how this translates to the number of departures, available seats and emissions. From this, I estimate the tax's economic benefit by comparing the cost per reduced tonne of  $CO_2$  with the social cost of carbon. In the analysis, I account for spillovers, traffic shifting, and the potential endogeneity of the treatment. Since April 2018, travelers departing from Swedish airports have been subject to an air passenger tax. Neighboring countries, such as Denmark and Finland, with similar air transport markets, have not introduced comparable measures. I exploit this tax variation within origin-destination airport-pairs over time in a difference-in-differences framework using event-study techniques. Tax rates are divided into three tax brackets and increase non-monotonically with the distance to the destination country. Within destination countries, tax rates are equal. The tax applies to all passengers on commercial flights of aircraft registered for carrying 10 passengers or more. The average statutory tax rate corresponds to around 4.7% of mean total airfare in Sweden. Airlines are responsible for transferring the tax to the fiscal office and thus have potential pricing power to decide the proportion of the tax that is ultimately borne by their customers. Tax revenues are not earmarked. Using variation in the market structure, this paper also studies the impact of competition and demand elasticity and its interaction on the tax incidence and passenger numbers. In Europe, airlines serve heterogeneous markets with varying degrees of competition and different travel classes. 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 and different demand elasticities and how this affects the economic benefit of an environmental tax.

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 is the main provider of the global airline ticket distribution system that airlines use for sales processing. 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. This is essential for estimating the incidence and the economic benefit of the tax, taking into account spillover

effects and traffic shifting. Second, the panel structure of the data set allows to identify the causal impact of the Swedish air tax using neighboring countries 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 demand elasticity and competition. For example, I use variation in passenger number concentration among airlines operating on the same city-pair routes to examine the impact of competition on tax incidence.

The results show that airlines choose an immediate and nearly full pass-through of air passenger taxes, on average. The pass-through increases linearly with the tax rate, keeping the pass-through rate nearly constant across tax brackets. In addition, the air passenger tax significantly reduces passenger numbers by an average of 8.8%, which translates into a similar supply reduction. In 2019, the tax reduces 1.48 million metric tonnes of  $CO_2$  equivalents<sup>2</sup> at \$230.34 per metric tonne. Effect sizes for passenger numbers and air transport capacity are in line with the average demand elasticity of air transport in the literature (Intervistas, 2008; Aryal et al., 2024). Pass-through rates decrease with higher market concentration at city-pair level. Factors reducing consumers' price elasticity such as business travel increase the pass-through of taxes, both consistent with the theory of tax incidence in imperfect markets. Although pass-through is lower in highly concentrated markets, demand responses remain similar to those in less concentrated markets. While pass-through is higher when demand is inelastic, the demand responses are smaller compared to those under elastic demand. In monopolistic markets, different price elasticities of demand converge.

With this paper, I extend and connect two strands of literature. First, this paper contributes to the extensive literature on pass-through of taxes and costs. Numerous papers analyze the incidence of consumption taxes or excise duties, finding substantial variation in average pass-through rates between 45% and above 100% (Genakos and Pagliero (2022); Benzarti and Carloni (2019); Kosonen (2015); Marion and Muehlegger (2011); Carbonnier (2007); Kenkel (2005). Other studies, for example, indicate that emission costs of the EU Emissions Trading Scheme are fully passed on to electricity and petrol retail prices (Hintermann, 2016; Fabra and Reguant, 2014; Alexeeva-Talebi, 2011). Thus, there is extensive evidence on the average pass-through of costs and taxes. However, the source of variation in pass-through rates remains a significant gap in the literature. One reason is that the evidence on the effects of competition is mixed. Miller et al. (2017) find that competition

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<sup>2</sup> A  $CO_2$  equivalent is a metric measure used to compare the emissions from various greenhouse gases, by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.

reduces pass-through of fuel cost changes to prices in a market in which the pass-through is above one. Similarly, 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. Another reason is that there is little empirical evidence on the effect of demand elasticity

In a closely related paper, Bradley and Feldman (2020) study the effect of a full-fare disclosure rule on tax incidence, thereby extending the literature on tax salience. Additionally, by highlighting the importance of competition, they have improved the understanding of variation in pass-through rates. They conclude that displaying tax-inclusive airfares is associated with a reduced tax burden for passengers, with the extent of this reduction depending on market concentration. Pass-through rates are lower in highly concentrated markets. My paper confirms their findings and provides two novel contributions. First, I employ a more representative sample. Instead of focusing on international round-trip economy class itineraries operated by U.S. carriers, my dataset includes domestic and international flights, different booking classes, travel segments instead of solely round-trips and all operating carriers. Second, distinguishing among booking classes allows me to identify the impact of different demand elasticities. By disentangling the impact of both demand elasticity and competition on tax incidence, I address a significant gap in the literature.

Second, this paper contributes to the extensive literature on the effectiveness of Pigouvian pricing. Accordingly, I connect the literature on pass-through with the literature on the effectiveness of Pigouvian pricing. For example, Caeli (2020), Jaraité and Maria (2016), and Petrick and Wagner (2014) analyze the impact of the EU Emissions Trading Scheme on  $CO_2$  emissions, finding that reductions vary from none to as high as 20% on average, depending on the country and sector. Simulating the impact of a soda tax, Dubois et al. (2020) find that sugar intake is reduced, but only among specific subsets of consumers. In closely related research, several papers demonstrate that air passenger taxes have significantly decreased demand for air travel in Europe. However, there is little evidence on the incidence of the tax, mainly because data on airfares is often not available (Falk and Hagsten, 2019; Borbely, 2019; Oesingmann, 2022). An important study in this literature - and closely related to this paper - is by Bernardo et al. (2024). Studying the pass-through of air passenger taxes across Europe and corresponding supply and emission responses, they find a 12% reduction in the number of flights, a 14% reduction in emissions and a

pass-through rate of 56 %, on average. My paper makes three important contributions to this literature. First, through the difference-in-differences design, I am able to provide a causal estimate of the pass-through. The findings suggest that previous estimates of pass-through rates may have been significantly downward biased, as the rates estimated in this study are, on average, about twice of those reported by Bernardo et al. (2024). A possible explanation is that pass-through rates in Bernardo et al. (2024) are not causally identified as the parallel trends assumption does not hold. Second, my data allows me to distinguish between different booking classes and travel segments rather than solely round-trips. This allows me to identify the impact of different demand elasticities and to account for spillover effects on inbound flights of round-trips, for example. Furthermore, the data I am using allows me to study not only airfares but also passenger numbers. Additionally, I calculate demand and supply reductions of the tax by considering spillovers and traffic shifting under different market conditions. By estimating pass-through and its impact on demand, supply and emission, I reveal the causal path from tax incidence to internalizing negative externalities.

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 consist 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

$$\rho = \frac{1}{1 + \frac{\Theta}{\epsilon_{\Theta}} + \frac{\epsilon_D - \Theta}{\epsilon_S} + \frac{\Theta}{\epsilon_{ms}}} \quad (1)$$

The conduct parameter  $\Theta$  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  $\rho$  depends on the variation of the conduct parameter  $\Theta$  as the quantity produced changes ( $\epsilon_{\Theta} = \frac{\Theta}{q \frac{d\Theta}{dq}}$ ), the determinants of the elasticity of demand  $\epsilon_D$ , the elasticity of supply as the inverse marginal cost curve  $\epsilon_S$ , and the demand functions' curvature  $\epsilon_{ms}$ . 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  $\rho$  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. Furthermore, as the Swedish aviation tax is a per-passenger tax it does not affect the constancy of marginal costs. 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  $\Theta$  is constant. The conduct parameter  $\Theta$  is a constant in a number of models, such as the Bertrand or Cournot model. It is usually assumed, that airlines compete under Bertrand or Cournot competition (Brander and Zhang, 1990; Ciliberto and Williams, 2014; Koopmans and Lieshout, 2016).

A remaining important determinant of the pass-through is the demand curvature  $\epsilon_{ms}$ . 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  $\Theta$  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 experience higher pass-through rates than economy class travelers.

## 3 Institutional Background and Data

### 3.1 The Swedish Air Passenger Tax and a Valid Control Group

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 is applied to all commercial outbound 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 tax rate progressively increases across three distance-dependent brackets<sup>3</sup> defined by three destination country groups (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) or 400 SEK (3. tax zone), depending on the travel distance. The 2nd tax zone encompasses medium and long-haul flights, while long-haul flights fall under the 3rd tax zone. Given the average exchange rate in 2017, tax rates are equivalent to \$7.2 in the 1st tax zone, \$30 in the 2nd tax zone and \$47.6 in the 3rd tax zone (Table A1). A flight from Stockholm to Berlin that used to cost \$100 before the reform costs \$107.2 after the reform – everything else equal. A flight from Stockholm to Beijing that used to cost \$400 before the reform costs \$447.6 after the reform.

