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THE IMPACTS OF AVIATION TAXATION IN IRELAND

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Introduction

The aviation sector has a significant role to play in the reduction of carbon emissions, particularly in light of EU emissions targets. Within the EU, aviation emissions constitute 13.9 per cent of total transport emissions, where under the Green Deal a target of 90 per cent reduction in transport emissions by 2050 has been set. Several tax exemptions apply to the aviation sector due to its international nature, which have contributed to an increasing trend in emissions. Recent movements in EU policy under the 'Fit for 55' package, as well as public and political interest, have focused attention on changing the taxation structure of the aviation industry in order to reduce CO_2 emissions. This report focuses on several different potential policies and taxation structures which would attempt to decrease the emissions of the aviation sector: the removal of kerosene taxation exemption (in line with the recent EU proposal), removal of VAT exemption, introduction of a passenger tax, and abolition of free EU ETS allowances by 2026 (in line with the recent EU proposal). Each of these policies, as well a combination scenario, is assessed with respect to the impacts on the aviation industry, spillover effects, macro-economic and government revenue effects, and household effects, as well as the emissions impacts. This analysis applies the Ireland, Environment, Energy and Economy (I3E) model, which allows for the examination of spillover effects of the aviation industry to government, households and other industries. This methodology does not, however, allow for a detailed analysis of different passenger or airline types. In what follows, results are shown as cumulative percentage changes compared to no aviation taxation. Hence a decrease does not present an annual decrease but the build up of a cumulative decrease from 2022 to the given year.

The I3E model was used to investigate a range of taxation and pricing scenarios, including measures proposed in the 'Fit for 55' package and more illustrative scenarios such as the introduction of passenger taxation or removal of a VAT exemption. Scenarios were assessed in terms of their impact on key macroeconomic indicators such as GDP, their impact on individual sectors such as Tourism, their impact on the Aviation industry measured by the impact on its value-added (VA), and finally their emissions impact.

Main Findings

- In order to examine the impacts of the different taxation structures on the aviation industry, this paper analyses the effects on aviation value-added (VA), which are presented in Table 1. VA represents the additional economic value that the sector adds to its inputs used when producing a good or service. This is equivalent to the difference between the input cost of total production and the revenues received from sales. VA captured both the impacts from price changes and changes in the level of production and hence better represents economic impacts for aviation. The impacts on aviation VA vary between a 0.5 per cent decrease and a 4.4 per cent decrease in 2030 depending on the level of taxation (where the introduction of VAT would result in the highest impacts) and the taxation method (where e.g. the impacts of kerosene taxation on aviation are relatively lower as the petroleum sector shares in the costs of this form of taxation).

- Recent policy proposals under the 'Fit for 55' package propose the implementation of kerosene taxation and the abolition of free EU ETS allowances to aviation. These policies are expected to come into force in the next year and would result in a more than 3 per cent cumulative decrease in aviation VA. When a rise in ETS prices (in line with recent estimates) is assumed, impacts for the aviation sector become considerably larger, with an almost 14 per cent cumulative decrease in VA by 2030. This illustrates how EU policies and the future path of the ETS will have important repercussions for the aviation industry.

- All forms of aviation taxation result in increased prices of aviation services. Demand for aviation services decreases as a result, however, because of the lack of adequate substitutes for an island nation, the decrease in demand in reaction to increased prices is limited, i.e. the price elasticity (resulting from the structure of the I3E model) is relatively low.

- Effects on most other sectors in the economy through the impacts on the aviation sector (so called spillover effects) are limited. There are, however, several industries which more directly interact with aviation that are significantly affected, such as the petroleum sector, warehousing, machine repair and installation, and travel and tourism. For travel and tourism, this paper estimates the decreased spending by tourists resulting from a decrease in arrivals. The highest impacts are seen with the introduction of a VAT, reducing VA in the accommodation and hotel services sector by approximately 1 per cent in 2030.

- An increase in prices in the aviation sector result in a decrease in economic activity (measured by GDP and investment), and an increase in government debt. However, estimates for the GDP with increased aviation taxation suggest that the impact on GDP will be small and are strongly correlated with impacts in the aviation sector, see Table 1. When an increase in the ETS price is assumed together with the recent EU proposals on aviation ETS allowances and kerosene taxation, the cumulative decrease in GDP reaches almost 0.6 per cent by 2030. On an annual basis, however, GDP continues to grow at approximately 3.7 per cent under all taxation scenarios. Direct taxation of carbon inputs, as is the case with kerosene taxation and free EU ETS allowance abolition, results in lower secondary impacts and hence lower GDP impacts.

- With regard to government revenue, changes to the aviation taxation structure result in both increased tax revenue from the aviation industry and decreased tax revenue from other sectors of the economy (due to decreased economic activity). This analysis shows that the increase in aviation taxation outweighs the decrease in other tax revenue in the medium run. However, in the long run this relationship is reversed and the decreased taxation resulting from decreased economic activity dominates, resulting in decreased tax revenues.

- An analysis of household types (distinguished by location and income) shows that the overall impacts on household wage income are small, though they are also regressive (poorer households are impacted more). Impacts on real disposable income are also small, but progressive (richer households are impacted more) due to decreased capital income for higher income households.

- The resulting emission reductions are also shown in Table 1. An analysis of reduced aviation VA and decreased GDP per tonne of emission reduction shows that the most cost effective policies (lowest VA and GDP reduction per tonne of emissions reduced) are taxing kerosene and removing free ETS allowances. This shows that that taxing carbon inputs directly is most cost effective. The introduction of a VAT and a passenger tax results in higher reductions in VA and GDP per tonne of emissions reduced.

Table 1: Cumulative % impact 2021-2030

Scenario	GDP Impact	Aviation VA Impact	Emissions Impact
Kerosene Exemption Abolished	-0.04	-0.5	-0.8
VAT 30	-0.2	-4.4	-1.7
Passenger Tax	-0.1	-2.5	-0.8
ETS 26	-0.05 -0.54*	-2.6 -13.41*	-1.1 -14.27*
EU Policy	-0.09 -0.57*	-3.1 -13.68*	-1.9 -14.80*

Note: All results above assume EU Reference Scenario ETS Allowance Price of €32 per tonne in 2030 unless otherwise stated. EU Reference Scenario is one of the European Commission's key analysis tools in the areas of energy, transport, and climate action. It allows policymakers to analyse the long-term economic, energy, climate and transport outlook based on the policy framework in place in 2020.
*: Results assume ETS Allowance Price of €100 per tonne in 2030.

1 Introduction

Aviation based emissions account for 3.8 per cent of EU CO_2 emissions. In addition to this, there are non-CO_2 effects from aviation, such as emissions of nitrogen oxides, contrails and aviation-induced cirrus clouds. These effects are estimated to be almost as significant as aviation's CO_2 emissions in terms of their global warming potential (Azar & Johansson, 2012; Lee et al., 2010). Technological progress in both aircraft design and flight operations has led to a 24 per cent decrease in fuel consumption per passenger-km flown since 2005. However, the number of passengers carried has increased by more than 60 per cent over the same period in Europe (European Commission, 2019), leading to an increasing trend in emissions from aviation.

The aviation industry will need to play a significant role in emissions reduction for the EU emissions targets to be met. Under the Green Deal, the EU target for emission reduction in transportation is set at 90 per cent by 2050. Though aviation falls under the EU Emissions Trading System (ETS), several tax exemptions apply to aviation, which have contributed to the growth in emissions from the sector. Motivated by the climate crisis, many EU Member States have moved towards taxing aviation carbon by levying taxes on domestic air travel and applying taxes/fees to air passengers. Furthermore, in July 2021, within their 'Fit for 55' package, the European Commission has proposed a taxation of aviation fuels, the abolition of free EU ETS allowances for aviation, and initiated the RefuelEU scheme (European Commission, 2021). These proposals are still to be negotiated by the Member States and the European Parliament before coming into force. A revision of the 2003 Council Directive 2003/96/EC, or Energy Taxation Directive (ETD), which limits taxation of aviation fuel, will allow for the taxation of aviation fuels at a minimum rate of €10.75 per gigajoule. Revisions to the ETS Directive will result in the elimination of free ETS allowances to the aviation sector by 2026. The RefuelEU scheme will impose a minimum share of sustainable fuels in aviation.

Against this background, this report investigates the potential impacts for Ireland, particularly on key sectors of price changes resulting from these recent EU proposals and other potential aviation taxation schemes. Ireland is unique in this regard as it is a small open island economy and, hence, will be affected to a higher degree than states with low carbon alternatives to aviation, such as rail. This makes production sectors (in addition to consumers) particularly vulnerable to the impacts of an aviation tax as alternatives (such as land transport) are limited. When considering the implementation of an aviation tax, understanding its impacts for the aviation industry is paramount, particularly given the effects that the COVID-19 crisis has had on the aviation industry. Furthermore, the concomitant impacts for other sectors in the economy and the economy as a whole should be investigated. A greater understanding of the impacts of aviation taxation will allow for better policy setting to help support those sectors most impacted, allowing for a smoother transition to lower carbon aviation.

This report will investigate through modelling the impacts of several aviation taxation options in respect to their potential application in Ireland. Firstly, we investigate the recently proposed EU level policies concerning kerosene taxation and EU ETS allowances. Secondly, given that many EU states have introduced a passenger tax, we study the potential impacts of an Irish passenger tax. Finally, the introduction of a Value Added Tax (VAT) for aviation services will be considered, where currently aviation is exempt from VAT taxation. In this analysis, the Ireland, Environment, Energy and Economy (I3E) model is applied, which explicitly models intersectoral linkages enabling us to examine the spillover effects from the aviation industry to the government, households, and other industries. Moreover, this analysis takes into account the EU ETS system, the impacts of the COVID-19 crisis and greenhouse gas (GHG) emissions from fuel usage. This will allow us to estimate the impacts of different aviation taxation schemes on the macro-economy, production sectors, labour and employment, households, and emissions. We will compare the relative impacts of the different forms of aviation taxation and discuss how they differ in terms of costs and emission reduction potential.

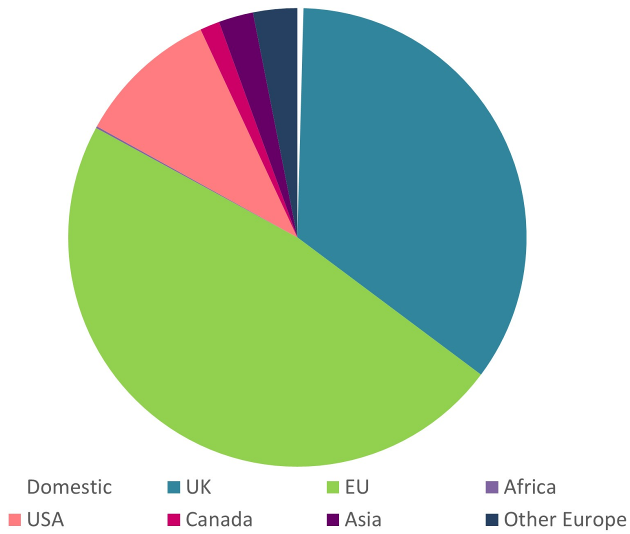
Though this report provides valuable insights into the impacts of aviation taxation, several limitations should be considered when interpreting the results. There remains a high level of uncertainty concerning the recovery path of the aviation industry as well as the price path of EU ETS permits, both of which significantly impact the results. Two policies in aviation are not considered here, namely CORSIA and ReFuelEU. The methodology applied here does not consider differences between types of passengers and airlines, which are likely to be impacted differently. Finally, this analysis does not consider the implementation costs of policies.

The rest of this report is structured as follows. The next section provides an overview of the Irish aviation sector. Section 3 focusses on summarising current aviation taxation and Section 4 summarises the literature concerning the impacts of aviation taxation. Section 5 gives a short introduction to the I3E model. Section 6 describes the aviation taxation scenarios investigated in this report.Section 7 present the results, focusing first on the impacts for the aviation sector and then on spillovers to other sectors and tourism. The impacts for government revenue, macroeconomy and households are discussed next. The impacts on emissions are presented in Section Section 8, where we also discuss the cost effectiveness of different taxation measures and the impacts of an increased ETS price. Finally, Section 9 concludes.

2 Overview Irish aviation

Given that Ireland is an island state, aviation plays an important role in both the Irish economy and in leisure activities. In 2019, just over 38 million passengers arrived and departed from Irish airports. The vast majority (86 per cent) of passengers arrived and departed Dublin airport. Cork (with 7 per cent) and Shannon (with 4 per cent) airports represent the second and third largest passenger turnover. Figure 2.1 shows the share of passenger arrivals and departures by destination. The majority of passengers depart to and arrive from airports within EU (48 per cent) and UK (35 per cent). Departures and arrivals from the US represent 10 per cent of total, whereas domestic departures and arrivals represent a mere 0.4 per cent.

Figure 2.1: Passenger arrival and departure Irish airports by destinations in 2019



Source: **Central Statistics Office (CSO, 2021b)**

According to IATA (2019), the aviation sector generates 143,000 jobs in Ireland of which 39,000 are directly, and another 36,000 are indirectly, related to the sector. The remaining 48 per cent of the total number of employees are employed in tourism-related activities. The total gross value added of the sector is around USD 20.6 billion,which constitutes around 6.8 per cent of GDP in 2017. USD 5.6 billion of the sector's contribution comes from the spending of foreign tourists. The 2017 projections showed that the sector had a potential of handling between 23.8 and 27 million passengers in 2037, by generating jobs in the range of 150,000-170,000 and gross value-added up to USD 32 billion [1].

3 Overview of current aviation taxation

This section presents an overview of the various forms of aviation taxation currently in place and their implementation. These policies in the European context are fuel taxation, air cargo tax, VAT, passenger tax, the EU ETS, and the CORSIA in the global context.

3.1 Aviation fuel taxation

Taxing fuel usage, a common policy used to reduce emissions of most other transport modes, is not common in aviation. The 1944 Chicago Convention on International Civil Aviation, article 24, prohibits taxing fuel arriving to an airport on a plane (ICAO, 2006). However, this does not include fuel taken

[1] Passengers are counted as departures, including connections. The passenger forecasts are based on the IATA 20-year passenger forecast (October 2018). Data on GDP and jobs 2017 are from Oxford Economics. GDP and jobs forecasts are from IATA Economics.

on board while grounded. For the latter, the 2003 Council Directive 2003/96/EC, or Energy Taxation Directive (ETD) applies, which states that EU Member States must exempt aviation fuel from taxation for intra-EU, and extra-EU flights (European Union, 2003), except in the case of a bilateral agreement on the taxation of jet fuel.[2] However, in July 2021 the EU commission adopted a proposal for a revision to the ETD within the context of the 'Fit for 55' package, which aims to align the taxation of energy products with the EU climate goals of reaching at least 55 per cent emission reduction in 2030. This revision will allow for the taxation of fuel for intra-EU air transportation. The proposal sets out a transition to kerosene taxation starting in 2023 with incremental increases of 10 per cent a year, reaching a minimum rate of €10.75 per gigajoule (equivalent to approximately €131 per tonne of carbon or €0.40 per litre) by 2033. Outside Europe, other countries such as the US, Canada, Australia, Thailand, Vietnam and Japan levy excise duties on jet fuel. Rates vary between €0.02 per litre in Australia to €0.70 per litre in Hong Kong.

3.2 Value Added Tax

Both the International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA) have endorsed a zero VAT rate with respect to the sale or use of international transport. It is argued that a zero VAT rate should be applied, as international air transport generally takes place outside any tax jurisdiction. Moreover, it ensures equal treatment across the jurisdictions of international aviation. However, because domestic air transport falls under a single jurisdiction, it is often subject to VAT. Besides imposing VAT on (mainly domestic) air fares, states may also impose VAT on fuel, or on charges such as airport charges, air navigation charges or service fees. Under the EC directive on the common system of Value Added Tax (2006/112/EC)23, EU Member States may exempt passenger transport from VAT or apply a zero VAT rate. The following air transport related activities are exempt from VAT (Article 148) for commercial air traffic on international routes:

- the supply of goods for the fuelling and provisioning of aircraft;
- the supply, modification, repair, maintenance, chartering and hiring of aircraft, and the supply, hiring, repair and maintenance of equipment incorporated or used therein;
- the supply of other services as mentioned in the point above, to meet the direct needs of the aircraft or of their cargoes.

Most European countries (23) do charge VAT on domestic flights. Some countries apply reduced rates such as Sweden (6 per cent), Belgium (6 per cent), Portugal (6 per cent) and Luxembourg (3 per cent) whereas other countries apply their general VAT rate (with values ranging up to 24 per cent in Greece and 27 per cent in Hungary). Ireland does not currently charge VAT on aviation services.

[2] Currently, no such agreements are in place.

3.3 Passenger tax

Many EU Member States have bypassed the ETD exemptions by levying taxes on domestic air travel and applying taxes/fees to air passengers. Passenger tax is by far the most applied method of enforcing aviation taxation in Europe. European countries that have implemented a passenger tax and the associated rates are given in Table 3.1. The rates generally depend on the distance travelled (long vs short haul) and in some cases also on the class (economy vs business). How these rates translate into average taxes per passenger is given in Figures 3.1 and 3.2.

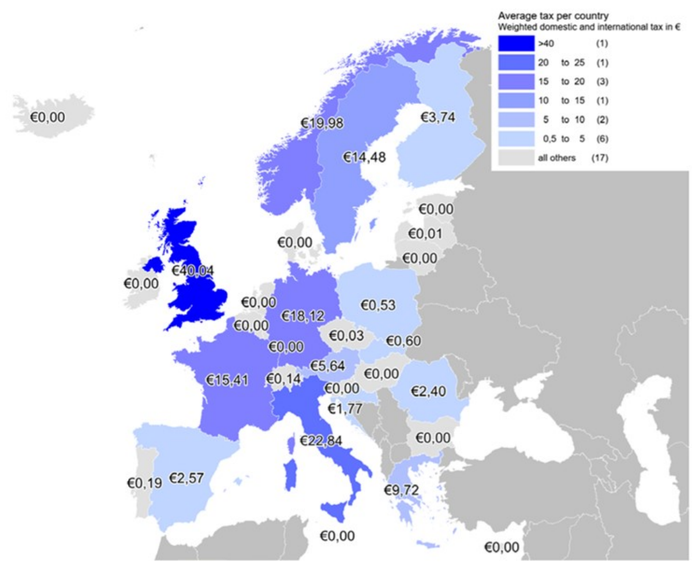
Table 3.1: Effective ticket taxes

Country	Tax name	Rate	
Austria	Austria Air Transport Levy	€3.50	short haul
		€7.50	medium haul
		€17.50	long haul
France	France Civil Aviation Tax	€4.48	within European Economic Area (EEA)
		€8.06	all other
		€1.33	per tonne of freight
	Air Passenger Solidarity Tax	€1.13	within EEA, French overseas (economy)
		€11.27	within EEA, French overseas (business)
		€4.51	outside EEA (economy)
		€45.07	outside EEA (business)
	Fiscal Tax Corsica	€4.57	
Germany	German Air Transport Tax	€7.47	short haul
		€23.32	medium haul
		€41.99	long haul
Italy	Italy Embarkation Tax	€6.57	domestic
		€12.69	EU & EEA
		€18.14	non-EEA
	Italy City Council Tax (passenger tax with varying rates across airports)	€7.07	
	Italy Luxury Tax (applied on executive charter flights)	€10	distance < 100 km
		€100	distance < 1,500 km
		€200	distance > 1,500 km
Sweden	Air travel tax	€6.26	domestic/EU
		€26.06	international commercial < 6,000 km
		€41.70	all other
United Kingdom	Air Passenger Duty	€14.42	lowest class < 2,000 miles
		€28.85	all other classes < 2,000 miles
		€86.54	craft > 20 tonne for < 19 pax; < 2,000 miles
		€86.54	lowest class > 2,000 miles
		€173.10	all other classes > 2,000 miles
		€499.24	craft > 20 tonne for < 19 pax; > 2,000 miles
Norway	Norway Air Passenger Tax	€8.77	

Source: IATA TTBS: https://www.iata.org/en/services/finance/ttbs/

Though Ireland currently does not impose a passenger tax, the Irish Air Travel Tax (ATT) was enforced between March 2009 and April 2014. The ATT imposed a tax of €10 per passenger on all flights from Irish airports to airports which are situated more than 300 kilometres from Dublin Airport. As this would lead to a comparative disadvantage for the smaller non-Dublin airports compared to Dublin airport, the ATT was only applied to flights leaving from Dublin. For flights from Irish airports to airports within this limit (all Irish airports and the UK airports of Cardiff, Glasgow, Prestwick, Liverpool, Manchester, Blackpool, and Isle of Man) a reduced rate of €2 applied. As the differential rate was considered by the EU to be an interference with the internal market, from 1 March 2011 a flat rate of €3 was introduced. The ATT was strongly opposed by airlines and the tourism industry and finally abolished.

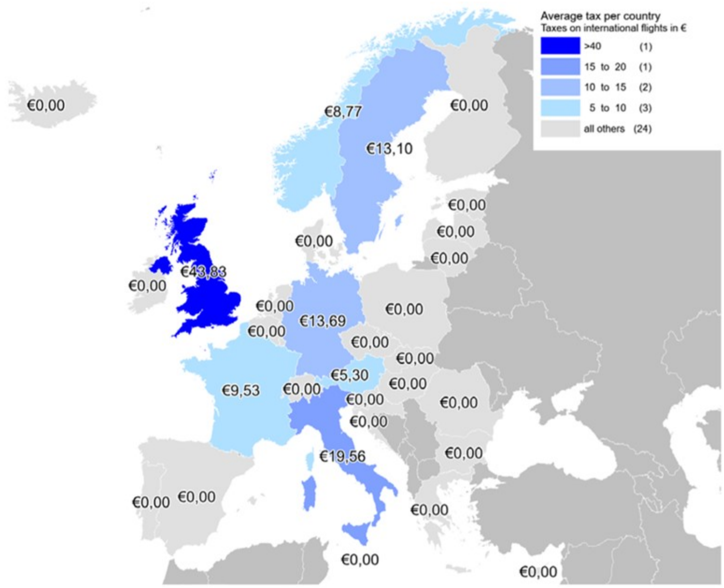
Figure 3.1: Average aviation taxes per passenger in the EU, EFTA and UK, for domestic passengers



Source: **Faber & Huigen (2018)**

Recently, support for aviation taxation has been increasing, with nine EU countries (Germany, France, Netherlands, Sweden, Belgium, Italy, Luxembourg, Denmark and Bulgaria) calling for an EU-wide aviation tax in late 2019. Furthermore, there is growing public support for aviation taxation, for example, the recent "flyskam" (flight shame) movement in Sweden, as the industry is considered to be taxed lighter than other forms of transportation. To ensure a level playing field, an EU wide (and preferably global) system of aviation taxation would be needed. In this context, the EU commission's proposal for revision of the ETD within the 'Fit for 55' package examines several harmonised EU passenger taxes though no rate is officially proposed. Firstly, a flat tax of €10.43 for all passengers is considered. Secondly, a multi-rate passenger tax is considered, which increases with distance flows. This option would tax passengers €10.12 for intra European Economic Area (EEA) flights, €25.30 for extra-EEA flights up to 6,000 km and €45.54 for extra-EEA flights over 6,000 km. Finally, a multi-rate passenger tax decreasing over distance flown is considered with a tax of €25.30 for flights up to 350km and €10.12 for flights over 350km. This proposal includes an exemption for flights to and from EU outermost regions to ensure connectivity of such regions with the rest of the EU.

Figure 3.2: Average aviation taxes per passenger in the EU and EFTA, for international passengers



Source: **Faber & Huigen (2018)**

3.4 Air cargo tax

Similar to a passenger tax, an aviation tax can be levied on air freight as a means to bypass the ETD. Within the EU, only the French civil aviation tax is levied on air freight, with a rate of €1.33 per tonne of freight.

3.5 Aviation in the EU ETS

In accordance with increasing awareness of climate change and the need for global cooperation in terms of mitigation, the global-scale mitigation efforts were initiated by the Kyoto Protocol (ratified in 1997 and became effective in 2005) to reduce the GHG emissions, and were reinforced by the ratification of the Paris Agreement (ratified by 195 states and the European Union (EU) in 2015). The goal of the Paris Agreement is to limit the increase in global temperature to 1.5°C.

After ratifying the Paris Agreement, the EU set its Intended Nationally Determined Contributions (INDCs): at least 40 per cent reduction in GHG emissions (compared to 1990 levels), at least 32 per cent share for renewable energy, and at least 32.5 per cent improvement in energy efficiency. The EU introduced an EU-wide carbon allowance market, namely the Emissions Trading System (ETS), which is central EU policy to achieve these goals. The EU ETS covers emissions of international aviation, industrial processes, and manufacturing combustion to achieve these targets. The ETS works on a cap-and-trade principle: the unit price of an allowance (one metric tonne of carbon dioxide) is determined via an auctioning process for the fixed amount of total allowances. As the firms covered by the ETS increase their ETS emissions, the demand for allowances boosts and therefore the unit price of an allowance increases, as does the cost of production.[3] Concerning the reduction of non-ETS emissions, each Member State has legally-binding targets for each of these EU targets (both for 2020 and 2030).

In 2008, the EU decided to include aviation in the EU ETS, which remains the only form of carbon policy in aviation, meaning that all airlines operating in Europe, (i.e. landing at or taking off from any EEA airport) would be required to monitor, report and verify their emissions, and to surrender allowances against those emissions from 1st of January 2012. However, the decision was made in April 2013 to only include flights within the EEA due to the strong degree of resistance on the part of international carriers, which considered the EU regulation to be illegal and to breach non-EU countries' sovereignty. The decision to exempt non-EEA flights was justified on the grounds of discussions with the Assembly of the ICAO and its intention to develop a global market-based mechanism to deal with aviation emissions at the international level.

The number of allowances allocated to the aviation sector is based on historical emissions, corresponding to 95 per cent of average total emissions in the years 2004 to 2006. Yearly allowances are constant over time (and do not grow with emissions) for the years 2013 to 2020 (phase III). Up to 82 per cent of these allowances are granted for free and the remaining 15 per cent and 3 per cent are auctioned and given to fast-growing airlines and new entrants, respectively. Because of the growth in the aviation sector, these free allowances only covered 60 per cent of 2013 emissions and just 44 per cent in 2019, making it necessary for airlines to purchase allowances from the other EU ETS sectors. Over the period (2013-2020), the aviation sector purchased allowances for up to 74 million tonnes of CO_2 eq. from other EU ETS sectors. This indicates that, though there is no reduction in emissions from aviation (due to the strong growth of the sector), the aviation demand for permits reduces emissions in other EU ETS sectors.

In July 2021, the European Commission released the 'Fit for 55' package, which includes a set of policy proposals spanning all major sectors of the economy to achieve emission reductions of at least 55 per cent below 1990 levels in 2030. The 'Fit for 55' package includes a proposal for amending the ETS Directive, which would eliminate free ETS allowances allocated to the aviation sector by 2026.

3.6 ReFuelEU Aviation

The ReFuelEU Aviation is an initiative set out in the EU Action Plan of the Sustainable and Smart Mobility Strategy. It aims to boost the production and uptake of sustainable aviation fuels in aviation. This regulation sets out a quota for Sustainable Aviation Fuels (SAF) and synthetic aviation fuels. The blending shares currently proposed are 2 per cent in 2025 reaching 63 per cent in 2050, with a minimum share of synthetic aviation fuels of 0.7 per cent in 2025 and 28 per cent in 2050. Though this initiative will result in considerable additional costs to the aviation industry, these are not considered here as these costs are highly uncertain and estimates of their levels are not available.

[3] A firm is not covered by the ETS either because the sector that the firm operates in is exempted (for instance, the agriculture sector) or its combustion capacity is lower than the threshold. For more information, see EPA (2018).

3.7 CORSIA

At a global level, the ICAO decided in 2016 to implement a Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) with the aim of achieving 'carbon neutral growth' from 2020 (ICAO, 2016). The agreement under this scheme stipulates that airlines are obliged to offset their increase in emissions after 2020 by purchasing credits (so called Certified Emission Reductions (CERs)) from emissions mitigation projects outside the aviation sector (e.g. renewable energy). Between 2020 and 2027 the system is voluntary and thereafter becomes mandatory; all EU countries have joined the scheme. Though this is not a direct tax on aviation, it constitutes an increase in costs for airlines. In past years, the traded prices for CERs have been extremely low, where the highest price since 2016 was €0.33 per tonne of CO_2, representing a small cost for aviation. The level of the costs aviation will face under this scheme in the future is highly uncertain. No recent CER price projections are available and CER prices do not currently correspond with EU ETS prices or other carbon prices, hence estimating future costs is highly problematic. For this reason, the costs of CORSIA for aviation have not been included in this analysis. That being said, as carbon pricing becomes more harmonised across the EU and globally, CER prices should become comparable to carbon prices and could present a significant cost to aviation.

3.8 Summary of aviation taxation in Europe

In the Table 3.2 an overview of the discussed aviation taxation in Europe is given.

Table 3.2: Overview of aviation taxation in Europe

Aviation Fuel Taxation	Currently not applied in the EU. A recent EU commission ETD revision proposal includes a kerosene tax of €0.40 per litre, if approved by EU Parliament, this rate would apply in the near future.
Air Cargo Tax	Only applied in France and likely to be exempted from kerosene taxation under the ETD revision proposal.
Value Added Tax	In most EU countries (Ireland included) International Aviation is exempt from VAT. In 23 EU countries (Ireland excluded) VAT is levied on domestic aviation on rates between 6%-27%.
Passenger tax	Five EU countries, Norway and the UK impose a passenger tax at levels ranging from €1.13 to €173.10 depending on class and distance.
EU-ETS	Aviation emissions fall under the EU ETS system where, in 2019, aviation received 44% of its needed allowances for free. A recent EU-ETS Directive revision proposal includes the abolition of all free allowances for aviation by 2026. This proposal would come into force once approved by EU parliament.
ReFuelEU Aviation	EU initiative that sets targets for the use of Sustainable Aviation and Synthetic Fuels in aviation.
CORSIA	A ICAO Carbon Offsetting and Reduction Scheme, currently voluntary, but to become mandatory after 2027.