<sup>3</sup> See Figure A4a for the average distance per tax group of the estimation sample

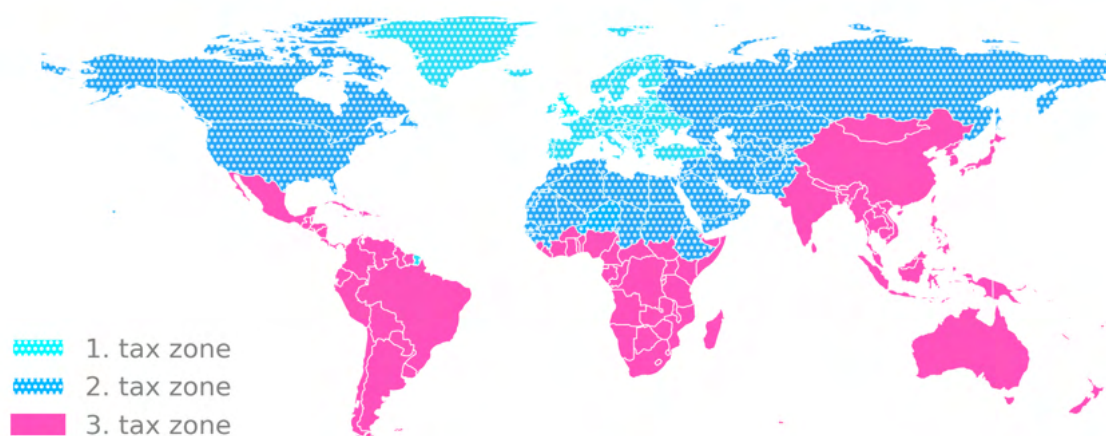


Figure 1: Tax zones of the Swedish air passenger tax

*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.*

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.

I use Denmark and Finland as a control group in the main analysis. I vary the control group by using other suitable countries in a robustness check. Sweden, Finland and Denmark have similar economies (Barth et al., 2014) and are similarly integrated in global air transport. Taking Denmark and Finland as a control group improves the alignment between the control and treatment groups since the competitive conditions in international air transport are more similar between Denmark and Sweden, while domestic air transport in Finland and Sweden is more alike (Malighetti et al., 2008; Arvis and Shepherd, 2011). Denmark and Finland have not introduced air passenger taxes yet. 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. 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<sup>4</sup>.

All countries of departure included in this study participate in the EU Emissions Trading Scheme (EU ETS), which requires airlines to purchase emission certificates for flights within the European Economic Area (EEA) since 2013. Through this system, airlines must either

<sup>4</sup> According to Taxes in Europe Database v3 and European Commission (2014)

hold sufficient allowances to cover their emissions or acquire additional certificates from the carbon market, thereby integrating the cost of carbon into flight operations and encouraging emissions reductions (Fageda and Teixidó, 2022).

### **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 and airlines. Sabre Market Intelligence includes sales data from traditional travel agencies, online travel agencies as well as direct bookings (Sabre, 2015b). The unit of observation are itineraries between origin and destination airport-pairs which are separated by airline, cabin-class and connecting airports. 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 with different cabin classes. The corresponding return trip is listed separately in the dataset. This is a significant difference compared to other datasets in related studies, which only identify round-trips (e.g. Bradley and Feldman (2020); Bernardo et al. (2024)). For itineraries, monthly average total and base airfares and the number of passengers are provided. Airfares are transaction fares (Sabre, 2015a).

For the main analysis, the data set includes 918,048 mutually exclusive itineraries to worldwide destination airports departing from Sweden, Finland and Denmark airports over the period from 2015 to 2019. 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. However, although these are the majority of itineraries they only account for 3% of the overall passenger volume. 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. Furthermore, any itinerary whose origin airport is in the control group and destination airport is in the treatment group (or vice versa) is excluded to avoid potential spillovers. As a result, the total number of itineraries decreases to 122,717. Finally, a sample is employed of airport-pairs that are served by throughout

the period of investigation. This includes non-seasonal airport-pairs, available every month throughout the observation period, or seasonal airport-pairs, but only if they are offered in the same months each year. Again, this reduces the number of itineraries significantly to 20,113. In the end, a sample of 329,383 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. Due to the close spatial proximity of certain airports, passengers may shift to departure airports that are not subject to the tax, creating potential spillover effects. This violates the non-interference assumption between control and treatment groups. To address this issue, a specification curve analysis is conducted in Section 5.3, involving the random exclusion of NUTS-3 regions from the estimation sample. To further account for potential spillovers or sample selection bias, 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).

Panel A of Table 1 shows that the mean statutory tax incidence is \$18.23. This can be interpreted as a 100% pass-through of the air passenger tax, based on the destination country's applicable tax rate. Accordingly, 64% of the Swedish itineraries are grouped in tax-zone 1, 20% in tax-zone 2 and 15% in tax-zone 3.<sup>5</sup> In 2019, 18.7 million passengers<sup>6</sup> started their itinerary in Sweden, resulting in a tax revenue of \$340.901 million.

Panel B of Table 1 shows substantial variation in the characteristics of the 329,383 itinerary-month observations. The main variable of interest, weighted total airfares, range from only \$1.63 to \$52446.53 with a mean of \$384.79 and a much larger standard deviation of \$1303.81. I weight airfares by average passengers numbers per tax-zone over the sample period. This explains why the extremes of the variable are so pronounced. Total fares include taxes, surcharges, and additional fees. Ancillary fees charged by airlines, such as baggage and preferred seating, are not included in total fares. Weighted base fares, which exclude taxes, surcharges, and other fees, range from only \$0.06 to \$45309.93 with a mean of \$280.84.

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<sup>5</sup> 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

<sup>6</sup> According to the full Sabre data set

In the airline industry, airfares are quoted in the local currency of the departure airport. 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 each country's corresponding monthly exchange rate.<sup>7</sup> After that, I multiply airfares by the average exchange rate of 2017. This is performed before weighting airfares by passenger numbers. Figure A6 shows the correlation between exchange rates and airfares before converting the airfare (Panel (a)) and after (Panel (b)). Fixing exchange rates to the average of 2017 reduces time-varying unobserved heterogeneity between countries.

Passenger numbers per itinerary range from 10 to 28,038 with a mean of 355.73 passengers. Distance, measured in kilometers of the great circle distance, indicates that, on average, itineraries tend to be medium or long-haul. Note that the average flight distance per passenger is significantly lower, as traffic volume decreases with distance.

Revenue passenger kilometers (RPK)<sup>8</sup> – used to estimate the tax impact on emissions – show substantial variation as well. In 2019, 37.43 billion RPK<sup>9</sup> originated in Sweden.

Business class and economy class account for 12% and 88% of the observations in the data set, respectively. About 89% of the itineraries in the data set are carried out by full service or regional carriers whereas 11% are operated by low-cost carriers.<sup>10</sup> It is worth noting that the proportion of air passengers carried by low-cost airlines, for example, would be significantly higher.

The normalized Herfindahl-Index (HHI) is based on the distribution of carried persons at the city-pair<sup>11</sup> level between airlines in the year 2017. HHI gets values between 0 and 1, with 0 indicating perfect competition and 1 a monopoly. 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, the year prior to tax implementation. With an average value of 0.58, the HHI points to an oligopolistic level of competition. Based on findings of Bresnahan and Reiss (1991) and Genakos and Pagliero (2022), which indicate 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 40% of itineraries are monopolies or duopolies, respectively.

<sup>7</sup> Finland: Euro/USD, Denmark: Danish Krone/USD, Sweden: Swedish Krone/USD

<sup>8</sup> RPK = Number of passenger per itinerary  $\times$  great circular distance between airport-pairs

<sup>9</sup> According to the full Sabre data set

<sup>10</sup> The ICAO provides a list of low-cost airlines that is used to establish the category of low-cost airlines.

<sup>11</sup> Airports are assigned to the area of a city

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.