4 Literature on the impacts of aviation taxation

This section presents an overview of the literature concerning the impacts of aviation taxation within Europe. Firstly, the concept of price elasticity and its determinants are discussed as most of the aviation taxation literature either estimates price elasticities or applies price elasticities to determine taxation impacts.

4.1 The concept of price elasticity

The bulk of the literature on the impacts of aviation taxation centres around the concept of price elasticity. This measure shows how transport demand reacts to price changes. Price elasticity is the ratio of the percentage change in demand Q to the percentage change in price P of, in this case, air transportation services:

$$\varepsilon_{price} = \frac{\Delta Q/Q}{\Delta P/P}$$

The price elasticity represents how sensitive consumers (passengers or importers) are to price changes. It shows how the number of flights demanded changes as prices increase by e.g. 1 per cent and depends on, among other things, the passenger in question and the purpose of the trip. Price elasticity of the demand for aviation is directly related to the possibilities of substitution for aviation. Multiple levels of substitution can be identified in aviation (Brons et al., 2002). The first level corresponds to non-travel substitution and represents the substitutability of travel and non-travel goods and services in the consumer's utility function or producer's production function. The second level refers to destination substitutability and represents how a consumer would be willing to substitute the destination of their trip or origin of their import for another. The third level represents mode substitution and represents the substitutability of different modes of transport, e.g. train versus aeroplane. For an island state, level three substitutes for aviation are limited.

In the literature, a large range of price elasticities for air passenger transport have been estimated. We do not give a detailed discussion of this literature here, but present a brief overview. Brons et al. (2002) perform a meta-analysis of these estimates, finding values ranging from -3.2 to 0.2. The exact level of price elasticity will determine the impacts of any change in prices. On average, price elasticities vary between -1.0 and -2.7 for leisure trips and between -0.65 and -1.15 for business trips. This means that for leisure trips a 1 per cent increase in price could decrease demand for trips by up to approximately 3 per cent, whereas the same increase in price for business trips could lead to at most a slightly higher than 1 per cent decrease in demand. In other words, passengers travelling for holidays are more sensitive to price changes than passengers on business trips. For air freight transport, average price elasticities vary between -0.8 and -1.6 (Profillidis, 2016). There is also a difference between short-term and long-term elasticities, where long term elasticities are expected to be of a higher value, or passengers are less price sensitive in the short run.

Andersson (2019) finds that the price elasticity of gasoline for transport is three times larger when the price change is caused by a carbon tax as opposed to an increase for other reasons. If the same reasoning were to apply to aviation taxation, we would expect these elasticity estimates to underestimate demand impacts of aviation carbon taxation.

4.2 National aviation taxation studies

Various papers consider the impacts of aviation taxes on passenger numbers, as this is the most frequently applied method of aviation taxation. Generally, the literature finds that the implementation of an aviation tax results in reduced passenger numbers, i.e. the price elasticity of demand is negative. Very few studies estimate economic impacts or secondary impacts of aviation taxation and the few studies that do have applied simplistic methods and assumptions.

Gordijn et al. (2011) look at the behavioural response of passengers, airlines and airports following the introduction of an air passenger tax in the Netherlands (of €11.25 for EU and under 2,500 km flights and €45 for other flights). Using media analysis, data analysis and survey data, they find that the tax had a negative effect on the volume of Dutch passengers departing from Dutch airports. Of the surveyed travellers, 14 per cent changed their travel plans due to the tax, half of which opted to use airports in neighbouring countries instead. This confirms the high potential of emission leakage of aviation taxation across European countries.

Morlotti et al. (2017) analyse internet fares for all EasyJet flights departing Amsterdam Schiphol airport between March and September 2015. It finds that the price elasticity of demand for flights, though always negative, varies according to the nature of the passengers' flight, i.e. business or leisure, and also the timing of the flights, i.e. in summer months or other times of the year. Similarly, Borbely (2019) finds, applying a synthetic control method, that the introduction of an aviation tax in Germany significantly reduced passenger numbers in Germany and increased passenger numbers in bordering countries. They also find that smaller, regional airports (predominantly serving low-cost airlines) lost proportionately more passengers after the introduction of the tax.

Falk & Hagsten (2019) assess the impacts of the recently introduced aviation tax in Germany and Austria on passenger numbers at both domestic and bordering airports. They use passenger data from 310 airports across Europe between 2008-2016 in a dynamic panel difference-in-differences estimation to assess the short-run impacts of the flight departure tax on air travel. The tax reduced the number of passengers by 9 per cent in the year of introduction, and by 5 per cent in the subsequent year at Austrian and German airports. They find that these results are mostly driven by airports that predominantly serve low-cost airlines and contrary to Gordijn et al. (2011) and Borbely (2019), they find no significant impact of the tax on passenger numbers at airports across the border. In a similar vein, Krenek & Schratzenstaller (2016) examine how an efficient aviation tax is optimally designed. To avoid competition in aviation taxation and to limit cross-border carbon leakage, they reach the conclusion that a carbon-based flight ticket tax on an EU-level should be implemented.

Areas that are relatively isolated geographically appear to have more inelastic demand of air transport. Mayor & Tol (2007) study the impact of the aviation tax in the United Kingdom on passenger numbers and CO_2 emissions. They evaluate different policy proposals using different elasticity levels and estimate that a doubling of the aviation tax in the UK does not significantly impact passenger numbers in the UK. They find a substitution from short-haul to long-haul flights, as the price of long-haul flights is impacted relatively less with the increase in passenger tax. This in turn leads to an increase in emissions. A more recent UK study by Seetaram et al. (2014) confirms that the UK aviation tax was ineffective in reducing demand for air travel and that passengers were prepared to pay higher prices for flight tickets.

When considering changes in air passenger data related to the Swedish aviation tax, Ekeström & Lokrantz (2019) published a report on behalf of the Swedish Transport Agency. They find the number of passengers travelling to European countries to be less than was forecast. Yet, the number of passengers travelling to international non-European countries was higher than was forecast. This again shows the substitution towards long-haul flights. However, no statistical determination of the change in the number of passengers is made. Also in Sweden, Kopsch (2012) estimate short-run aggregated price elasticity of demand for domestic air travel at -0.84, whereas long-run elasticity is estimated at -1.13.

Other literature suggests that airline passengers have a relatively high willingness to pay (WTP)[4] for aviation carbon taxation. In this context, a customer's WTP indicates the highest tax they are willing to pay in addition to the ticket price. Seetaram et al. (2018) find that UK travellers' WTP for the air passenger duty tax (ADP) was in the range of £16-37 depending on flight distance and class (economy or business class). The highest WTP was for long-haul business class trips, whereas short-haul economy class trips had the lowest WTP. This in line with elasticity results in other studies, such as Brons et al. (2002). The WTP for short-haul trips was higher than the actual ADP at the time, while it was lower for long-haul journeys. In a similar study, Sonnenschein & Smedby (2019) report that more than 70 per cent of the respondents had a positive WTP to compensate for travel emissions. Again, absolute WTP was higher in the long-haul context than for short-haul journeys, but WTP per tonne CO_2 was significantly higher in the short-haul context. Choi & Ritchie (2014) and MacKerron et al. (2009) also find support among many airline passengers for carbon taxes. This suggests that some market segments have a high acceptability for carbon taxes on air travel, and that concerns of demand responses to ticket price increases may be exaggerated.

4.3 EU studies

In the context of the July 2021 revision of the ETD, a European Commission proposal for a council directive restructuring the Union framework for the taxation of energy products compares the possible impacts of a harmonised EU-wide fuel tax to the possible impacts of EU ticket taxes on aviation (European Union, 2021b). The study covers the whole of the EEA, namely the EU27 plus Norway and Iceland. In this study,

[4] WTP is the highest amount someone would be willing to pay for a good, service or attribute. WTP is derived in the valuation literature by directly asking consumers their WTP, through experiments or price differences across goods with different attribute

an aviation sector model and a macroeconomic model are applied. They examine the implementation of a fuel tax on intra-EEA aviation by applying three levels of taxation: the current minimum excise duty rate for kerosene as per the ETD, namely €0.33 per litre, a lower level of €0.17 per litre and a higher level of €0.50 per litre. The implementation of a kerosene tax on fuel loaded for intra-EEA flights results in emission reduction of of between 6 per cent and 15 per cent for intra-EEA flights, relative to the baseline, for tax rates from €0.17 to €0.50 per litre. While the fuel tax leads to a small improvement in aircraft fuel efficiency, the large majority of the reduction in emissions is due to a reduction in demand due to increased ticket prices. The impacts of the fuel tax and the consequent changes in demand reduce total GDP in the EU27 by approximately €9 billion (about 0.05 per cent) by 2050, under the assumption that revenues collected are used for deficit reduction purposes. The proposal also examines a passenger tax applying three different taxation levels: a flat tax of €10.43, a multi-rate passenger tax, which increases with distance flows (€10.12 for intra-EEA flights, €25.30 for extra-EEA flights up to 6,000 km and €45.54 for extra-EEA flights over 6,000 km) and a multi-rate passenger tax, which decreases with distance flows (€25.30 for flights up to 350km and €10.12 for flights over 350km). For the flat ticket tax, the reduction in demand is 9 per cent for intra-EEA flights and 1.5 per cent for extra-EEA flights. The increasing multi-rate option would result in a slightly lower impact on the demand for intra-EEA flights and a greater decrease in demand for extra-EEA flights (a 4.5 per cent reduction). The decreasing multi-rate results in slightly lower intra-EEA demand compared to the flat rate. In terms of emissions, the different ticket tax options lead to reductions of between 8 per cent and 10 per cent for intra-EEA flights and between 3 per cent and 5.5 per cent for extra-EEA flights.

Fageda & Teixido-Figueras (2020) examine the impacts of the EU ETS system on the supply of air passenger travel. They find that low-cost airlines reduced seat availability by 7.4 per cent relative to the counterfactual of aviation not being included in the EU ETS. These impacts increase to 21 per cent when only short-haul flights are considered. This is due to the availability of alternative means of transport, such as high speed trains. Results suggest that network airlines have increased the average size of aircraft on short-haul flights in response to the scheme to reduce costs. Larsson et al. (2019) conclude that the EU ETS and CORSIA initiatives have only marginal effects on carbon emissions from Swedish air travellers.

4.4 Irish studies

As discussed, Ireland currently does not impose a passenger tax, but the Irish Air Travel Tax (ATT) was enforced between March 2009 and April 2014. Veldhuis et al. (2009) published a report commissioned by Aer Lingus, Ryanair and CityJet regarding the implications of the ATT. Using airline data and assumptions concerning the price elasticities of demand for flights, they estimate the impacts of the ATT on the revenue of airlines, airports, tourism and the government. They conclude that impacts will be high, outweighing the ATT income four-fold. The Veldhuis et al. (2009) report applies scenarios assuming the tax is absorbed by airlines or passed on to consumers. In both cases impacts are significant. When the ATT is fully passed on to the consumer, airlines face revenue losses of €87 million, airports face losses of €26 million and the tourism industry of €224 million as a results of the tax. When the tax is partially absorbed, losses for airlines are estimated at between €60 million and €114 million, at €38 million for airports, and €330 million for the tourism industry, whereas ATT revenues are estimated at between €117 million and €124 million.

The methodology applied in Veldhuis et al. (2009) has significant drawbacks. Firstly, the impacts on passenger demand are derived by applying a generic estimate of price elasticity, which is likely to overestimate the Irish price sensitivity given the lack of alternative transport modes for island states. The loss of revenue to airlines is then calculated by multiplying the reduction in demand by the average ticket price. This ignores any costs reductions for the airlines resulting from fewer passengers. The revenue losses for airports are calculated in much the same way where the change in demand is multiplied by the average passenger charge and parking fares. This again ignores any costs reduction due to fewer passengers. Many costs of flying a plane and maintaining an airport are fixed, though not all. Fewer passengers would result e.g. in lower cleaning fees or water usage. The largest impact in this study is found for the tourism sector, where the change in incoming non-Irish passengers is multiplied by the average length of stay of a tourist and the average daily expenditure. This would highly exaggerate impacts, where it is assumed that all incoming passengers are tourists. A significant portion of these passengers could be expected to be non-Irish citizens living in Ireland, business travellers or minors travelling with parents (hence without a daily expenditure). Regarding government revenue and job losses, bold assumptions are again made concerning how reduced revenues will result in job losses and reduced tax income for the government. Overall, the methods applied in this report exaggerate the impacts of the ATT.

Faber & Huigen (2018) examines several aviation taxation scenarios for Ireland (note that Veldhuis et al. (2009) was also written by consultants at CE Delft. They apply a partial equilibrium model. Using the price elasticity of demand, demand impacts are estimated. The change in demand results in a change of supply, i.e. the number of flights changes and connectivity changes as a result. This also has an impact on noise and emissions. The change in demand causes a change in output of the aviation sector which has an impact on direct and indirect jobs and value added. This impact is calculated by an input-output analysis. The change in fiscal revenue also has an impact on the output of other sectors, which has an impact on jobs and value added. Together, these impacts cause a change in GDP.

In the first scenario a ticket tax is introduced with the same structure and level as the German Air Transport Tax. The average ticket price rises by €7.47, corresponding to a 5 per cent increase. As a result, both the number of passengers and the number of flights decrease by 5 per cent. In turn, both the number of direct jobs and value added of the aviation sector fall by 5 per cent. However, this is compensated by an almost equal increase in jobs in other sectors of the economy, so the net effect on employment is close to zero. The fiscal revenue resulting from the introduced ticket tax is €183 million and CO_2 emissions also decrease by 5 per cent, and the number of people affected by noise by 4 per cent.

In the second scenario, a VAT rate is applied that is based on the standard VAT rate on international transport tickets in Ireland, which is 19 per cent. The resulting number of flights declines by 20 per cent.

This leads to a reduction in the number of direct jobs and the value added by the aviation sector of 21 per cent, although the overall effect nationally on jobs and GDP is negligible. The introduction of the VAT results in a total fiscal revenue of €708 million. The reduction in CO_2 emissions is 20 per cent. In the third scenario, the introduction of a fuel excise duty of 330 €/kilolitre causes the average ticket price to increase by 8 per cent. The number of flights and passengers decline by 8 per cent, as do the CO_2 emissions. The fiscal revenue amounts to €299 million. The relative reduction of the number of direct jobs and the value added by the aviation sector is 9 per cent for both. The methodology applied in this report is more robust than that of Faber & Huigen (2018). Again a generic international price elasticity is applied for Ireland. However, the corresponding impacts are calculated applying an input output analysis, which results in a more robust estimation of economic impacts. There is a clear difference in the expected impacts across these reports due to the methodological differences, where Faber & Huigen (2018), estimates negligible macroeconomic and employment impacts.