Table 1: Descriptive statistics

	Mean	Std	Min	Max	Observations
<b>Panel A</b>					
Statutory tax incidence (USD)	18.23	15.71	7.12	49.35	54880
1. tax zone	0.64	0.48	0.00	1.00	54880
2. tax zone	0.20	0.40	0.00	1.00	54880
3. tax zone	0.15	0.36	0.00	1.00	54880
<b>Panel B</b>					
Base airfare (USD, , weighted)	280.84	1082.55	0.06	45309.93	329383
Total airfare (USD, weighted)	384.79	1303.81	1.63	52446.53	329383
Economy total airfare (USD, weighted)	259.43	764.38	1.63	23035.59	289921
Business total airfare (USD, weighted)	1305.82	2988.78	12.22	52446.53	39462
Passenger numbers	355.73	1311.47	10.00	28038.00	329383
Economy passenger numbers	394.26	1391.78	10.00	28038.00	289921
Business passenger numbers	72.66	183.95	10.00	3368.00	39462
Distance (km)	4309.50	3623.15	45.00	20263.00	329383
RPK/1000	747.98	2227.70	0.54	60330.41	329383
Business class	0.12	0.32	0.00	1.00	329383
Economy class	0.88	0.32	0.00	1.00	329383
Low-cost carrier	0.11	0.32	0.00	1.00	329383
Full service or regional carrier	0.89	0.32	0.00	1.00	329383
Herfindahl-Index	0.58	0.25	0.14	1.00	329383
Monopoly	0.13	0.33	0.00	1.00	329383
Duopoly	0.40	0.49	0.00	1.00	329383
<b>Panel C</b>					
Population/km <sup>2</sup>	333.57	269.42	3.40	756.00	329383
GDP per capita (USD)	42883.21	7702.80	24900.00	51700.00	329383

*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 NUTS-2 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 has 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 data set 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 analyze the monthly number of planned departures and the average number of seats per flight between airports, separated by operating airline and type of aircraft between 2015 and 2019. I restrict the sample to those airport-pairs used to study airfares and passenger numbers. Descriptive statistics of the flight schedule data are shown in Table A4.

### **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 presents the monthly average indexes for total airfare and passenger numbers for both the control and treatment groups, with all values indexed to their 2015 averages.

In both 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 develop very similar. Any differences between the control and treatment group before the passenger tax reform are 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 and



passenger numbers in Finland and Denmark represent a credible counterfactual. Following the introduction of the air passenger tax the total airfare increases in the treatment group compared to the control group. There tend to be a decrease in the number of passengers in the treatment group compared to the control group following the tax implementation.

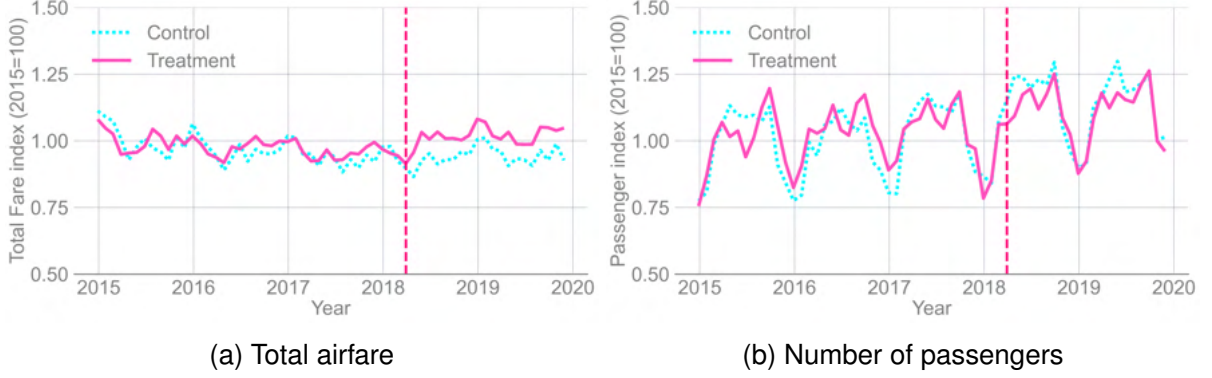


Figure 2: Trends in the control and treatment group

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. With this model, I compare the development of itineraries of the same airline and booking class, for example, from Helsinki-Vantaa Airport to John F. Kennedy Airport, with itineraries from Stockholm/Arlanda Airport to John F. Kennedy Airport before and after the tax. The basic model reads:

$$y_{it} = \alpha + \beta Taxrate_{it} + X'_{it}\gamma + \delta_i + \delta_t + \delta_y d(i) + \delta_m c(i) + \epsilon_{it}, \quad (2)$$

where  $y_{it}$  indicates the outcome of interest for itinerary  $i$  which are total 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 discrete treatment of itinerary  $i$  at time  $t$  by the unit value of the air passenger tax. 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  $\delta_i$  capture any time-invariant

itinerary characteristics such as the travel distance, historical links between countries, booking class and airline heterogeneity. Time fixed effects  $\delta_t$  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  $y$ , to account for endogeneity of the distance dependent tax brackets. 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  $c$  of tax zones 1st, 2nd, and 3rd (see Table A2) in month  $m$ . In order to reduce unobserved heterogeneity, Bradley and Feldman (2020), for example, apply multiple sample restrictions such as excluding business class passengers. Instead, I interact the three tax rate categories with a binary indicator that equals unity if a business itinerary is taxed. Consequently, point estimates of  $Taxrate_{it}$  reflect the outcomes for economy class, while the results for business class are presented later in the heterogeneity analysis. 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 plausible. The introduction of an air passenger tax should not have any impact during pre-treatment periods. The extended model is:

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

where the discrete 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.<sup>12</sup>

## 5 Results

### 5.1 Airfares and Passenger Numbers

**Main Effects** This section presents the estimation results for the impact of the air passenger tax introduction on airfares and passenger numbers. Table 2 reports the main OLS

<sup>12</sup> Event dummies are binned up at the endpoints of the event window (i.e.,  $k = -12$  and  $k = 12$ )

results for the air passenger tax on total airfares (Columns (1)-(3)) and passenger numbers (Columns (4) - (6)) for different functional forms. Each cell in this table represents an estimate for  $\beta$  according to Equation 2 from a separate regression of airfares or passenger numbers on air passenger tax. Controls included are indicated at the bottom of each column. Estimates of the  $\beta$  coefficient measure the total effect of the air passenger tax on airfares and passenger numbers, which include demand and supply responses. Therefore, results are reduced-form effects. 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).<sup>13</sup> Controls for relevant time-variant regional characteristics are included by GDP per capita and population density at NUTS-2-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 which could be non-orthogonal to the treatment. Destination-month fixed effects control for any seasonal differences between destination country groups. To account for market characteristics that are endogenous to the treatment, I include an interaction term of business class and tax rate categories. Consequently, point estimates apply to economy class itineraries only.

In Column (1) of Table 2, I regress airfares on a discrete variable indicating itineraries subject to the Swedish air passenger tax rate. This reveals a statistically significant pass-through rate of 0.963 for a tax increase of \$1. As a result, a \$300 economy class ticket, subject to a \$47 air passenger tax, totals \$345.26. Estimates in Columns (2) and (3) provide evidence in favor of a linear relationship between tax pass-through and tax rates. In Column (2), a non-linear relationship is imposed using a binary indicator that equals unity for itineraries subject to the Swedish air passenger tax. It reveals a significant pass-through rate of 1.02<sup>14</sup> at the mean. In line with theoretical priors under convex demand in imperfect markets, the joint significant pass-through rate for economy and business class passengers is 1.62<sup>15</sup> at the mean and thus above one (Table 5). In Column (3), the three tax categories of the Swedish air passenger tax are interacted with a binary indicator that equals unity if an itinerary is taxed. The point estimate of the 1st tax zone is \$8.01 and significantly different from zero. This corresponds to a pass-through rate of 1.11. The significant point estimates of the 2nd and 3rd tax zone are \$30.28 and \$46.03, respectively. Consequently, the pass-through rate is 1.01 in the 2nd tax zone and 1.06 in the 3rd tax zone. To fully utilize

<sup>13</sup> 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.

<sup>14</sup>  $18.76/18.23 = 1.02$

<sup>15</sup>  $29.619/18.23 = 1.62$

the available information in the data, I prefer the discrete specification of Column (1) for a more in-depth analysis of the pass-through in the following. According to Weyl and Fabinger (2013), pass-through rates depend on competition as well as supply and demand elasticity. Thus, finding variation in pass-through rates by tax rate categories could be explained by different market structures, which are analyzed in the following. However, tax compliance costs in the European Union correspond to 1.9% of revenues on average (EC, 2022), which could also explain pass-through rates above 100%.