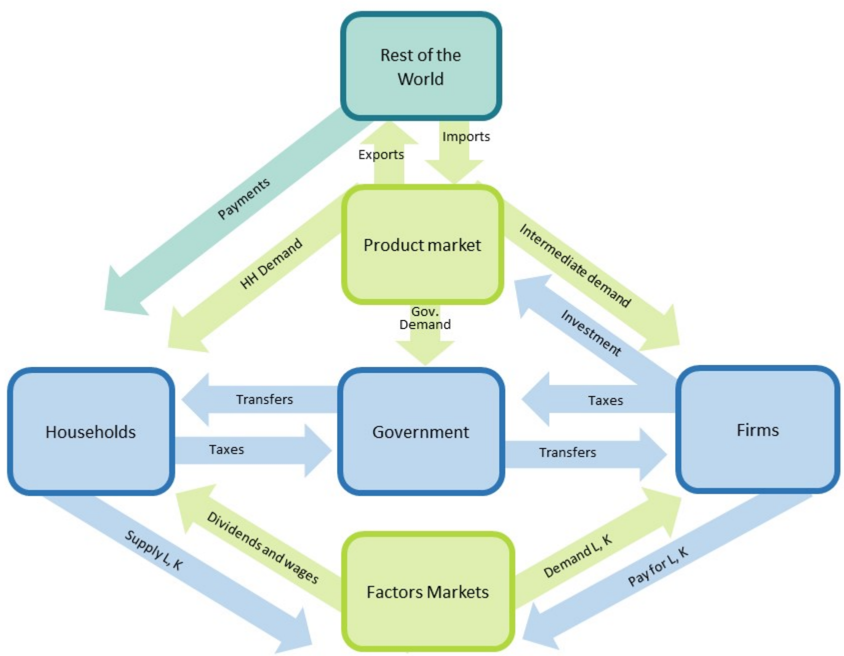
In this report, we will apply a Computable General Equilibrium (CGE) model for Ireland, namely I3E. Applying a CGE has several advantages over the methods applied in the past to examine aviation taxation in Ireland. Firstly, we do not need to assume a generic price elasticity but directly model the impacts of consumer/producer choice and the first (travel vs non travel) and third level (travel modes) substitutabilities (as discussed in Section 3). When an aviation taxation policy is introduced in the model, this changes aviation prices as well as all other prices in the model due to its general equilibrium nature. Furthermore, the aviation policy also has impacts on household income. The I3E model includes all these mechanisms, which result in a demand change of aviation services. In other words, based on the substitution elasticities in the I3E model, it creates a more realistic Ireland specific demand response as a result of the introduced aviation taxation, without assuming a price elasticity. This will allow for a better estimation of demand responses to changes in ticket prices and freight transport costs. Secondly, a CGE model is able to distinguish between different forms of aviation taxation and mechanisms through which taxation impacts behaviour. In Faber & Huigen (2018), all taxation scenarios lead to impacts via changes in ticket prices only. Furthermore, all emissions reductions come from reduced passengers only. A fuel tax or reduced EU ETS permits would incentivise airlines to become more energy efficient where possible. A CGE model can account for this and model how consumers, producers and airlines respond to the taxation. Most importantly, the I3E model represents the interconnection of all sectors in the Irish economy and can give a robust estimation of the economic and employment impacts of aviation taxation throughout the economy and in terms of government revenue. Unlike an input output analysis, where producers and consumers are assumed to not change their behaviour, I3E takes the behavioural changes of producers and consumers into account. Finally, in the above mentioned studies, it is assumed that the reduced spending on air tickets due to reduced air transport demand is not used elsewhere in the economy, significantly increasing estimated impacts of taxation. When consumers use less air transportation, this will reduce economic activity in the air transportation sector. However, consumers will shift their consumption to other goods and services, increasing economic activity in other sectors of the economy. In the I3E framework, we take into account how consumers and producers spend or save all their income and can examine the general equilibrium impacts. We are also able to take into account other policies such as the Irish carbon tax.

5 The I3E model

5.1 Introduction

This analysis applies the Ireland Environment, Energy and Economy model (I3E). The I3E model is an intertemporal computable general equilibrium (CGE) model, which reproduces the structure of the economy in its entirety. It includes productive sectors, households, and the government, among others. In the model, the nature of all existing economic transactions among diverse economic agents is quantified. According to microeconomic behaviour, producers/consumers maximise their profits/utility given their budget constraints. In other words, a CGE model examines how inputs and outputs flow between production sectors of the economy and, finally, result in final goods consumed by households. Figure 5.1 gives an overview of the interlinkages in the I3E model. The technical details of the model are available in de Bruin & Yakut (2021b).

Figure 5.1: Interlinkages within the I3E model



The explicit modelling of sectoral inter-linkages makes it possible to investigate the wider economic impacts of a specific shock or policy through the different transmission channels in the economy. In this report, this would mean the increased costs of aviation would spill over to production sectors dependent on aviation for the transportation of goods as inputs to their production or as exports. The I3E model can analyse the welfare and distributional impacts of an aviation tax, whose effects may be transmitted through multiple markets and channels in the economy. Due to the level of detail in the I3E model, it is possible to simulate specific policies, e.g. taxes on aviation fuel, taxes on flights, reduction of free ETS permits of aviation.

5.2 Agents

The main agents (decision-makers) in the I3E model are households, production sectors and the government. We briefly discuss each in turn.

A CGE model's household sector consists of Representative Household Groups (RHGs). A RHG represents all households with one or several common characteristics. In the I3E model, the household sector is first divided into two major groups based on the area of residence of households: urban RHGs and rural RHGs. Subsequently, each of these major groups is further disaggregated into five RHGs according to household disposable income. Households make their decisions based on the maximisation of their utilities in an intertemporal manner subject to their budget constraint. RHGs take various issues into account in their decision-making process, including the valuation of tomorrow relative to today (time preference rate), the future values of commodity prices and the interest rate, and economic growth. Each household chooses the optimal level of consumption in the utility maximisation process, and its savings are determined as a residual, i.e. what they do not spend, they save. The budget constraints of RHGs equate the disposable income – the sum of wage income, dividend income, welfare transfers and pension income from the government, and net factor income from abroad – to the sum of total consumption expenditures and savings. The equilibrium between total income and expenditures must hold in every period of time.

The production sector comprises 37 representative activities/firms. The main data source to replicate intersectoral linkages in the Irish economy is the Supply and Use Tables (SUTs) provided by the Central Statistics Office (CSO). The original SUTs comprise 58 industries and provide information on which products an industry produces, the monetary value of production of each product, the cost of intermediate inputs, the value of gross value-added (payments to the factors of production), production taxes paid to the government, etc. These production sectors are first merged into 29 sectors based on their shares in total value-added, employment and emissions. Subsequently, three sectors (Mining, Quarrying, and Extraction; Petroleum, Furniture and Other Manufacturing; and Electricity and Gas Supply) are further disaggregated, and the total number of activities reaches 37.[5] Activities determine the level of physical investment, i.e. additions to their physical capital stock, by maximising the value of the firm in an

[5] Mining, Quarrying, and Extraction sector is disaggregated into two sectors; Peat and Other Mining. Petroleum, Furniture, and Other Manufacturing is also divided into Petroleum and Other Manufacturing. Electricity and Gas Supply sector is first disaggregated into Electricity and Gas sectors and, subsequently, the former sector is further disaggregated into Electricity, Wind and Other Renewables sectors.

intertemporal manner. The composition of each firm's energy demand across energy commodities is based on the nature of the production process. Some sectors do not have an opportunity to switch their energy demand from one energy commodity to another, whereas some sectors can substitute an energy commodity for another at different degrees of substitutability. In order to introduce heterogeneities across sectors in terms of their ability to switch between energy inputs, three different substitution elasticities, i.e. degrees of substitution, are defined, and each firm is uniquely assigned to a group.

The I3E model has an explicit representation of the government sector. The government collects direct taxes on labour incomes and sectoral profits (corporate tax), indirect taxes on sales of commodities, the carbon tax on energy commodities, the export tax on exported electricity, production tax on production activities, and half of the cost of ETS due to the EU legislation. The carbon tax, which is exogenously determined by the government, is implemented as a fixed price of per-tonne equivalent of carbon and collected on the domestic consumption of energy commodities. The government allocates its total revenues to the consumption of commodities, welfare transfers and pension payments to households, and interest payments over the outstanding foreign debt stock. The total welfare transfers is positive functions of unemployment rate and consumer price index, and the total pensions is fixed in real terms and adjusted by inflation. The total government consumption on commodities has an autonomous part which is fixed in nominal terms, and an induced part which is a positive function of the current period's nominal gross domestic product. This structure indicates that Irish fiscal policy is pro-cyclical and is consistent with the previous findings of Cronin & McQuinn (2018). The difference between total revenues and expenditures, i.e. public saving drives changes in the foreign debt stock, i.e. as public saving increases (decreases), the government debt stock becomes lower (higher).

The detailed government account is an essential characteristic of a CGE model due to the fact that a change in the structure of the economy has repercussions on the government budget and thus income distribution and welfare, even if there is no change in any policy variable controlled by the government. For instance, changes in the composition of private demand change the tax collection of the government over the consumption of commodities. Each policy option of the government, such as higher carbon tax, lower subsidies on fossil fuels, ceasing of fossil fuels, subsidising investments on cleaner energy sources - among others - has differentiated effects on the overall economic activity, profits of firms, employment, household welfare, etc. Analysing the potential implications of each of these options, solely or jointly, requires a detailed government account.

5.3 Energy

The I3E model includes energy flows and emissions in addition to the standard monetary flows. Each production sector produces an economic commodity using labour, capital, material inputs and energy inputs. The I3E model explicitly comprises a set of carbon commodities, including peat, coal, natural gas, crude oil, fuel oil, LPG, gasoline, diesel, kerosene, and other petroleum products.

Production activities produce commodities in the cheapest way possible by using the optimal set of capital, labour, energy and other intermediate inputs, based on both relative prices and substitution possibilities. When an additional tax is implemented, production sectors will, where possible, substitute the more expensive inputs for other inputs. The explicit inclusion of carbon commodities and emissions makes it possible to evaluate the emissions reduction associated with a specific policy. A distinction is made between emissions that fall under the EU ETS system (and are hence exempt from Irish carbon taxes) and non-ETS emissions which fall under the carbon tax. I3E explicitly models free ETS emission permits received by each production sector. If a production sector emits more ETS emissions than its permits, it will need to buy permits from the EU ETS market. If it consumes less, it can sell permits on the market. The activities that fall under the EU ETS directly internalise any change in the EU ETS, such as the sequence of free allowances or the price of EU ETS permits, and alter their cost-minimising set of capital, labour, energy and other intermediate inputs.

5.4 Dynamics

I3E is a dynamic model, which incorporates economic growth over the modelling horizon which runs from 2014 to 2050. Economic growth originates from three sources: the growth of employment driven by population growth, the growth in capital stock driven by investment, and the growth in total factor productivity or productivity of factors of production. It is assumed that the total population grows at a constant rate and the technology, i.e. the productivity of labour force, also grows at a constant rate. In the current version, the values of population growth and economic growth are retrieved from the medium-run estimates of the macro-econometric forecast model of the ESRI, namely COSMO (COre Structural MOdel for Ireland).

6 Aviation taxation and carbon pricing scenarios

In the analysis we examine four aviation taxation scenarios. Firstly, we investigate the kerosene taxation exemption removal as recently proposed by the EU. Secondly, the removal of free ETS allowances for the aviation sector by 2026 as set out in the proposed revisions to the ETS directive are investigated. These two scenarios form the EU policy proposals, which the aviation industry will likely face in the near future. Thirdly, a passenger tax is investigated applying several levels. Finally the removal of the VAT exemption for aviation services is examined. This is a policy that is not likely to come into place in the medium term, but can give insights into the implications if it were to be introduced. Here we discuss the common assumptions across all scenarios concerning the carbon tax path and the COVID-19 crisis impacts on the aviation sector, after which we discuss the different taxation options included in our analysis.

6.1 Common assumptions

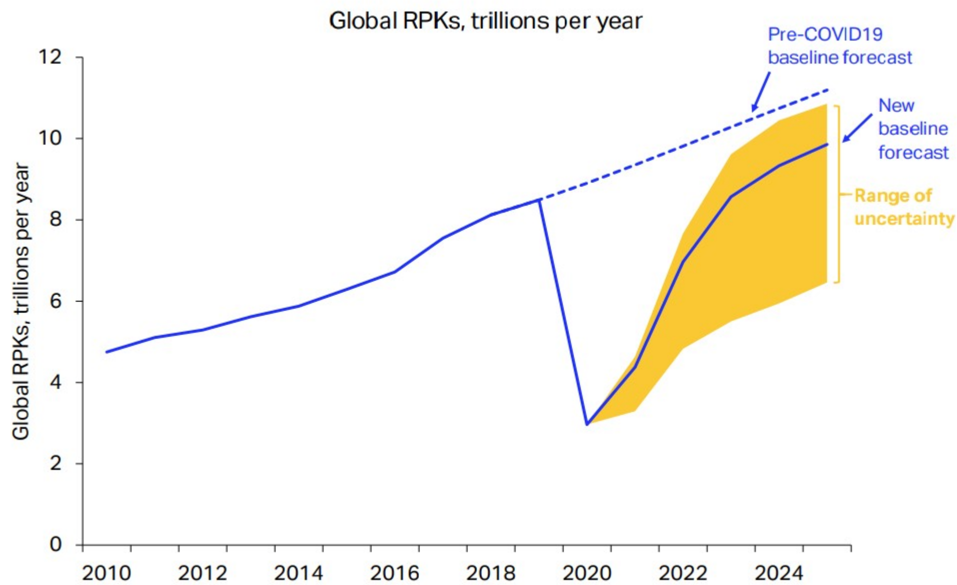
In all scenarios, we assume the carbon tax follows the path announced in the Programme for Government 2020 and reaches €100 per tonne in 2030 (Department of the Taoiseach, 2020). This constitutes an important climate policy and will affect the impacts of aviation taxation. Concerning the ETS, we assume the ETS price remains at its 2020 level of €32 per tonne. Given the recent movements in EU ETS policies under the 'Fit for 55' package, the ETS price has risen sharply over 2021 (reaching a level of above €65 per tonne in July 2021). The assumption of a constant ETS price is unrealistic, where high increases are expected in the future. Given the uncertainty of the exact increase in ETS, we assume a price of €32 per tonne, consistent with the EU 2020 reference scenario. In the results section we investigate the impacts with an illustrative increase in ETS price (reaching €100 per tonne by 2030) for the *CT*, *ETS_26*, and *KRSEX_ETS26* scenarios. This increase reflects a more realistic assumption of the development of the ETS price. All scenarios include the impacts of the COVID-19 crisis, which includes impacts on production sectors, export demand, and government transfers to households as described in Appendix B. Here we highlight the assumptions concerning the impacts for the aviation sector. To estimate the impacts of the COVID-19 crisis on aviation in 2020, we apply CSO data for flights and passengers arriving and departing from Irish airports (CSO, 2021b). Compared to 2019, there was a 65 per cent decrease in flights in 2020, a 78 per cent decrease in passengers, and a 5 per cent decrease in freight transported. Examining the impacts on the largest Irish aviation companies, we see similar decreases in revenue of between 70 per cent and 80 per cent (Ryanair, 2021; International Airlines Group, 2021).

The future impacts of the COVID-19 crisis are highly uncertain, particularly for the aviation sector. Though international travel has restarted, restrictions are expected to stay in place for some time (e.g. pre-departure COVID testing and self quarantine). People have also become more cautious concerning foreign travel, which is likely to limit the pick-up in demand. The International Air Transport Association (IATA) has published projections of the impacts on global aviation, and the DAA (previously the Dublin Airport Authority), which operates Dublin and Cork airports in Ireland, has estimated impacts on Irish flights. These projections show similar trends with an initial sharp recovery followed by a steady increase in aviation reaching pre-COVID levels in 2025. Figure 6.1 shows the global recovery path as estimated by IATA. Consistent with these estimates, we assume a sharp recovery with a steady increase reaching pre-COVID levels by 2025.

6.2 Removal of excise exemption for aviation fuels

The 1944 Chicago Convention on International Civil Aviation, article 24, prohibits taxing fuel arriving to an airport on a plane (ICAO, 2006). However, this does not include fuel taken on board while grounded. For the latter, the 2003 Council Directive 2003/96/EC, or Energy Taxation Directive (ETD) applies, which states that EU Member States must exempt aviation fuel from taxation for intra-EU, and extra-EU flights (European Union, 2003). The Irish Kerosene excise exemption resulted in an effective subsidy of €460 million in 2014 (the base year of I3E), this exceeds the total carbon tax collection for the same year

Figure 6.1: IATA forecast of global revenue passenger kilometres



Source: **IATA/Tourism Economics Air Passenger Forecast January 2021**

by approximately €70 million. The revisions proposed (which still need to be negotiated with Member States and the European Parliament) in July 2021 to the ETD, would result in the taxation of kerosene from 2023. This would be introduced by applying an increasing taxation level, reaching €10.75 per gigajoule by 2033, this corresponds to approximately €131 per tonne of carbon or €0.33 per litre. To compare, the current level of excise and carbon taxation on a litre of gasoline is €0.62 (of which 12.5 per cent is carbon taxation). In the scenario *KRS_EX*, we remove the kerosene taxation exemption in line with the EU proposed revision of the ETD.

6.3 Removal of free allowances for aviation under the EU ETS

The July 2021 proposed revisions of the ETS Directive would eliminate free allowances to the aviation sector by 2026. In the EU ETS scenario (*ETS_26*), we implement a gradual decrease in free allowances resulting in zero free permits by 2026.

6.4 Passenger taxes

Motivated by the climate crisis, some EU Member States have bypassed the ETD exemptions by levying taxes on domestic air travel and applying taxes/fees to air passengers. As previously discussed, a range of such taxes is applied within Europe. As discussed in Section 4 the proposal for revision of the ETD investigates the impacts of a flat rate of €10.43 for all passengers, an increasing multi-rate passenger tax (€10.12 for intra-EEA flights, €25.30 for extra-EEA flights up to 6,000 km and €45.54 for extra-

EEA flights over 6,000 km) and a decreasing multi-rate (€25.30 for flights up to 350km and €10.12 for flights over 350km). Applying the increasing multi-rate for Ireland would result in an approximate average passenger tax of €14 and the decreasing multi-rate in an approximate average passenger tax of €12. For illustrative purposes we implement a passenger tax at three levels. In *PT_5*, we implement a €5 passenger tax on outgoing flights; this represents the lowest levels currently implemented within the EU. In *PT_16*, we implement a €16 passenger tax, which is consistent with the average of all passenger taxes levied within the EU and UK. In *PT_UK*, we implement a passenger tax at the same level as the UK, which represents the highest level within Europe. The average level of passenger tax in the UK is approximately €40, where taxes range from €14 to €170 depending on the flight destination and class. We have applied the rates based on destination and class to the 2019 Irish flights. Given that a larger share of UK flights are to further destinations (outside the UK and EU) than is the case with Irish flights, the calculated average tax for Ireland applying the UK aviation tax system is lower at approximately €29.

6.5 Removal of Value Added Tax (VAT) exemption for aviation services

In line with the EC directive on the common system of Value-Added Tax (2006/112/EC)23, currently no Member State levies VAT on international air passenger fares (European Union, 2006). However, because it falls under a single jurisdiction, domestic air transport is often subject to VAT. In Ireland, no VAT is charged for aviation services. We develop two scenarios in which the VAT on aviation services steadily increases to reach the service VAT rate of 13.5 per cent. In the first scenario *VAT_25*, the VAT rate reaches 13.5 per cent in 2025; in the second scenario *VAT_30*, the VAT rate reaches 13.5 per cent in 2030.

6.6 Explicit tourism impacts

A significant share of demand in the accommodation and food and beverage service sectors (ACC) consists of demand by foreign tourists. To investigate these potential impacts, we implement additional explicit tourism impacts in several scenarios. In these scenarios, we estimate the impacts on ACC demand of a reduction in tourist arrivals. We implement these tourism impacts into five scenarios, namely EU ETS free allowance abolishment in 2026, scenario (*ETS_26*); the VAT introduction by 2030 scenario (*VAT_30*); the passenger tax of €16 scenario (*PT_16*); the kerosene taxation (*KRS_EX*); and the kerosene taxation with abolition of free ETS allowances (*KRSEX_ETS26*). These scenarios are discussed in more detail in Section 7.2.

6.7 Overview of scenarios

An overview of the scenarios is given in Table 6.1. Besides the scenarios described above, a combination scenario (*KRSEX_ETS26*) has been modelled combining the recent EU proposals of taxation on kerosene (*KRS_EX*) and the abolishment of free allowances to aviation under the EU ETS scheme (*ETS_26*). This combination scenario represents the increased taxation the aviation industry will face in the short term at an EU level. Note that in all policy scenarios, the level of the carbon tax gradually increases, reaching €100 per tonne in 2030.

Table 6.1: Scenario definitions

Scenario	**Overview**	**Policy Relevance**
CT	Includes key realisations between 2014 and 2021, COVID-19 impacts (see Appendix B for further details), and a constant EU ETS price. Carbon Tax follows the path announced in the Government Plan 2020 and reaches €100 in 2030.	Main scenario against which results are compared.
KRS_EX	Kerosene excise duty exemption is abolished and kerosene is taxed at the EU proposed minimum rate.	Proposed measure set out in the EU 'Fit for 55' package.
VAT_25	Value Added Tax (VAT) is gradually introduced reaching 13.5% in 2025.	Aviation is exempt from VAT in the EU. There is no proposal to change this currently. This scenario is illustrative of the impact of alternative aviation pricing methods.
VAT_30	VAT is gradually introduced reaching 13.5% in 2030.	Aviation is exempt from VAT in the EU. There is no proposal to change this currently. This scenario is illustrative of the impact of alternative aviation pricing methods.
ETS_26	Free EU ETS allowances for aviation are abolished by 2026.	Proposed measure set out in the EU 'Fit for 55' package.
PT_5	A passenger tax of €5 is applied to all departures.	This represents the lowest level of passenger tax in the UK and EU and a similar rate to the Irish Air Travel Tax before its abolition in 2014.
PT_16	A passenger tax of €16 is applied to all departures.	This represents the average rate of passenger tax applied across the UK and EU.
PT_UK	A passenger tax of €29 is applied to all departures.	The average level of passenger tax in the UK (which represents the highest in Europe), adjusted to the Irish profile of flights (shorter distances) for 2019.
KRSEX_ETS26	A combination of the Kerosene Exemption Abolition and ETS_26 scenario discussed above.	Both of these measures are proposed in the EU 'Fit for 55' package and are likely to be implemented together. Therefore, this represents the most likely scenario to emerge over the medium term.

7 Results

This section presents the results of the scenarios described in the previous section. Firstly, the impacts on the aviation sector are discussed, after which spillover effects to other production sectors are presented, with a focus on tourism. Government revenue and macroeconomic impacts are discussed next. Finally, household and emission impacts are presented. Throughout this section, results are displayed as percentage differences compared to the *CT* scenario, where a carbon tax trajectory is included. In this way, the incremental impact of each aviation taxation scenario is shown. The results can be interpreted as cumulative impacts, where a percentage change in e.g. 2030 does not represent an annual change, but the change by 2030 compared to no policy change. This is the accumulation of smaller annual impacts over almost a decade.

7.1 Impacts on the aviation sector

To assess the impacts on the aviation industry, we examine the changes in aviation value-added (VA) for the different taxation scenarios. Value-added represents the difference between the total input costs and the sales revenue of the sector and corresponds to the profits and payments to capital, labour and taxes of the aviation industry. Hence, VA captures the impacts on the aviation sector of both price changes and of demand changes due to aviation taxation.

Figure 7.1: Percentage change in aviation value added compared to CT over scenarios

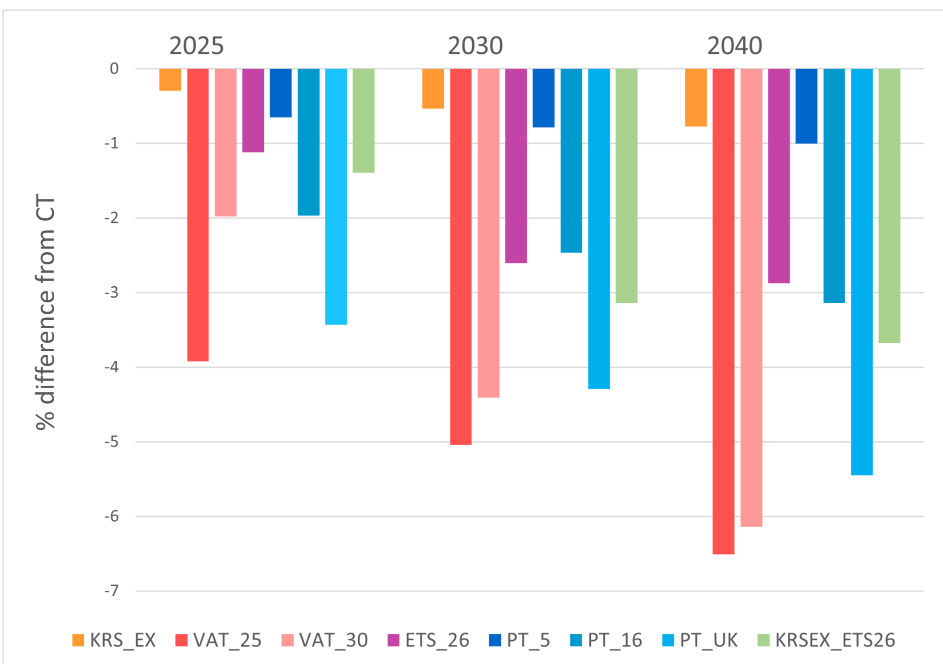
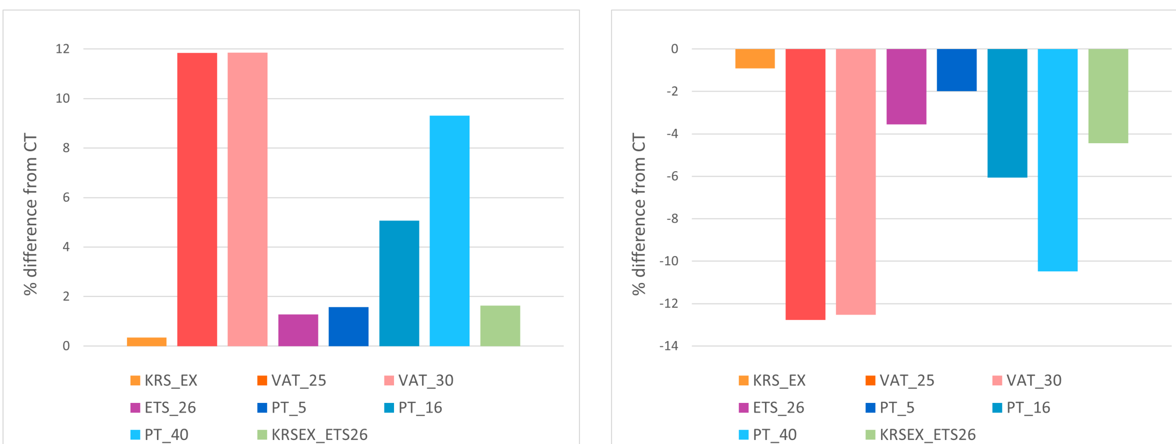


Figure 7.1 shows the change in real (adjusted to the price level) value-added (VA) for the various taxation scenarios. As this figure shows, implementing a VAT has the largest impacts on aviation VA

(*VAT_25* and *VAT_30*). Comparing these two scenarios, a more gradual implementation of the VAT decreases the negative impacts on VA, even in the long run. Though the implementation of VAT is unlikely in the medium term, it forms a good comparison in terms of the level of taxation that the other scenarios represent. In other words, compared to a VAT level of 13.5 per cent, the other forms of taxation have less impacts. The second-largest impacts are found in the higher level passenger tax scenarios (*PT_16* and *PT_UK*). The impacts of an abolishment of free ETS allowances (*ETS_26*) are also significant. The impacts of a low level of passenger tax (*PT_5*) and the removal of the kerosene excise exemption (*KRS_EX*) have relatively small impacts. The combination of removing both kerosene excise and ETS free allowances (*KRSEX_ETS26*) results in higher impacts than when each is introduced on its own ((*KRS_EX*) and (*ETS_26*)). This highlights the importance of considering multiple taxation schemes that may be implemented simultaneously. Note again that this combination scenario represents the policies proposed by the EU to be implemented in the short term. The impacts across scenarios vary over time depending on the timing of the introduction of tax. For example the impacts of *VAT_30* are relatively small in 2025 but increase significantly after 2030. This confirms the importance of the timing of policies and the importance of well designed policies giving the aviation industry time to adjust.

Figure 7.2: Percentage change in price and demand for aviation output compared to CT scenario in 2030



(a) Retail price **(b) Total demand**

Figure 7.2 shows the corresponding changes in demand for aviation services and prices of aviation services for the various scenarios in 2030. As aviation taxation is implemented the prices of aviation services increase, resulting in a decrease in demand for aviation services. We see that prices increase up to 12 per cent in the VAT scenarios. As the price change drives the impacts, the scenarios that show the highest price changes also show the highest VA impacts for the aviation sector. Demand decreases in response to the increased price, however, this decrease is relatively low. This is in line with the literature that suggests a low price elasticity due to the lack of adequate substitutes for aviation services on an island (Brons et al., 2002). Compared to Faber & Huigen (2018), which examines the implementation of VAT in aviation and a passenger tax, we find that resulting price changes are relatively lower (albeit a small difference), as the aviation industry does not pass on all the additional tax costs to consumers, but reduces prices to limit the decrease in demand. Furthermore, our results show lower impacts on aviation VA, this is due to both the behavioural responses of firms and the general equilibrium effects included in the I3E model and not in the static analysis of Faber & Huigen (2018). Compared to the analysis undertaken in the EU ETD proposal, we find smaller impacts on demand for the Irish case compared to their EU wide analysis. This is due to the lack of travel mode substitutes (Brons et al., 2002).