While the air passenger tax directly targets airfares, the key policy motivation for taxing airfares is to reduce passenger numbers. Column (4) of Table 5 shows that a \$1 increase in tax rates reduces economy class passenger numbers by 0.598 per itinerary. This translates into an elasticity of -0.40<sup>16</sup>. However, this relatively inelastic response could be explained by different functional forms of pass-through and demand response. For instance, according to Section 2 there is no theoretical basis for the pass-through rate to vary between a \$7 and a \$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). Thus, a binary indicator is employed in Column (5) that equals unity if an itinerary is taxed, revealing a reduction in passenger numbers of 8.8%<sup>17</sup> at the mean. The joint effect for economy and business class passengers is 9.1%<sup>18</sup> at the mean (Table 5). Estimates in Column (6) 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. In the 1st tax zone, passenger numbers are significantly reduced by 44.167 per itinerary. Furthermore, the passenger numbers in the 2nd and 3rd tax zone are significantly reduced by 17.076 and 21.481 per itinerary, respectively. It is reasonable to find the highest price elasticity of demand in the 1st tax zone, given the availability of substitutes such as high-speed rail.

To account for differences in the functional form of airfares and passenger numbers, it can be beneficial to use non-parametric estimates when analyzing the relationship between these two variables. According to Table 1, the average economy total airfare amounts to \$259.43. The Swedish air passenger tax results in an average economy class airfare increase of \$18.756 (Table 2, Column (2)), equivalent to a 7.2% increase in the average total airfare. Consequently, the observed average decline in economy class passenger num-

<sup>16</sup>  $(-0.598/394.26)/(0.963/259.43) = -0.40$

<sup>17</sup>  $34.798/394.26 = 0.088$

<sup>18</sup>  $32.60/355.73 = 0.091$

bers of 8.8%, which corresponds to an elasticity of -1.22, is consistent with the anticipated elasticity range found in the literature (Intervistas, 2008).

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

	(1)	(2)	(3)	(4)	(5)	(6)
	Airfares			Passenger numbers		
Tax rate	0.963*** (0.156)			-0.598*** (0.160)		
Tax		18.756*** (3.445)			-34.798*** (8.492)	
1. tax zone			8.012*** (2.914)			-44.167*** (13.835)
2. tax zone			30.283*** (8.547)			-17.076** (6.168)
3. tax zone			46.029*** (7.578)			-21.481** (8.684)
<i>Controls:</i>						
Itinerary FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Distance (Km) $\times$ Year	Yes	Yes	Yes	Yes	Yes	Yes
Destination $\times$ Month	Yes	Yes	Yes	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Tax zone $\times$ Business	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted $R^2$	0.98	0.98	0.98	0.90	0.90	0.90
Observations	329383	329383	329383	329383	329383	329383

*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 discrete variable for itineraries subject to 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 tax pass-through and passenger numbers 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 passenger numbers. In case of airfares, the effects start to appear already in the first month after the reform and remain relatively constant over time. Coefficients vary between 0.5 and 1. Pre-reform trends are flat and not statistically different from zero. The reduction of passenger numbers in Panel (b) is in line with increased airfares. The decline in passenger numbers is already evident in the initial months following implementation and persists relatively consistently despite some fluctua-

tions. Point estimates are noisier compared to airfares. Again, pre-reform trends are flat and not statistically different from zero.

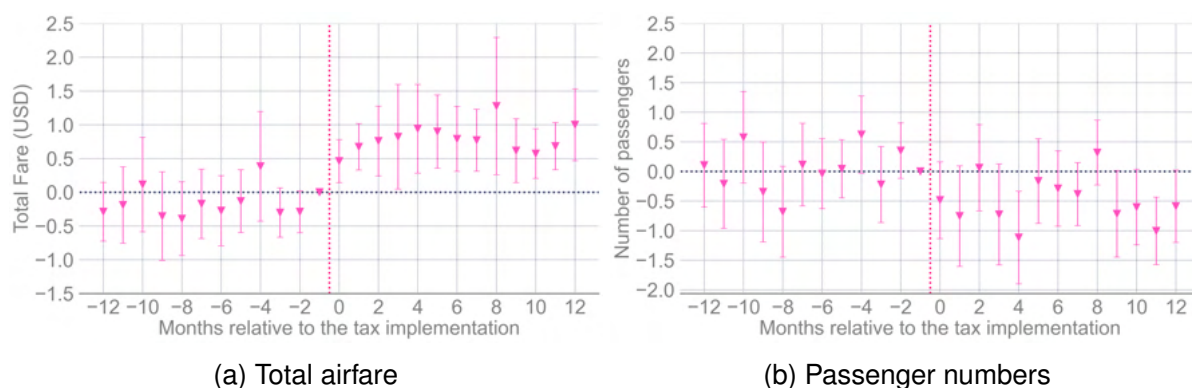


Figure 3: Event study estimates: Airfares and passenger numbers

*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.*

**Heterogeneous Effects** Table 3 explores whether the impact of the air passenger tax on total airfares and passenger numbers differs between market structures. I regress airfares (Columns (1)-(4)) and passenger numbers (Columns (5)-(8)) on a discrete variable indicating itineraries subject to the air passenger tax rate, interacted with the indicators listed on the left-hand side. Column (1) presents tax pass-through categorized by duopoly and monopoly relative to all other remaining itineraries. In non-monopolistic and non-duopolistic markets, the pass-through rate is 1.006. In case of duopolistic markets, pass-through remains unchanged, whereas it decreases to 0.121 in monopolistic markets. This aligns with the economic theory on tax incidence in imperfect markets presented in Section 2.2 and corroborates the findings of Bresnahan and Reiss (1991) or Genakos and Pagliero (2022), indicating a reduced pass-through in highly concentrated markets. To minimize the loss of demand in profitable monopoly markets, the tax is passed on to customer to a lesser extent.

In theory, business class travel is presumed to have lower price elasticity than economy class travel. In Column (2), the tax rate is interacted with a business class indicator, revealing a pass-through rate of 0.907 for economy class travel and 5.06 for business class travel. Over-shifting aligns with the theory under oligopolistic competition due to convex demand curvature. Inelastic business class travelers compensate for revenue losses caused by elastic economy travelers.

Column (3) investigates whether 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. Because business class travelers exhibit inelastic demand, airlines may decide against reducing pass-through rates for them in a monopolistic setting, unlike in the case of economy class travelers. According to Column (3), in monopolistic markets, over-shifting for business class travelers is reduced by more than 50%. Once consumer surplus has been extracted in a monopoly, raising prices to the same extent as in less concentrated markets may not be feasible without causing significant reductions in demand.

Costumers of low-cost carriers are expected to have higher price elasticity. Therefore, a low-cost carrier indicator is interacted with the tax rate in Column (4). The estimator implies that low-cost carriers do not pass through taxes differently than other carriers. One explanation is that the mark-ups of LCCs are relatively low, giving them limited pricing power.

Column (5) displays the impact of the tax rate on passenger numbers categorized by duopoly and monopoly in comparison to all other itineraries. For every \$1 increase in the air passenger tax, passenger numbers respond independently of market concentration, although only one-tenth of the tax is passed on to passengers in monopolistic markets (see Table 3 Column (1)). This indicates that passengers in monopolistic markets belong to the high-elasticity part of the demand curve. Potentially because the consumer surplus has already been largely extracted by the monopolistic airline. As a result, finding a low pass-through rate of an environmental tax does not necessarily indicate a low demand response, which is crucial for the tax's economic benefit.

Column (6) examines disparities in how the air passenger tax affects passenger numbers of business and economy class travelers by interacting the tax rate with a business class indicator. A one-dollar increase in the air passenger tax leads to a decrease in the number of business class passengers that is three times smaller than the reduction for economy class travelers, although the pass-through rate for business class travelers is over four times higher than for economy class travelers. This can be ascribed to the lower price elasticity observed among business class travelers. Consequently, demand elasticity appears to reduce the economic benefit of the tax more than market concentration.

Column (7) examines whether the air passenger tax has a different impact on passenger numbers for economy and business class travelers in monopolistic markets, using a triple interaction term. This term combines the tax rate with two indicator variables that equal unity for monopolistic and business class itineraries, respectively. The results shed light on complex market interactions that shape the tax's economic benefit.

Table 3: Heterogeneous effects of the air passenger tax on total airfares and passenger numbers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Airfares			Passenger numbers				
Tax rate	1.006*** (0.172)	0.907*** (0.145)	0.998*** (0.156)	1.013*** (0.152)	-0.474** (0.189)	-0.596*** (0.159)	-0.624*** (0.167)	-0.581*** (0.159)
Tax rate $\times$ duopoly	0.300 (0.333)				-0.492 (0.373)			
Tax rate $\times$ monopoly	-0.885*** (0.232)		-0.724*** (0.156)		-0.047 (1.383)		0.209 (0.188)	
Tax rate $\times$ business		4.149*** (1.113)	4.347*** (1.211)			0.416*** (0.135)	0.497*** (0.150)	
Tax rate $\times$ monopoly $\times$ business			-2.692* (0.182)				-0.847** (0.339)	
Tax rate $\times$ low cost carrier				-1.785 (1.418)				-0.602 (1.220)
<b>Controls:</b>								
Itinerary FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Distance (Km) $\times$ Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Destination $\times$ Month	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tax zone $\times$ Business	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Adjusted $R^2$	0.98	0.98	0.98	0.98	0.90	0.90	0.90	0.90
Observations	329383	329383	329383	329383	329383	329383	329383	329383

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: \*\*\* :  $p < 0.01$ , \*\* :  $p < 0.05$ , \* :  $p < 0.1$ .