7.2 Sectoral spillovers and tourism impacts

Aviation taxation will have spillover effects to other sectors in addition to the aviation sector. Spillover effects are a result of the interconnection of production sectors or changes in consumer demand due to price changes. Spillover effects due to the interconnection of production sectors are the result of either the dependence of a sector on aviation services inputs to their production or the dependence of a sector on aviation services purchasing their output. In the former case, as aviation services prices increase, the sector's input costs will increase. In the latter case, as the aviation industry's output shrinks, it demands fewer inputs from the sector, in turn reducing the sector's output. Due to the substitution structure of consumer demand, as prices in the economy change due to aviation taxation, consumers adjust their consumption bundles to maximise their utility, i.e. they substitute higher priced goods for lower priced alternatives. The spillover effects to most sectors are limited, where fractions of a percentage change are seen. However, several sectors face significant impacts; our discussion focuses on these sectors.

Several production sectors are impacted due to their relatively high share of inputs to the aviation sector. As the aviation sector's activity is reduced, their demand for inputs reduces, impacting these sectors that deliver inputs to aviation. The percentage changes in VA of the most affected sectors are given in Table 7.1. The petroleum sector (PET) delivers fuel to aviation, warehousing (OTR) delivers services to aviation, aviation demands machine repair and installation services (OIN), and finally travel and tourism services (ADS) are delivered to aviation. The highest impacts among these sectors are seen in the petroleum sector as kerosene sales to aviation are a large part of this sector's output. In the case of the removal of the kerosene excise exemption, we find even larger relative impacts for the petroleum sector (PET) than other sectors. As kerosene is being taxed in this scenario, which the petroleum sector delivers and to a small degree produces, the petroleum sector bears a larger share of the costs than in other scenarios.

Several sectors also rely on aviation inputs into their production and, as the price of aviation increases, their costs of production will increase. This is the case for rental and leasing services, which is in the ADS, and transportation equipment (TRE) sectors.

Concerning other transportation (land transportation (LTS) and water transportation (WTS)), consumers substitute aviation with these forms of transportation as aviation prices increase, increasing the relative share of these in total transportation demand. However, this substitution effect is small in Ire-

Table 7.1: Real Value-added of selected sectors, % deviation from CT

Year	Scenario	PET	LTS	WTS	OTR	TRE	OIN	ADS
2025	KRS_EX	-0.12	-0.02	-0.02	-0.03	-0.02	-0.01	-0.06
	VAT_30	-0.34	-0.36	-0.13	-0.15	-0.15	-0.06	-0.46
	ETS_26	-0.15	-0.02	-0.01	-0.04	0.01	0.01	-0.02
	PT_16	-0.33	-0.44	-0.18	-0.17	-0.13	-0.06	-0.22
	KRSEX_ETS26	-0.27	-0.04	-0.02	-0.06	-0.01	0.00	-0.09
2030	KRS_EX	-0.22	-0.04	-0.04	-0.05	-0.04	-0.03	-0.06
	VAT_30	-0.70	-0.95	-0.35	-0.36	-0.27	-0.13	-0.45
	ETS_26	-0.33	-0.09	-0.03	-0.13	-0.01	-0.01	-0.02
	PT_16	-0.39	-0.48	-0.18	-0.19	-0.13	-0.06	-0.22
	KRSEX_ETS26	-0.58	-0.14	-0.39	-0.49	-0.05	-0.03	-0.09
2040	KRS_EX	-0.32	-0.07	-0.07	-0.19	-0.05	-0.04	-0.06
	VAT_30	-0.98	-1.21	-0.43	-0.46	-0.31	-0.16	-0.45
	ETS_26	-0.37	-0.11	-0.03	-0.15	-0.02	-0.02	-0.02
	PT_16	-0.49	-0.57	-0.20	-0.23	-0.15	-0.08	-0.21
	KRSEX_ETS26	-0.74	-0.19	-0.09	-0.22	-0.07	-0.05	-0.09

Note: The acronyms for sectors are as follows: PET Petroleum, LTS Land Transportation, WTS Water Transportation, OTR Other Transportation, TRE Transportation Equipment, OIN Other Industry, and ADS Administration and Support Services. The corresponding NACE codes are available in Appendix A.

land, where the share of non-aviation transport in total transport increases in the most stringent taxation scenario from 70 per cent to 73 per cent. Hence, as aviation transportation prices rise, consumers reduce their demand for all transportation types, resulting in (albeit small) decreases in VA for LTS and WTS.

An important concern regarding the introduction of aviation taxation is its impacts on the tourism industry. The tourism sector is reliant on tourists from abroad, who most often arrive in Ireland by plane. The impacts on travel and tourism services have been discussed previously. However, the I3E model does not include an explicit mechanism to capture the impacts of a reduction in tourist arrivals on the tourism sector in terms of tourist spending on other goods and services. In other words, demand for goods in the economy is not linked to international arrivals. However, in reality, a significant share of demand consists of demand by foreign tourists. To investigate these potential impacts, we implement several additional tourism scenarios. In these scenarios, we estimate the percentage reduction in tourist arrivals (this includes business travellers) due to a decrease in aviation demand. Further, the CSO estimates the expenditures by overseas travellers, allowing us to calculate the decreased spending due to decreased tourist arrivals. The bulk of these tourist expenditures (66 per cent) fall under expenses for accommodation and food and beverage services covered by NACE 55 and 56 (Fáilte Ireland, 2019). These sectors together represent the Accommodation and Hotel Services (ACC) sector in the I3E model. In the following tourism scenarios, we directly implement a reduction in demand in the ACC sector as a result of decreased international arrivals. Through this, we can gain a better understanding of the impacts of aviation taxation on tourism. This method, however, does not account for the potential and likely increase in domestic tourism expenditures as flight tickets to abroad become more expensive.[6] We implement these tourism impacts to five scenarios, namely: EU ETS free allowance abolishment in 2026, scenario (*ETS_26*); the VAT introduction by 2030 scenario (*VAT_30*); the passenger tax of €16 scenario (*PT_16*); the kerosene taxation (*KRS_EX*); and the kerosene taxation with abolition of free ETS allowances (*KRSEX_ETS26*). The impacts on the ACC are given in Table 7.2. In the most stringent scenario (*VAT_30*), VA is reduced by just over 1 per cent in 2030. Compared to Veldhuis et al. (2009), we find much lower impacts on tourism. In their study they find that losses to tourism in nominal terms are twice the size of the impacts in the aviation sector. We find that impacts on the ACC sector are significantly lower than that of the aviation sector in both percentage and nominal terms. This difference is due to the simplistic assumptions made in Veldhuis et al. (2009) as described earlier.

Table 7.2: Real value-added of ACC sector, % deviation from CT

	2025	2030	2040
ETS_26 with tourism impacts	-0.09	-0.76	-0.67
VAT_30 with tourism impacts	-0.40	-1.11	-1.24
PT_16 with tourism impacts	-0.52	-0.59	-0.60
KRS_EX with tourism impacts	-0.09	-0.21	-0.29
KRSEX_ETS with tourism impacts	-0.29	-0.90	-0.93

Though these secondary spillover effects seem small when we examine them by sector, the total of these impacts can be large. As an example, in the (*VAT_25*) scenario aviation VA is reduced by approximately 5 per cent in 2030 relative to the CT scenario; the secondary impacts on the petroleum sector are a 0.8 per cent reduction, a 1 per cent reduction in land transportation and a 1.1 per cent reduction in the accommodation sector, all relative to the CT scenario. To fully understand the extent of the spillover effects, we need to investigate the impacts over all sectors simultaneously, which we do in the next section by discussing the impacts of aviation taxation on GDP.

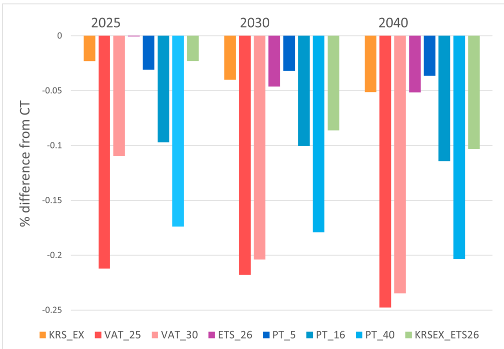
7.3 Macroeconomic impacts

Though aviation taxation will mainly impact the aviation sector, as we saw in the previous section, secondary impacts affecting other sectors and hence the macro economy are important. This section focuses on the impacts of aviation taxation on the macroeconomic environment.

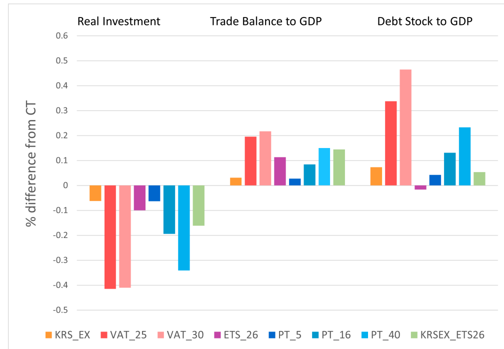
An increase in aviation taxation will have a dampening effect on the economy through increased prices. This results in a reduction in GDP and investments and an increase in government debt. The use of a targeted aviation tax revenue recycling scheme could reduce this impact or even create benefits to the macroeconomic aggregates by using the revenue to boost the economy through other channels (e.g. reduced taxation elsewhere in the economy). Although this is outside the scope of this report and is not included in the analysis here, this is an important channel through which the government can limit the

[6] Though there is a general substitution effect between all goods in the I3E model, there is no explicit link or bundling of aviation and ACC for households.

Figure 7.3: Macroeconomic environment, % difference from CT



(a) Real Gross Domestic Product



(b) Other macroeconomic indicators (2030)

overall impacts of increased aviation taxation. Figure 7.3a shows the reduced GDP[7] in 2025, 2030, and 2040, compared to no policy change (*CT*). The aviation taxation schemes reduce GDP by up to 0.22 per cent in 2030. Impacts grow over time due to cumulative effects. This represents how the level of GDP will differ in 2025, 2030 and 2040 and does not represent an annual decrease in GDP. Furthermore, though the level of GDP is lower with aviation taxation, GDP still continues to grow over time. Table 7.3 displays the average growth rate of GDP for the different scenarios over the periods 2021 to 2030 and 2021 to 2040. Examining the table, impacts on the growth rate of GDP are extremely small.

Table 7.3: Average growth rate of GDP

	2021-2030	2021-2040
CT	3.716	3.480
KRS_EX	3.713	3.478
VAT_25	3.700	3.471
VAT_30	3.700	3.471
ETS_26	3.710	3.477
PT_5	3.714	3.479
PT_16	3.709	3.476
PT_40	3.704	3.473
KRSEX_ETS26	3.707	3.475

7 The CSO updated its national accounting framework in 2015 by adjusting the macroeconomic figures based on the special circumstances of the Irish economy, which are attributed to *globalisation*. The definitions of GDP and thus GNI include all economic activity generated by agents located in Ireland. Although some of the transactions of multi-national companies belong to Irish National Accounts, the actual economic activity is conducted outside Ireland. Therefore, the CSO introduced a new measure in 2017, namely Modified GNI or GNI*, excluding all those transactions, which are factor income of redomiciled companies, depreciation in R&D service imports and trade in Intellectual Property (IP), and depreciation of aircraft leasing. The office advises to use this measure *to give an even more precise indicator of the domestic economy* (CSO, 2021a). Since the base year of the I3E model is 2014, the GDP figure and all its components are not affected by the methodology update, and the calculated GDP in the model produces closer results to those of the GNI*.

Examining other macroeconomic indicators, in line with decreased economic activity, real investments decrease, Figure 7.3b. The increase in aviation taxation increases domestic prices and thus the cost of production, which, in turn, lowers the total exports of Irish firms; whereas the slowdown in economic activity reduces the overall import demand. The import effect is larger than the export effect, resulting in an improvement of the trade balance and thus its ratio to (nominal) GDP, but only slightly (Figure 7.3b). Decreasing economic activity increases both government expenditures on transfers to households and government consumption (it follows a cyclical pattern), which in turn, makes public savings negative. As a result, the debt stock-to-GDP ratio increases in all scenarios, Figure 7.3b. On the other hand, in the short run, the ETS scenarios lead to a decline in the government indebtedness as the abolition of free allowances increases the cost of ETS for aviation, half of which is currently received by the Irish government (though this is likely to change under the new ETS proposals), but has a limited impact on the economy.

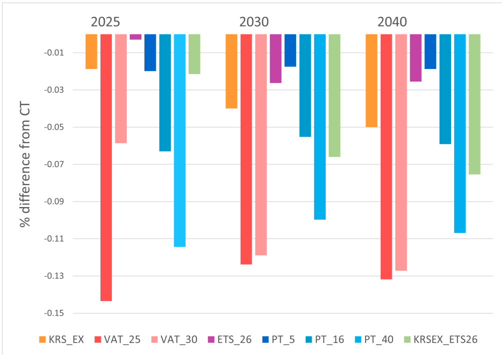
Table 7.4: Ratio of % change in GDP and % change in aviation VA

KRS_EX	0.07
VAT_25	0.04
VAT_30	0.05
ETS_26	0.02
PT_5	0.04
PT_16	0.04
PT_40	0.04
KRSEX_ETS26	0.03

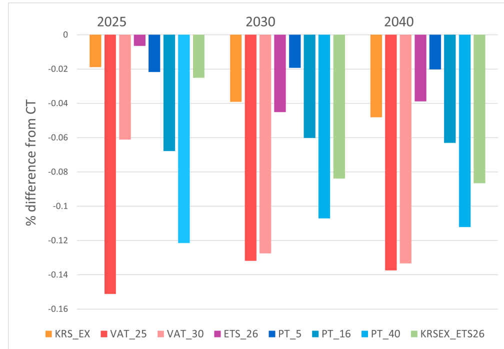
The relative impacts of the different taxation schemes are similar to those of aviation VA, in other words the scenarios that impacted aviation VA the most also impact GDP the most. However, the extent of secondary impacts on the overall economy does differ across scenarios. Table 7.4 shows the percentage change in GDP divided by the percentage change in aviation VA for the taxation scenarios. As seen in the table, relative secondary impacts are largest for the kerosene exemption removal scenario (*KRS_EX*). As discussed in the previous section, in the case of higher tax on kerosene, the costs are borne not only by the aviation sector but also by the petroleum sector, which produces (albeit a small amount) and sells kerosene, and other production sectors that use kerosene inputs. The secondary impacts of the removal of free ETS allowances for aviation (*ETS_26*) are lowest. This is because in this scenario the carbon input itself is taxed, which would limit the secondary impacts. The relative secondary impacts are similar with a passenger tax and VAT introduction. Compared to the analysis in the recent European Commission proposal for ETD, we find similar GDP impacts due to the removal of the kerosene tax exemption.