For instance, when market concentration is low, low demand elasticity results in a pass-through rate of 5.345<sup>19</sup> (Table 3, Column (3)), leading to a reduction in passenger numbers of -0.127<sup>20</sup> (Table 3, Column (7)). However, when market concentration is high, low demand elasticity leads to a pass-through rate of 1.929<sup>21</sup> and a reduction in passenger numbers of -0.765<sup>22</sup>. Furthermore, the interaction term indicates that different price elasticities of demand converge in a monopoly. In monopolistic markets, the difference in the elasticity between business and economy class travel is reduced by factor seven. Potentially because the consumer surplus has already been largely extracted by the monopolistic airline. Therefore, low demand elasticity under high market concentration reduces the economic benefit of the tax less than under low market concentration.

In Column (8), a dummy variable for low-cost carriers is interacted with the tax rate. The coefficient for low-cost carriers is negative but insignificant. This is in line with the finding that low-cost carriers do not pass through taxes differently than others carriers (see Column (4), Table 3).

Figure 4 displays the tax pass-through on total airfares in an event study framework, categorized by monopoly and duopoly and other remaining itineraries (Panel (a)), and categorized by business and economy class (Panel (b)). Panel (a) shows that in non-monopoly or non-duopoly markets, taxes are passed on immediately and remain relatively stable over time. Conversely, in monopoly or duopoly markets, 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 travel are considerably larger compared to those for economy class, consistent with the findings in Table 3. In the second and third months after the reform, differences are particularly large. Again, pre-reform trends are rather flat and not statistically different from zero.

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<sup>19</sup>  $0.998+4.347$

<sup>20</sup>  $-0.624+0.497$

<sup>21</sup>  $0.998-0.724+4.347-2.692$

<sup>22</sup>  $-0.624+0.209+0.497-0.847$

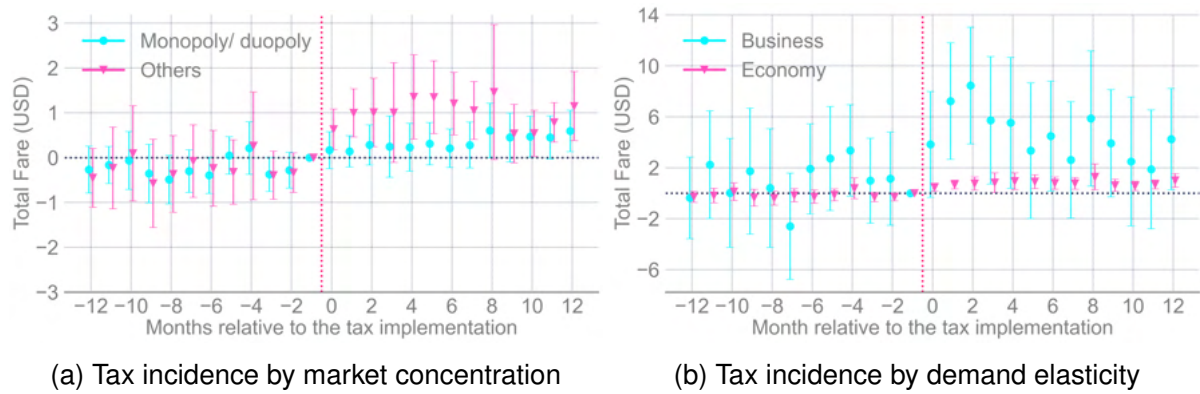


Figure 4: Event study estimates: Pass-through by market characteristics

*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 Air Transport Capacity, Revenue Passenger Kilometers, Emissions and Economic Benefit

**Air Transport Capacity** 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 4 shows how the air passenger tax affects air transport capacities departing from Sweden, while using the same set of controls as in Table 2. According to Table 4, the air passenger tax significantly reduces the air transport capacity. Specifically, given the mean air passenger tax of \$18.23, capacity is reduced by 4.7 departures and 4.83 seats per flight, which accounts for 11.7% and 3.1% of the mean, respectively (see Table A4).

Table 4: Effect of the air passenger tax on supply

	Seats	Departures
	(1)	(2)
Tax rate	-0.265*** (0.072)	-0.259*** (0.067)
<i>Controls:</i>		
Itinerary FE	Yes	Yes
Time FE	Yes	Yes
Distance (Km) $\times$ Year	Yes	Yes
Destination $\times$ Month	Yes	Yes
Region characteristics	Yes	Yes
Tax zone $\times$ Business	Yes	Yes
Adjusted $R^2$	0.97	0.92
Observations	35895	35895

*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 discrete variable for itinerants subject to 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: \*\*\* :  $p < 0.01$ , \*\* :  $p < 0.05$ , \* :  $p < 0.1$ .*

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 8.8% mentioned in Section 5.1. Consequently, the air passenger tax reduces air transport emissions. It is important to note that the impact on departures is already apparent two months after the implementation of the tax, as depicted in Figure 5. This aligns with the immediate onset of decreases in passenger numbers. The onset of reductions in seats appears delayed. Presumably because it is not so easy for airlines to replace larger with smaller aircraft. Consequently, the air passenger tax reduces Swedish emissions.

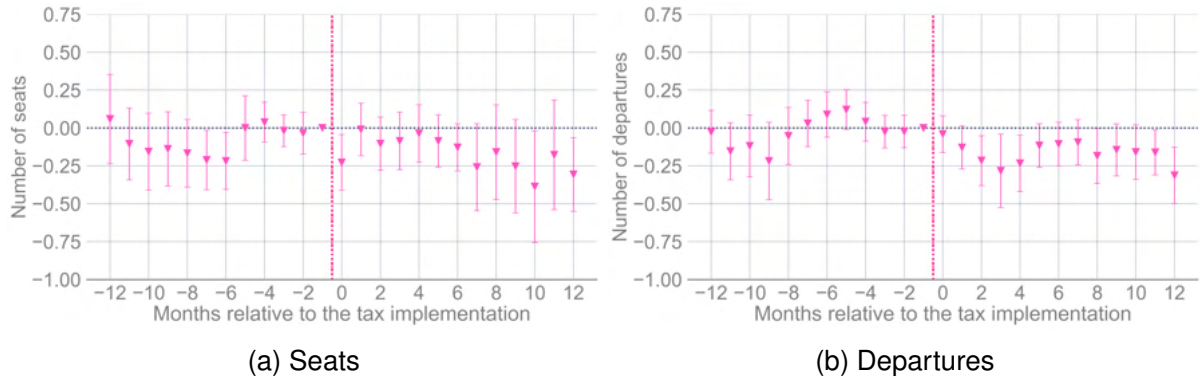


Figure 5: Event study estimates: Seats and departures

*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.*

**RPK and Emissions** The results presented so far have shown that the introduction of the air passenger tax significantly increased airfares and reduced passenger numbers and air transport capacity. In Table 5, I regress airfares, passenger numbers and RPK on a binary indicator that equals unity for itineraries subject to the Swedish air passenger tax. By omitting the interaction term for the business class, these point estimates represent the combined effects of the economy and business classes. RPK are useful for estimating the tax impact on emissions. A joint average increase in airfares of 7.7% for economy and business class passengers translates into a 9.1% reduction in passenger numbers and a 8.6% reduction in revenue passenger kilometers at the mean (Table 5).

Table 5: Overall effect of the air passenger tax

	Airfare	Passengers	RPK
	(1)	(2)	(3)
Tax	29.619*** (5.901)	-32.600*** (8.107)	-64.560*** (18.011)
<i>Controls:</i>			
Itinerary 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	No	No	No
<i>Adjusted R<sup>2</sup></i>	0.98	0.90	0.86
Observations	329383	329383	329383

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

In the full sample, itineraries originating in Sweden account for a total of 37.43 billion revenue passenger kilometers in 2019. Consequently, without the air passenger tax revenue passenger kilometers would have been 3.22 billion higher. 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 a reduction of 286,580 metric tonnes of  $CO_2$  for departures. In addition to  $CO_2$  emission, so called non- $CO_2$  effects constitute approximately two-thirds of the climate warming associated with air transport. Among these, the most significant contributors to warming, alongside  $CO_2$  are the effects stemming from contrail cirrus and alterations in the chemical composition of the atmosphere driven by  $NO_x$  emissions. As a rule of thumb,  $CO_2$  emissions need to be multiplied by a factor of three to estimate the total climate impact of air transport in  $CO_2$  equivalents (Lee et al., 2021). This results in a reduction of 859,740 metric tonnes of  $CO_2$  equivalents.

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 A3, 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 6.4% or 6.0% of the mean, respectively (see Table A8). For the full sample with 19.38 million passengers arriving in Sweden which generate 38.52 billion revenue passenger kilometers in 2019, this leads to an additional reduction of 2.31 billion revenue passenger kilometers. 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 205,590 metric tonnes of  $CO_2$  for arrivals. Multiplied by a factor of three to estimate the total climate impact of air transport in  $CO_2$  equivalents (Lee et al., 2021), the reduction is 616,770 metric tonnes of  $CO_2$ .

**Economic Benefit** In 2019, 18.7 million passengers departing from Sweden pay a total tax burden of \$340.9 million. The air passenger tax reduces 1.48 million metric tonnes  $CO_2$  equivalents, corresponding to \$230.34 per reduced metric tonne of  $CO_2$  equivalents. 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 average price per metric tonne of  $CO_2$  within the EU Emissions Trading System is approximately \$90 in 2023 (European Commission, 2023). The social cost of  $CO_2$  – measuring the monetized value of the damages to society caused by an incremental metric tonne of  $CO_2$  – has been estimated unlikely to exceed \$413 (Rennert et al., 2022). However, current estimates suggest that this cost could potentially reach as high as \$1000. Despite the high variation, the social cost of carbon significantly exceeds the tax cost per tonne of reduced  $CO_2$  equivalents.

The reduction in the number of flights diminishes the utility of air travel (Ciliberto and Williams, 2014), creating a welfare effect that should be considered when assessing the tax's overall welfare effect. Nevertheless, this consideration lies beyond the scope of the present paper.

**Shifting** If reduced air traffic is relocated to other countries, overall climate impacts would decrease. In Table A5, I analyze whether such traffic shifting occurs among the five airlines with the largest share of departures from Sweden (Figure A1). These airlines are expected

to have the largest decline in demand, making them more likely to reallocate a larger amount of operations elsewhere.

First, I analyze if these five airlines are on average similarly affected by the air passenger tax compared to airlines that operate less flights in Sweden in terms of passenger numbers (Column (1)) and departures (Column (2)). In Column (1), I use the same sample and specification as in Table 2 (Column (1)), and in Column (2), I use the same sample and specification as in Table 4 (Column (1)). In these regressions, the tax rate variable is interacted with a binary indicator that equals unity if an airline is among the five carriers with the largest number of departures in Sweden. The resulting interaction terms are insignificant, indicating that, on average, these airlines are not affected by the tax any differently than airlines with fewer operations in Sweden.

In Column (3) in Table A5, I interact the tax rate – assigned according to Swedish air passenger tax zones – with an indicator for whether the airline is one of the five most affected in Sweden. Instead of using Swedish flight schedule data, I use data on departures from Denmark and Finland between 2015 and 2019. Due to its regional proximity, airports in Denmark and Sweden are the most likely to be affected by traffic shifting from Sweden for the same destination. I then compare whether departures by these five airlines increase compared to those of other airlines at Danish and Finnish airports when the destination country is taxed under Sweden's air passenger tax. If traffic shifting is occurring, the estimated coefficient should be positive. However, in Column (3), the insignificant coefficient provides no evidence of such behavior. In Column (4), I expand the sample to include the Netherlands, Latvia, Lithuania, and Estonia, but the coefficient remains insignificant. Thus, there is no indication of traffic shifting in either case.

### 5.3 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 NUTS-3 region and their associated airport combinations from the estimation sample, with an exception for the collective exclusion of all Swedish regions.<sup>23</sup> 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.

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<sup>23</sup> The geographical locations of airports and NUTS-3 regions are depicted in Figure A2

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 A6 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 essential 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** To further test the plausibility that airfare increases are entirely driven by the tax and not by other shocks, I focus on the difference between base and total airfare over time. Statutorily, the air passenger tax is included in the total airfare, not in the base airfare. Therefore, if any surcharges or taxes have not been adjusted over time, except for the aviation tax, the difference between the total and base airfare increase by one dollar for each dollar increase in the tax rate.

Figure 6a shows the average monthly indexes for the difference between base and total airfare of the control and treatment group. The base period is the corresponding average of 2015. The development of this index demonstrates that before the passenger tax reform, differences between the base and total fare in the control and treatment group develop identical. Following the introduction of the air passenger tax discrepancy between total and base airfare increases immediately in the treatment group compared to the control group. Additionally, employing an event study approach in Figure 6b, as outlined in Equation (3), confirms that the changes in the difference between base and total fares are attributable to the introduction of the passenger tax.

In the majority of months following the introduction of the tax, a one-dollar increase in the tax rate results in a one-dollar increase in the difference between base and total airfare. Increases below one dollar indicate that certain airline-imposed fees, such as fuel surcharges, have been shifted to the base airfare due to the reform.



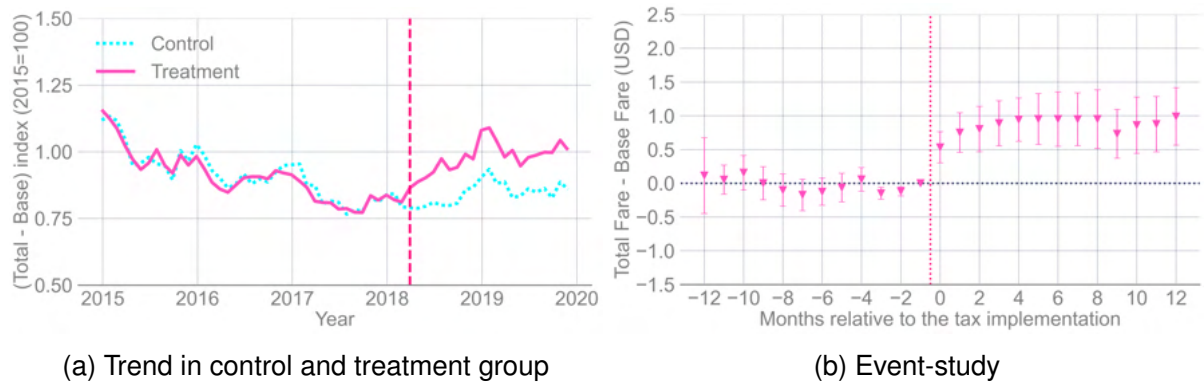


Figure 6: Difference between base and total airfare

Notes: Panel (a) shows the average monthly indexes of the difference between total and base fare for the control and the treatment group (2015 = 1). The dotted vertical line indicates the month of the passenger tax introductions (April 2018). Panel (b) illustrates the estimated treatment effect from OLS regression of the air passenger tax rate on the difference between total and base airfare 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.

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 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 Figure A8 provide strong evidence against the null hypothesis of no effect. Randomizing the total airfare A8a and the passenger numbers A8b across all observations and running 10,000 replications, empirical p-values of 0.01 and 0.08 are obtained.

Table A7 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.

## 6 Conclusion

Environmental taxes are often designed to reduce emissions by increasing prices, which in turn decreases demand and subsequently lowers supply. Using a difference-in-differences approach and event study techniques, this paper exploits the introduction of an air passenger tax in Sweden and analyzes the pass-through on airfares, the impact on passenger numbers, revenue passenger kilometers, air transport capacity and economic benefit across different market structures.

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 \$0.96. Consistent with theoretical priors in oligopolistic and monopolistic markets, the results show that higher market concentration or greater demand elasticity reduces the tax incidence. In monopolistic markets, the tax incidence is 0.12 compared to 1 in non-monopolistic markets. Factors reducing consumers' price elasticity, such as business travel, significantly enhance the pass-through, 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 8.8% reduction in the number of passengers. Although pass-through is lower under higher market concentration, demand responses are similar to those under lower market concentration. Despite higher pass-through under inelastic demand, the demand responses are smaller compared to those under elastic demand. Interestingly, different price elasticities of demand converge in monopolistic markets. Therefore, it can be misleading to use the pass-through rate to infer the effectiveness of an environmental tax.

The decline in passenger numbers 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. The air passenger tax reduces 1.48 million metric tonnes  $CO_2$  equivalents, corresponding to \$230.34 per reduced metric tonne of  $CO_2$  equivalents. Compared to current estimates of the social cost of carbon, this is significantly lower.

The insights of the paper are crucial for policy-makers, offering a more comprehensive perspective on how taxes can contribute to emission reduction, depending on the market structure. Taxes can be successful in achieving a fast and significant emission reduction even if market concentration is high and pass-through is low. However, under conditions of low demand elasticity, the economic benefits of emissions reductions through taxation may be diminished.