In line with the macroeconomic impacts, total employment and real mean wage decrease and unemployment increases, see Figures 7.4a, 7.4b and 7.4c, respectively. In line with previous results, the largest impacts in the labour market are recorded in the *VAT_25* scenario with an almost 0.15 per cent decrease in employment. The most affected labour type is high skilled labour, as those sectors that are most affected

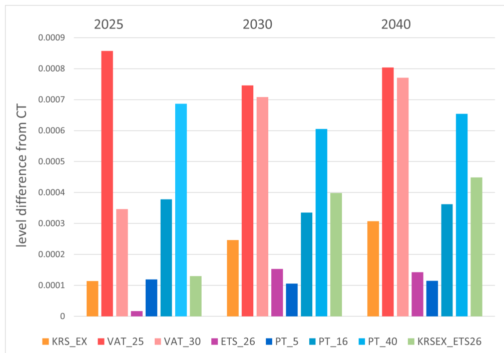
Figure 7.4: Aggregate labour market outcomes



(a) Total employment, % difference from CT



(b) Real mean wage, % difference from CT



(c) Unemployment rate, level difference from CT

by the policy changes are those which employ more high skilled labour relative to other labour types (such as petroleum, aviation and other transportation sectors).

7.4 Government revenue impacts

The introduction of aviation taxation in the form of VAT and a passenger tax will result in higher tax collection from aviation services. Removing free EU ETS allowances will increase the government's EU ETS permit cost collection, where currently Ireland receives half of these permit cost expenses (though this is likely to change in the future). Removing the excise duty exemption on kerosene will increase the governments excise duty receipts. However, due to the decreased economic activity, the government will receive less income from other forms of taxation. Table 7.5 shows the impacts of the various scenarios on government revenues. In the medium run (2025 and 2030) the increase in aviation taxation revenue outweighs the decrease in other taxation revenue. However, by 2040, the impact of decreased taxation through decreased economic activity dominates and the introduction of VAT or a passenger tax results in decreases in government revenue. This is not seen in the case of the removal of the kerosene excise exemption due to their smaller impacts on GDP.

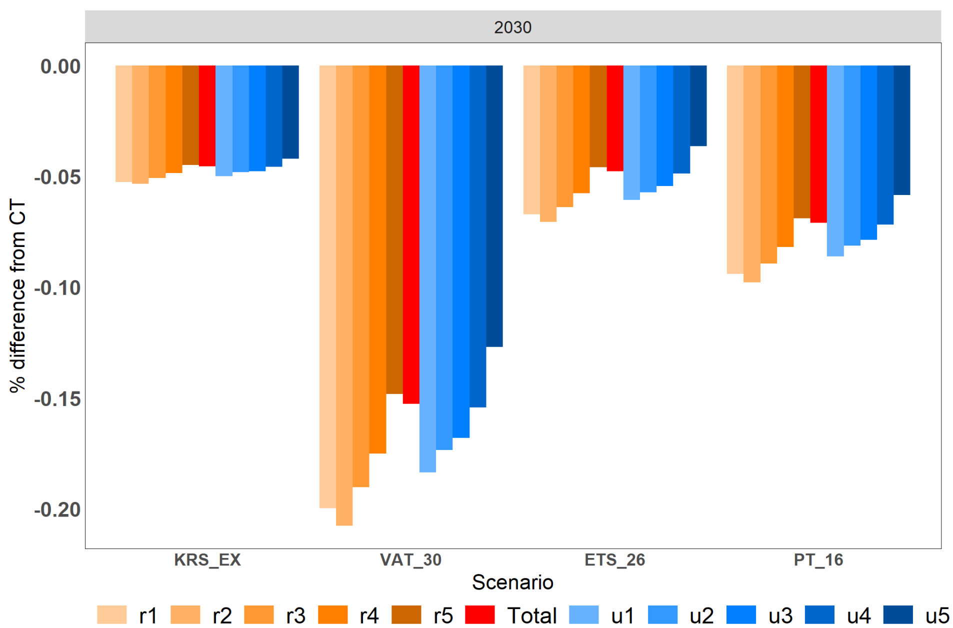
Table 7.5: Government revenue, % difference from CT

	KRS_EX	VAT_25	VAT_30	PT_5	PT_16	PT_UK
2025	0.02	0.21	0.11	0.02	0.06	0.11
2030	0.03	0.09	0.21	0.00	0.01	0.03
2040	0.03	-0.06	0.00	-0.02	-0.05	-0.07

7.5 Household impacts

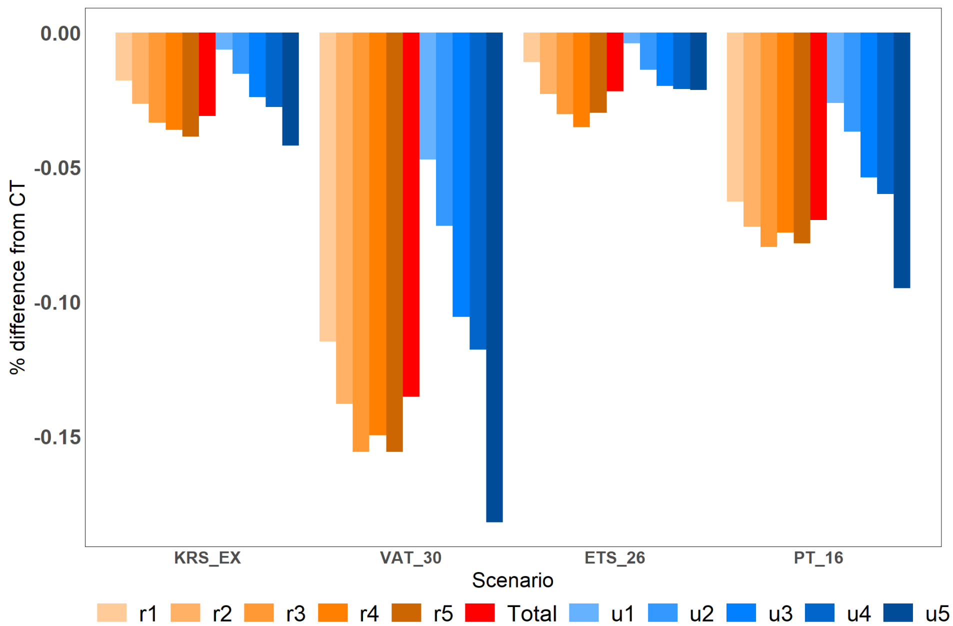
An important aspect of any policy is its impact on households, particularly concerning the distribution of impacts across household types. Here we examine the household impacts of the various aviation taxation scenarios. In the I3E model we distinguish between ten household types based on income and location (rural vs urban). Rural households are denoted by r1-r5, where r1 is the poorest household and r5 the richest. Urban households are similarly denoted by u1-u5. Figure 7.5 shows the impacts for households in terms of real wage income.

Figure 7.5: Real wage income, % difference from CT



In the I3E model households are impacted by a policy change through various channels. Firstly, as prices change, their consumption and consumption costs will change. Secondly, their labour and capital income will change due to the policy impacts on the capital and labour markets. Finally, transfers received by the households from the government (welfare and unemployment benefits) will change based on the aggregate unemployment rate and changes in overall price level (CPI). The household level parameters are calibrated by using the Household Budget Survey (HBS), the Survey on Income and Living Conditions (SILC), and the Labour Force Survey (LFS).[8]

Figure 7.6: Real disposable income, % difference from CT



We display only one scenario for each of the different taxation types as the distributional impacts show the same trends within the scenarios for each type, e.g. we only display *VAT_30* and not *VAT_25*. Overall, the impacts are small, with less than a 0.2 per cent decrease in households wage income due to aviation taxation. We observe a regressive trend where poorer households are impacted more than richer ones. Though aggregate impacts are small at a household level, specific households will face unemployment.

Figure 7.6 shows the impacts in terms of real disposable income across household types for the different aviation taxation schemes. Again, the impacts are small, with a maximum reduction in household disposable income of 0.2%. Contrary to wage income, we see a progressive trend in terms of disposable income, where richer households are impacted more (with some exemptions in rural households). This is due to a relatively large decrease in capital income, which predominately affects richer households. In addition, the higher unemployment rate and overall price level lead to an increase in the welfare transfers of the government, which corrects for the impacts of the policy changes on the market income of households in favour of poor households.

8 The details of the calibration process is available in de Bruin & Yakut (2021a).

8 Emission impacts

Table 8.1 shows the percentage changes in ETS and non-ETS emissions for all aviation scenarios, and in level changes for total emissions compared to the *CT* scenario. Though aviation emissions fall under ETS emissions, non-ETS emissions are also impacted due to the secondary impacts of the various taxation schemes. The implementation of VAT for aviation (*VAT_25* and *VAT_30*) leads to the highest decrease in emissions at approximately 1.8 per cent and 1.7 per cent in 2030 respectively. The removal of ETS free allowances (*ETS_26*) leads to 1.1 per cent less emissions in 2030.

Table 8.1: Emission impacts, compared to CT

		Total*	ETS*	Non-ETS*	Total**
2025	KRS_EX	-0.30	-0.46	-0.19	-123
	VAT_25	-1.69	-3.54	-1.34	-700
	VAT_30	-0.44	-1.09	-0.32	-183
	ETS_26	-0.13	-0.47	-0.01	-54
	PT_5	-0.25	-0.56	-0.19	-104
	PT_16	-0.78	-1.69	-0.60	-322
	PT_UK	-1.38	-2.93	-1.08	-570
	KRSEX_ETS26	-0.43	-0.92	-0.20	-176
2030	KRS_EX	-0.78	-1.15	-0.49	-347
	VAT_25	-1.81	-3.88	-1.38	-801
	VAT_30	-1.74	-3.73	-1.32	-767
	ETS_26	-1.11	-3.07	-0.12	-490
	PT_5	-0.27	-0.61	-0.20	-120
	PT_16	-0.84	-1.86	-0.62	-372
	PT_UK	-1.49	-3.22	-1.11	-656
	KRSEX_ETS26	-1.86	-4.15	-0.62	-824
2040	KRS_EX	-0.99	-1.45	-0.64	-595
	VAT_25	-1.99	-4.30	-1.51	-1,192
	VAT_30	-1.94	-4.20	-1.48	-1,164
	ETS_26	-0.88	-2.52	-0.12	-529
	PT_5	-0.30	-0.67	-0.22	-179
	PT_16	-0.93	-2.06	-0.68	-557
	PT_UK	-1.63	-3.56	-1.23	-979
	KRSEX_ETS26	-1.84	-3.91	-0.75	-1,106

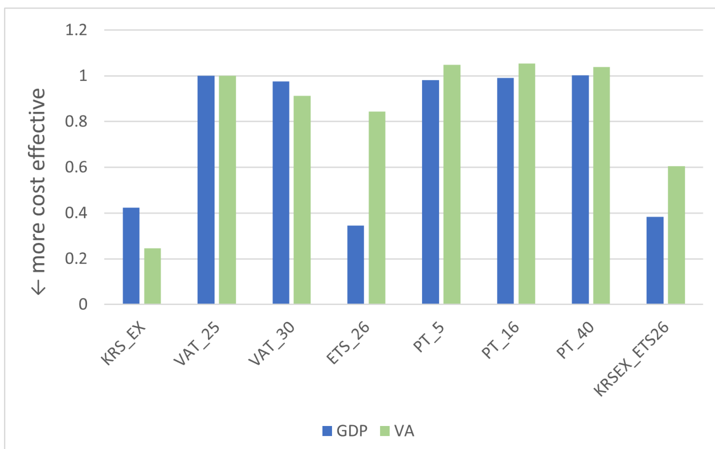
*: Percentage difference from CT
**: Level difference from CT in tonnes

The impacts of a passenger tax depend on the level applied, where a €5 tax (*PT_5*) leads to a 0.3 per cent emission reduction in 2030 and a level similar to that in the UK (*PT_UK*) leads to just under 1.5 per cent less emissions. Most emission reduction falls under the ETS, as aviation emissions fall under the ETS. In the case of *KRS_EX*, non-ETS emission reduction is significant as households use a significant amount of kerosene for heating purposes. As the costs of kerosene increase, households will decrease their use of kerosene. A decrease in non-ETS emissions is also seen in the other scenarios (with the exception of the ETS scenarios), as the decreased economic activity leads to a decrease in emissions outside of the aviation sector. Compared to the analysis in the recent European Commission proposal for ETD, we find significantly lower emission impacts for the removal of the kerosene exemption and the introduction of a passenger tax. This is presumably due to the higher demand response to price assumed in the EU level study.

8.1 Comparative effectiveness of different taxation options

In this section, we compare the cost effectiveness of the different forms of aviation taxation. To do this we compare the reduced aviation VA and reduced GDP (in % changes) per tonne of emission reduction achieved across the scenarios. We scale this by the levels in the *VAT_25* scenario for comparison. In other words, for the *VAT_25* scenario the levels are 1 and if a scenario is above that level this represents a higher cost per tonne of emissions reduced. The results are given in Figure 8.1 for 2030.

Figure 8.1: Cost effectiveness of scenarios, relative GDP decreases and aviation VA decreases per tonne of emissions reduced



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As can be seen in the figure, taxing kerosene (*KRS_EX*) and the removal of free ETS allowances (*ETS_26*) and their combination (*KRSEX_ETS26*) are most cost effective. This confirms the theory that the direct taxation of carbon is the most cost effective way of reducing emissions. As discussed before, the impacts on the aviation sector are lower in the case of kerosene taxation as the petroleum sector bears a large share of the costs of taxation. The introduction of VAT or a passenger tax have similar levels of cost effectiveness, where a passenger tax has slightly higher costs in terms of reduced aviation VA. This confirms the importance of the way in which aviation is taxed to reduce emissions. The use of indirect taxes such as VAT and a passenger tax are less cost effective as they do not tax only the source of emissions (carbon) but also other inputs and economic activities.

8.2 ETS price impacts

The impacts of the removal of free ETS allowances will depend on the ETS price. The ETS allowance market has been very volatile in the past and estimates of future prices are extremely uncertain. Due to this uncertainty, in the I3E model, we assume the ETS price will remain at its 2021 level of €32, this is slightly above the 2020 EU Reference scenario price of €30 by 2030 (European Union, 2021a). However, the recent EU 'Fit for 55' package includes major changes to the EU ETS that include: a one-off reduction to the cap and increased linear reduction factor (from 2.2 per cent to 4.2 per cent); the inclusion of the maritime sector into the EU ETS' scope from 2023 onward; a separate fuel ETS for buildings and transport; strengthened benchmarks and a faster phase down of free allocation; the introduction of a carbon border adjustment mechanism (CBAM) that prices imported goods based on their embedded emissions; and updated parameters of the Market Stability Reserve (MSR), including a new buffer threshold and an extension of the current intake rate of 24 per cent beyond 2023. The package has yet to go through the EU's legislative procedure before entering effect. However, these commitments signal a more stringent future EU ETS system and have led to a hike in the ETS price, where it has increased from below €30 in 2020 to above €65 in July 2021. Recent estimates of future EU ETS prices needed under the 'Fit for 55' package range from €60-€120 (OECD, 2021) to €130 (Pietzcker et al., 2021).