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# Appendices

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## 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	≈ 7.19 USD
2.	250 SEK	255 SEK	≈ 30.02 USD
3.	400 SEK	416 SEK	≈ 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	Country	Tax zone
Afghanistan	2	Lebanon	2
Albania	1	Libya	2
Algeria	2	Liechtenstein	1
Andorra	1	Lithuania	1
Armenia	2	Luxembourg	1
Austria	1	North Macedonia	1
Azerbaijan	2	Mali	2
Bahrain	2	Malta	1
Belarus	1	Mauritania	2
Belgium	1	Moldova	1
Bosnia and Herzegovina	1	Monaco	1
Bulgaria	1	Montenegro	1
Burkina Faso	2	Morocco	2
Canada	2	Netherlands	1
Cape Verde	2	Niger	2
Chad	2	Norway	1
Croatia	1	Oman	2
Cyprus	1	Pakistan	2
Czech Republic	1	Palestine	2
Denmark	1	Poland	1
Djibouti	2	Portugal	1
Egypt	2	Qatar	2
Eritrea	2	Romania	1
Estonia	1	Russia	2
Ethiopia	2	San Marino	1
Finland	1	Saudi Arabia	2
France	1	Senegal	2
Gambia	2	Serbia	1
Georgia	2	Slovakia	1
Germany	1	Slovenia	1
Greece	1	Spain	1
Guinea	2	Sudan	2
Guinea Bissau	2	Sweden	1
Hungary	1	Switzerland	1
Iceland	1	Syria	2
Iran	2	Tajikistan	2
Iraq	2	Tunisia	2
Ireland	1	Turkey	1
Israel	2	Turkmenistan	2
Italy	1	UK	1
Ivory Coast	2	Ukraine	1
Jordan	2	United Arab Emirates	2
Kazakhstan	2	USA	2
Kosovo	1	Uzbekistan	2
Kuwait	2	Vatican	1
Kyrgyzstan	2	Yemen	2
Latvia	1		

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

# B Data

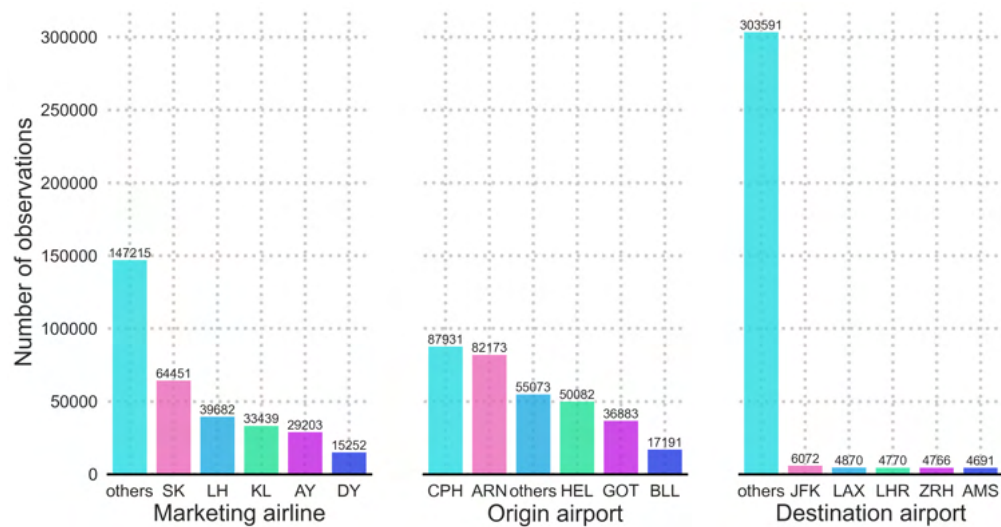


Figure A1: Observations of the top-5 airports and airlines

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

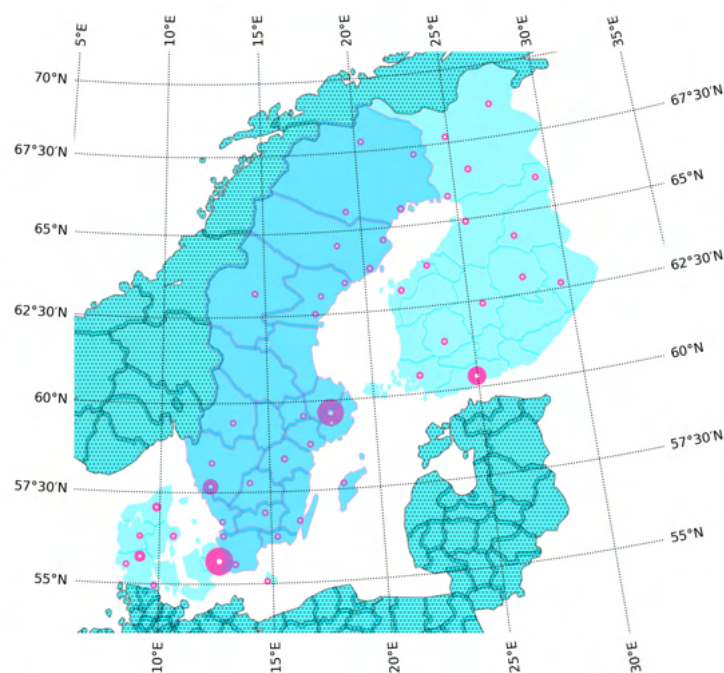


Figure A2: Airports of departure

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.

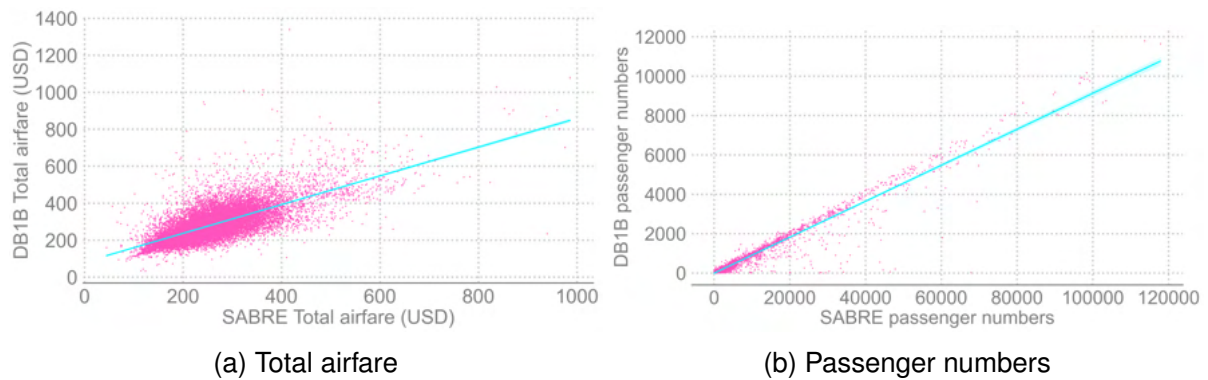


Figure A3: Correlation between SABRE and DB1B

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

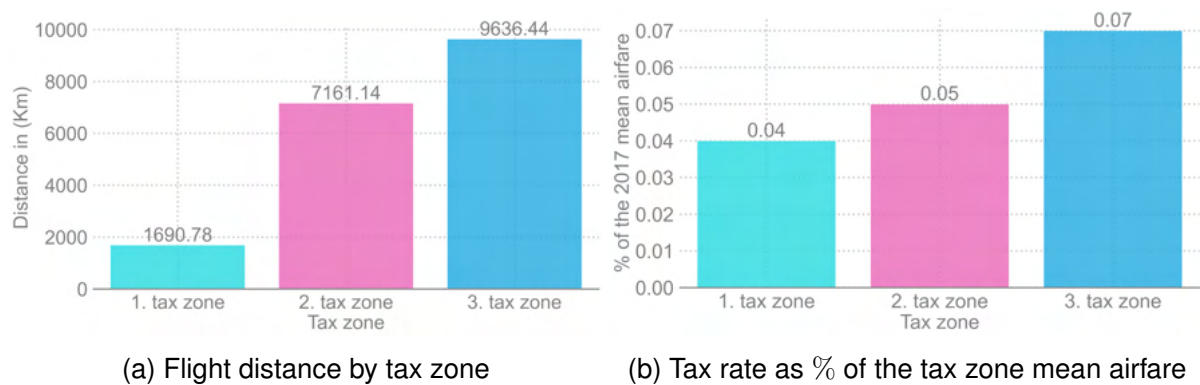


Figure A4: Tax zone characteristics

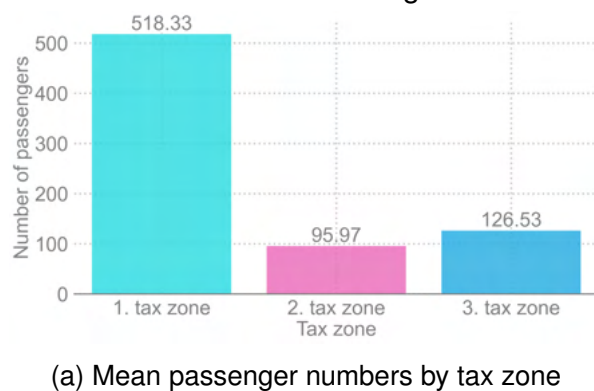


Figure A5: Tax zone characteristics

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.

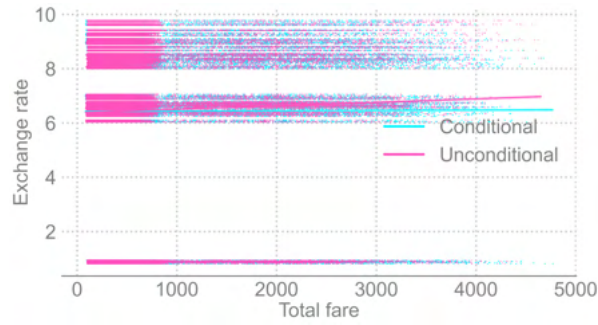


Figure A6: Correlation between exchange rate and total airfare

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

## C Additional Results

Table A3: Effect of the air passenger tax on return itineraries

	Total airfare	Passengers	RPK
	(1)	(2)	(3)
Tax	-1.971 (2.964)	-22.147*** (8.049)	-41.713** (17.248)
<i>Controls:</i>			
Itinerary FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Distance (Km) × Year	Yes	Yes	Yes
Destination × Month	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes
Tax zone × Business	No	No	No
Adjusted $R^2$	0.98	0.90	0.83
Observations	312555	312555	312555

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 subject to an 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 A4: Descriptive statistics of departures and seats

	Mean	Std	Min	Max	Observations
Departures	40.03	48.96	1.0	386.00	35895
Seats	157.88	57.94	0.0	523.84	35895

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

Table A5: Traffic shifting

	In Sweden		Regional Spillover	
	(1)	(2)	(3)	(4)
Tax rate	-0.517*** (0.161)	-0.143*** (0.046)	0.018 (0.026)	-0.011 (0.019)
Tax rate $\times$ [SK,LH,KL,AY,TK]	-0.030 (0.146)	-0.040 (0.078)		
<i>Controls:</i>				
Itinerary 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	No	No	No	No
Adjusted $R^2$	0.90	0.93	0.90	0.87
Observations	329383	37115	35037	79020

Notes: This table displays the estimates of OLS regression for traffic shifting. In Columns (1-2) the tax rate is interacted with a dummy indicating if an airline is among the five most important departing from Sweden and regressed on passenger number (Column (1)) and departures (Column (2)). Sample and specification are similar to Table 2 and Table 4. In Column (3) a sample of departures from Denmark and Finland and in Column (4) a sample of departures from Denmark, Finland, Lithuania, Latvia, Estonia and the Netherlands is applied. Significance levels: \*\*\* :  $p < 0.01$ , \*\* :  $p < 0.05$ , \* :  $p < 0.1$ .

## D Inference

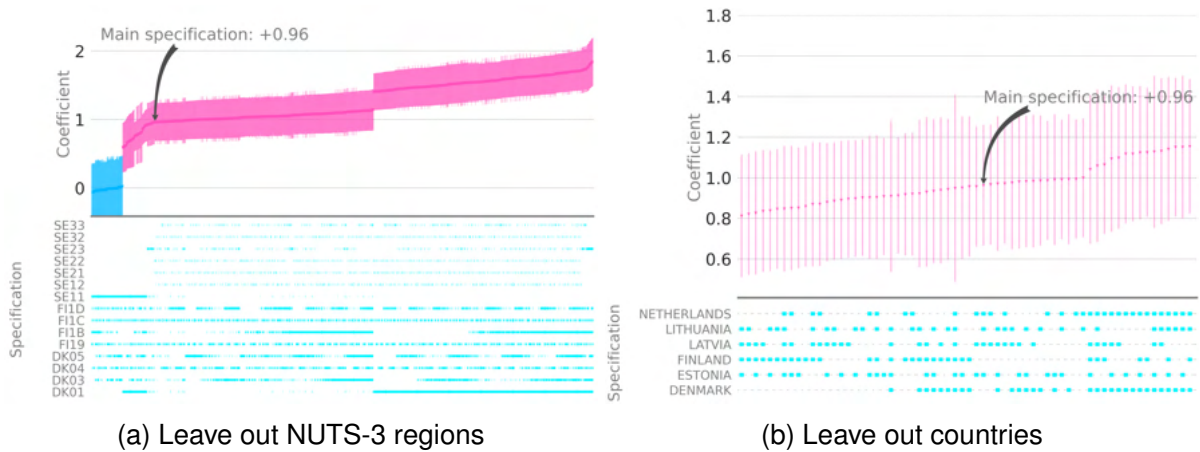


Figure A7: Specification curves

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.

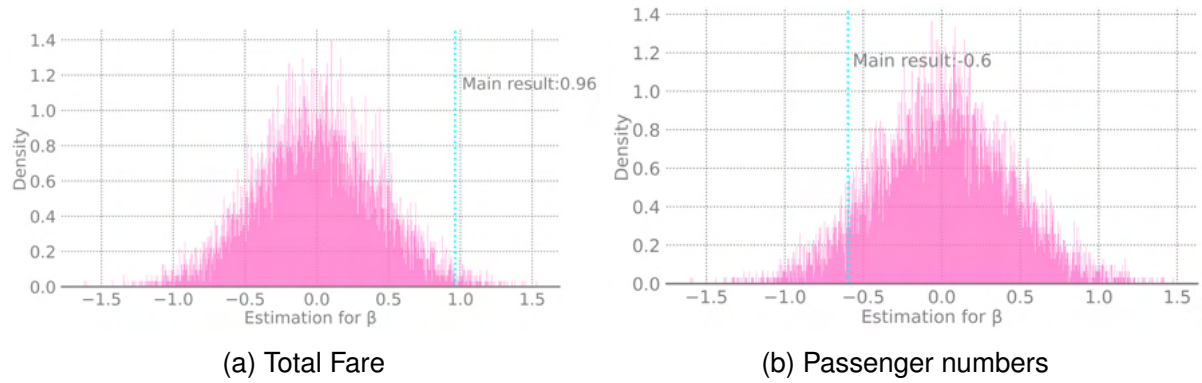


Figure A8: Placebo permutation test

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 of Table 2. The vertical lines indicate the corresponding point estimates.

Table A6: Robustness check based on full-sample

	Total fare		Passengers	
	(Main) (1)	(Full) (2)	(Main) (3)	(Full) (4)
Tax rate	0.963*** (0.156)	1.379*** (0.105)	-0.598*** (0.160)	-0.372*** (0.059)
<i>Controls:</i>				
Itinerary 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 $R^2$	0.98	0.97	0.90	0.88
Observations	329383	1516049	329383	1516049

Notes: Column (1) reproduces the point estimates of Column (1) 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 Table 2. 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 A7: Alternative clustering of standard errors

	Total fare		Passengers	
	(City-pair)	(Country-pair)	(City-pair)	(Country-pair)
	(1)	(2)	(3)	(4)
Tax rate	0.963*** (0.156)	0.963*** (0.173)	-0.598*** (0.160)	-0.598*** (0.229)
<i>Controls:</i>				
Itinerary FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Distance (Km) × Year	Yes	Yes	Yes	Yes
Destination × Month	Yes	Yes	Yes	Yes
Region characteristics	Yes	Yes	Yes	Yes
Tax zone × Business	Yes	Yes	Yes	Yes
<i>Adjusted R<sup>2</sup></i>	0.98	0.98	0.90	0.90
Observations	329383	329383	329383	329383

Notes: Column (1) reproduces the point estimates of Column (1) 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 (4) in Table 2. The standard errors in Column (4) are clustered at the country-pair level. Significance levels: \*\*\* :  $p < 0.01$ , \*\* :  $p < 0.05$ , \* :  $p < 0.1$ .

Table A8: Descriptive statistics of return itineraries

	Mean	Std	Min	Max	Observations
Total airfare	399.94	1398.34	1.74	62639.11	312555
Passengers	347.90	1288.00	10.00	28038.00	312555
RPK	700.17	1990.07	1.48	58123.06	312555

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