Table 8.2: Impacts of increased future ETS price, % change compared to CT (low price) in 2030

Scenario	ETS Price	GDP	VA	Emissions
ETS_26	Low price	-0.05	-2.60	-1.11
KRSEX_ETS26	Low price	-0.09	-3.14	-1.87
CT	High price	-0.40	-6.82	-11.74
ETS_26	High price	-0.54	-13.41	-14.27
KRSEX_ETS26	High price	-0.57	-13.68	-14.80

To understand how a sharp (but realistic) increase in the EU ETS price will impact the costs of ETS allowance removal, we run an additional scenario that includes a higher ETS price, reaching €100 by 2030. We have chosen this level as it is in line with the most recent forecasts of the ETS allowance price and it replicates the level of the Irish carbon tax. Table 8.2 compares the impacts (in 2030) of the *ETS_26* and *KRSEX_ETS26* to aviation VA, GDP and emissions under the current price (denoted as low) and assuming the ETS allowance price will grow to €100 by 2030 (denoted as high). Again, the price assumption of €100 by 2030 is used here for the purpose of investigating the potential costs given a rise in the ETS allowance price, but should be interpreted with caution, given the high level of uncertainty surrounding the future ETS price. We also examine the impacts of an increased ETS price in the *CT* scenario, without any changes the ETS allowance structure. As the table shows, the impacts increase significantly as the ETS price increases. The increased costs result in increased emissions reductions of 11.7 per cent even without a change in the the level of free allowances to aviation, and to 14.3 per cent when free allowances are removed. In summary, the costs to the economy and the aviation sector as well as emissions reduction would increase significantly in a higher ETS price environment.

9 Conclusions

The aviation sector has a significant role to play in the reduction of carbon emissions, particularly in light of EU emissions targets, where transportation emissions are targeted to reduce by 90 per cent by 2050. Despite this, the sector has seen an increasing trend in emissions. Recent movements in EU policy under the ‘Fit for 55’ package, as well as public and political interest, have focused attention on changing the taxation structure of the aviation industry, where several taxation exemptions apply, in order to reduce CO_2 emissions.

This report focuses on several different potential policies and taxation structures which would attempt to decrease the emissions of the aviation sector. Firstly, we investigate the recently proposed EU level policies concerning kerosene taxation and EU ETS allowances. Specifically we impose a kerosene tax from 2023 onward, reaching a level of €0.33 by 2033 and remove all free EU ETS allowances for aviation in 2026. To represent the recent EU level proposal concerning aviation taxation, a combination policy is considered that includes both kerosene taxation and ETS free allowance removal.

Other illustrative scenarios were also modelled which focused on passenger taxation and the removal of a VAT exemption. Given that many EU states have introduced a passenger tax, we estimated the impact of introducing an Irish passenger tax, which we examine at three levels: €6, €16 and €29. Finally, the introduction of a Value Added Tax (VAT) for aviation services (at a level of 13.5 per cent) is considered, where currently aviation is exempt from VAT taxation. We examine the implementation of VAT by 2025 (*VAT_25*) and by 2030 (*VAT_30*).

Each of these policies is assessed with respect to the impacts on the aviation industry, spillover effects, macroeconomic and government revenue effects, and household effects, as well as the emissions impacts. This analysis applies the Ireland, Environment, Energy and Economy (I3E) model, which allows for the examination of spillover effects of the aviation industry to government, households and other industries.

In order to examine the impacts of the different taxation structures on the aviation industry, this report analyses the effects on value-added (VA), which represents the profits and payments to capital, labour and taxes of the aviation industry (corresponding to total sales revenues minus input costs).

The largest impacts are from the implementation of a VAT, and from the introduction of a higher level passenger tax resulting in an up to 5 per cent cumulative decrease in VA by 2030. Kerosene taxation results in a less than 0.5 per cent cumulative decrease in VA by 2030, as the petroleum sector bears a large share of these taxation costs. The removal of free ETS allowances results in a decrease in VA of 2.6 per cent and combining allowance removal and kerosene taxation leads to 3.1 per cent decrease in VA.

All of the scenarios result in increased prices of aviation services, with the greatest impacts from VAT and high level passenger tax. Demand for aviation services decreases as a result; however, because of the lack of adequate substitutes for an island nation, the demand response to prices increases, i.e. the price elasticity is relatively low. Demand decreases are in range of 0.9 per cent (in the case of kerosene taxation) to 12.7 per cent (in the case of VAT introduction in 2025).

Recent policy proposals under the 'Fit for 55' package propose the implementation of kerosene taxation and the abolition of free EU ETS allowances to aviation. These policies (modelled using the EU Reference price assumption) would result in a more than 3 per cent cumulative decrease in aviation VA. However, the results suggest that the ETS allowance price will play an important role in determining the cost and efficiency of taxation measures.

Although spillover effects are limited, there are several industries affected which more directly interact with aviation, such as the petroleum sector, warehousing, machine repair and installation, and travel and tourism. For travel and tourism, this paper estimates the decreased spending by tourists resulting from a decrease in arrivals, then applies three taxation scenarios. The effects are not large, but not insignificant and range from a 0.6 per cent decrease in cumulative VA of the accommodation and food and beverage services sector to a 1.1 per cent decrease in VA of the accommodation sector.

An increase in prices in the aviation sector results in a decrease in GDP and investment, and an increase in government debt. However, estimates for GDP with the increased aviation taxation suggest that the impact on GDP will be small. Taxation policies that hit the aviation industry the hardest also decrease GDP the most. However, the relative impacts of the different policies on the macro economy differ, where direct taxation of carbon inputs, as is the case with kerosene taxation and free EU ETS allowance abolition, result in lower secondary, and hence lower GDP, impacts. Total employment decreases up to 0.12 per cent among the policies considered, decreasing mean wage and increasing the unemployment rate.

With regard to government revenue, changes to the aviation taxation structure result in both increased tax revenue from the aviation industry and decreased tax revenue from other sectors of the economy. This analysis shows that the increase in aviation taxation outweighs the decrease in other tax revenue in the medium run. However, in the long run this relationship is reversed and the decreased taxation resulting from decreased economic activity dominates.

An analysis of household types (distinguished by location and income) shows that the overall impacts on household wage income are small, though they are also regressive. Impacts on real disposable income are also small and progressive (richer households are impacted more) due to decreased capital income for higher income households.

This report also assesses the impact of the various taxation scenarios of emissions. Emission reduction ranges between 0.3 per cent and 1.9 per cent in 2030 across the policies considered, where policies that had the highest economic impacts also tend to have the highest emission impacts. However, an analysis of reduced VA and decreased GDP per tonne of emission reduction shows significant differences between cost effectiveness between policies, where the most cost effective policies are taxing kerosene and removing free ETS allowances, i.e. taxing the carbon input. This is consistent with the economic theory that the most efficient way of emission reduction is through direct taxation of carbon. Similarly cost effective are the introduction of a VAT and a passenger tax.

This report also examines the impacts of the future ETS price. When an increasing ETS price is assumed (reaching €100 by 2030), impacts increase significantly. The impacts of this price change alone would result in a cumulative decline in GDP of 0.4 per cent, in aviation VA of 6.8 per cent, and in emissions of 11.7 per cent by 2030. In combination with the recently EC proposed abolition of free ETS allowances for aviation and the kerosene taxation exemption, impacts increase further with a 0.6 per cent decrease in cumulative GDP, a 13.7 per cent decrease in cumulative aviation VA and 14.8 per cent decrease in emissions.

Overall, our results show that a gradual implementation of taxation leads to lower impacts for production sectors and the economy. Furthermore, the direct taxation of carbon inputs results in higher emission reduction at a lower cost. Furthermore, the policies considered would not reduce aviation emissions to the extent needed under the EU goals, where under the Green Deal transportation emissions should be reduced by 90 per cent by 2050. Though increased taxation would lead to decreased emissions, this emission reduction is driven predominantly by reduced output. Additional policies (such as ReFuelEU) would be needed to allow the aviation industry to reduce its carbon emissions through technological innovations without significantly decreasing its output.

The methodology applied in this report does not allow for the investigation of several aspects of aviation taxation. Firstly, the ReFuelEU and CORSIA policies are not considered in this analysis. Secondly, the I3E model only allows for an examination of the aviation sector as a whole, and passengers as being homogeneous. Impacts are likely to vary across different market segments of the aviation industry and different passengers or households. For example, recent literature suggests that low cost airlines are more impacted by aviation taxation than other airlines; different passengers (long vs short haul and leisure vs business) are likely to react differently to price changes; and many individual households working in the aviation industry may lose their jobs. Finally, this analysis does not include the implementation costs of different forms of taxation, where e.g. kerosene taxation implementation would be more costly than free EU ETS allowance abolition. There is also a high level of uncertainty surrounding the future growth of the aviation industry and should the industry not recover at the speed expected, it would face significant additional revenue losses.

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Appendix A Lists of activities and commodities

Table A.1: Commodities

C_AGR	Agriculture	C_HTP	High-tech products
C_PEA	Peat	C_TRE	Transportation equipment
C_COA	Coal	C_ELC	Electricity
C_CRO*	Crude oil	C_NGS	Natural gas
C_OMN*	Other mining	C_WAT	Water and sewerage
C_FBT	Food, beverage, and tobacco	C_CON	Construction
C_TEX	Textile	C_TRD	Trade
C_WWP	Wood and wood products	C_LTS	Land transportation
C_OIN	Other industrial products	C_WTS	Water transportation
C_GAL	Gasoline	C_ATS	Air transportation
C_KRS	Kerosene	C_OTR	Other transportation
C_FUO*	Fuel-oil	C_ACC	Accom. and hotel serv.
C_LPG	Liquid petroleum gas	C_TEL	Telecommunication services
C_DIE	Diesel	C_FSR	Financial services
C_OPP	Other petroleum products	C_RES	Real estate services
C_OTM	Other manufacturing	C_PSE	Professional services
C_CHE	Chemical products	C_ADS	Admin and support services
C_BPP	Basic pharmaceuticals	C_PUB	Public services
C_RUP	Rubber and plastic	C_EDU	Education
C_ONM	Other non-metallic minerals	C_HHS	Health
C_BFM	Basic fabricated metals	C_OSE	Other services

*: Not subject to private consumption.

Table A.2: Activities

Activity		NACE Codes	Aggregate Sector	
A_ACC	Accommodation and Hotel Services	55-56	ACC	
A_AGR	Agriculture	1-3	AGR	
A_CON	Construction	41-43	CON	
A_FSR	Financial Services	64-66	FSR	
A_PUB	Public Sector	84	PUB	
A_TRD	Trade	45-47	TRD	
A_ELC	Conventional		ELC	
A_WND	Wind		ELC	Electricity
A_ORE	Other Renewables		ELC	
A_BFM	Basic Metal Manufacturing	24-25	MAN	
A_BPP	Basic Pharmaceutical Products	21	MAN	
A_CHE	Chemical Products	20	MAN	
A_FBT	Food, Beverage and Tobacco	10-12	MAN	
A_HTP	High-Tech Products	26-28	MAN	
A_NGS	Natural Gas Supply		MAN	
A_OIN	Other Industrial Products	17,18,33	MAN	
A_ONM	Other Non-metallic Products	23	MAN	Manufacturing
A_OTM	Other Manufacturing	31-32	MAN	
A_PET	Petroleum		MAN	
A_RUP	Rubber and Plastic Products	22	MAN	
A_TEX	Textile	13-15	MAN	
A_TRE	Transportation Equipment	29-30	MAN	
A_WAT	Water and Sewerage	36,37-39	MAN	
A_WWP	Wood and Wood Products	16	MAN	
A_OMN	Other Mining Products		MIN	Mining
A_PEA	Peat		MIN	
A_ATS	Air Transportation	51	TRP	
A_LTS	Land Transportation	49	TRP	Transportation
A_WTS	Water Transportation	50	TRP	
A_OTR	Other Transport (Storage and Postal)	52-53	TRP	
A_EDU	Education Sector	85	SER	
A_HHS	Health Sector	86-88	SER	
A_RES	Real Estate Services	68	SER	Services
A_TEL	Telecommunication Services	61	SER	
A_PSE	Professional Services	69-75	SER	
A_ADS	Admin and Support Services	77-82	SER	
A_OSE	Other Services	remaining	SER	

*: It excludes NACE codes 5-9 (Mining, Quarrying and Extraction), 19 (Petroleum Products), and 35 (Electricity and Gas Supply).

Note: The activities without NACE codes are further disaggregated sectors.

Appendix B Assumptions for 2020 and 2021

The COVID-19 pandemic has led to changes in the structure of the economy in several aspects. These realisations are incorporated, and it is assumed that all those changes will be 50 per cent effective in 2021 as the country was in the lockdown during the first half of the year. In this respect, all structural variables of the Irish economy will go back to their original values, which have been calibrated by using the Irish ESAM, in 2022.

The CSO announced the National Accounts for the year of 2020. The overall economic activity is calculated by expenditure and production approaches. The model parameters are adjusted in order to catch the impact of the COVID-19 related lockdown measures on production (sectoral gross value added - GVA), households (private consumption), external demand (exports), government expenditures, capital formation, and net factor income of households. The sectoral parameters on production and value-added generation are adjusted in order to catch the percentage changes in the sectoral GVAs in 2020, compared to 2019. By using the Retail Sales Index of the CSO, the structural parameters of household demand are altered. In order to introduce the labour market shock, the labour force participation rates (LFPRs) of each type of labour are lowered, and low-skilled labour is assumed to be hit harder than high-skilled labour. Due to the economic shutdown, employees and self-employed individuals are supported by the government. The total amount of COVID-19-related transfers ('COVID-19 Pandemic Unemployment Payment'- PUP, and a Temporary Wage Subsidy Scheme -TWSS) is introduced into the household budget constraint as a non-means-tested government transfer. The net factor income of households, which is a fixed variable in real terms in the model, is lowered by following CSO estimates.

In late 2019, the prices of oil, coal, and natural gas declined by around 20 per cent, 16 per cent, and 19 per cent, relative to their closing prices in 2018. In the first months of 2020, energy prices plunged to the lowest levels in nearly two decades, which in turn softened the negative economic impacts of the virus crisis by lowering both the cost of production and the import bill of energy commodities for energy-importer countries.[9] In order to take into account the cushioning impacts of the lower energy prices, it is assumed that energy prices remained at their low level in 2020. However, in the first quarter of 2021, the prices of oil and coal increased by 40 per cent and the price of natural gas doubled, compared to their average prices in 2020. This remarkable surge in prices occurred in a period where the lockdown measures were in place across the globe, and there was a contraction in economic activity. Due to the vaccination roll-out in the developed countries and the attempts to ease/lift the lockdown measures, a strong rebound effect is expected due to the delayed consumption in 2020. Therefore, along all scenario paths, the energy prices are assumed to be constant at their levels at the end of the first quarter of 2021.

[9] The main reason for the lower prices was the price war between OPEC+ members. As of 13 April 2020, the war seems to have subsided as the members have agreed to cut the oil production by 9.7 million barrels per day (bpd) in May-June. The reduction in daily production will be 7.6 million bpd until the end of the year, and 5.6 million bpd in 2021 (Economic Times, 2020).

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