Using economic instruments to address emissions from air transport in the European Union

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Abstract

Air transport has become a vital component of the global economy. However, greenhouse gas emissions from this sector have a significant impact on global climate, being responsible for over 3.5% of all anthropogenic radiative forcing. Also, the accrued visibility of aircraft emissions greatly deteriorates the public image of the industry. In this context, incentive-based regulations, in the form of price or quantity controls, can be envisaged as alternatives to mitigate these emissions.

The use of environmental charges in air transport and the inclusion of the sector in the European Union Emissions Trading Scheme (EU ETS) are considered under a range of scenarios. The impacts of these measures on demand are estimated, and results suggest that they are likely to be minimal, mainly due to the high willingness to pay for air transport. In particular, in the EU ETS scenario currently favoured by the EU, demand reductions are smaller than 2%. This conclusion need not be valid in the longer run, for short trips, or if future caps become more stringent in the system. Furthermore, given current estimates of the social cost of CO_2 as well as typical EU ETS prices, supply-side abatement would be too costly to be encouraged by these policies in the short term. The magnitude of aviation CO_2 emissions in the EU is estimated, both in physical and monetary terms; the results are consistent with Eurocontrol estimates and, for the EU-25, the total social cost of these emissions represents only 0.03% of the region's GDP.

This study concludes that the use of multi-sector policies, such as the EU ETS, is unsuitable for curbing emissions from air transport itself. To that end, stringent emission charges or an isolated ETS would be better suited instruments. However, including aviation in the EU ETS has advantages under target-oriented post-2012 scenarios, such as policy costs dilution, certainty in reductions and flexibility in abatement allocation. This solution is also attractive to airlines, which would improve their public image with virtually no reduction of their own emissions, as they would be fully capable of passing on policy costs to their customers.

Keywords: carbon permits, carbon tax, emissions aviation, EU ETS aviation, climate change, Pigouvian tax, tradable permits, global warming, carbon emissions, taxes vs permits, emissions trading, carbon trading

1. Introduction

Air transport has ignited a revolution in the global economy, reducing travel times and allowing passengers and cargo to span distances unimaginable until recently. As of 2006, aviation transports approximately 2 billion passengers annually and has an impact on the global economy estimated at 8% of the world's GDP (Thompson, 2006, p.1). According to the Intergovernmental Panel on Climate Change (IPCC), global air passenger traffic has increased at approximately 9% per year since 1960, a rate which is far superior to the average GDP growth rate for the same period (IPCC, 1999, summary chapter 1). The sector is projected to continue growing by about 3-7% per year, at least until 2015 (Brasseur et al, 1998). With the recent publication of the Stern Review (2006), a robust economic analysis of global warming and possible policies, the need for immediate action has become clear. The choice of policy instruments by governments is essential and aviation is one of the sectors that need the most attention in this respect: 'the level of the carbon price faced by aviation should reflect the full contribution of emissions from aviation to climate change' (Stern Review, p.341).

Aviation is a CO_2-intensive mode of transport: its average emissions per passenger kilometre are greater than those from rail travel by a factor of two (Tyndall Centre, 2001). The best estimates yielded by meteorological models indicate that, in 1992, the radiative forcing[1] by aircraft corresponded to approximately 3.5% of all anthropogenic radiative forcing (IPCC, 1999, section 6.6.3). Section 2 of this paper presents an overview of emissions from aviation as well as their impact on radiative forcing and estimates of their magnitude in physical and monetary equivalent terms.

It could be argued that technological progress might have a significant influence in the

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[1] Radiative forcing is defined as an alteration in the balance between the share of solar radiation that is absorbed by the atmosphere and the share of radiation reflected into space. It can be caused by a change in the concentration of a greenhouse gas in the atmosphere, for example. A positive radiative forcing causes an increase in the average temperature of the Earth, whereas a negative radiative forcing implies a decrease in this temperature. Radiative forcing is measured in W/m^2 (watts per square metre).

evolution of emissions from air transport, affecting the development of more fuel-efficient aircraft and air traffic procedures. Indeed, during the last decades only, this efficiency improved at an average rate of 1.7% per year (IPCC, 1999, summary 6.1). Although even higher rates are expected in the future (British Airways, 2005, p.3), these improvements are expected to be largely offset by the increase in volume of the sector's activity. As a consequence, in a business-as-usual scenario, with no policy instruments employed for mitigation, the annual growth in emissions until 2015 is predicted to remain between 3% and 4% (IPCC, 1999, summary section 3; Wit et al, 2005, p.140).

The air transport sector is not covered by Kyoto protocol targets, and therefore it undergoes weaker pressure to curb its emissions. However, the European Union has recently expressed its view that aviation should be encompassed by the European environmental policy framework (EC, 2005a, p.3). Moreover, it has indicated that it intends to include international aviation in the EU Emissions Trading Scheme (EU ETS) (EC, 2005a, p.4; Hartridge, 2006, slide 10; Zapfel, 2006, slide 19). Section 3 outlines the main types of economic instruments that could be employed in air transport.

Section 4 discusses and estimates the supply and demand-side effects of the application of environmental regulation to aviation. Section 5 addresses the choice between price and quantity controls. Section 6 presents conclusions and policy recommendations.

2. Emissions from air transport

The aircraft emissions that have a significant contribution to climate change are carbon dioxide (CO_2), nitrogen oxides (NO_x), sulphur compounds (SO_xO and H_2SO_4), water vapour (H_2O) and aerosols (sulphur particles and soot) (IPCC, 1999, summary section 4). Their contribution can be either direct or indirect, depending on the chemical species considered.

Carbon dioxide (CO_2) is the unavoidable product of combustion and it is by far the most important greenhouse gas. As solar radiation, reflected on the surface of the Earth, makes its way up the atmosphere, it is absorbed by CO_2 molecules and induces their thermal agitation.

Therefore, an increase in CO_2 concentration in the troposphere leads to positive radiative forcing, and as a result, to an increase in temperature. The amount of CO_2 emitted by an aircraft during flight is determined by the total amount of fuel consumed. For instance, for every kilogram of kerosene burned, 3.16 kilograms of CO_2 are emitted into the atmosphere (EEA, 2005, annex of chapter B851).

Nitrogen oxides (NO_x) are the by-product of high-temperature combustions and are produced in a smaller quantity compared to CO_2. These emissions do not depend directly on the amount of fuel used, but rather on operating conditions and design of the engine (Royal Commission on Environmental Pollution, 2002, p.21, paragraph 4.3). Nitrogen oxides are not greenhouse gases themselves. Nevertheless, they have an important influence on the concentration of some greenhouse gases like methane (CH_4) and ozone (O_3) in the atmosphere.

H_2O emissions can present themselves in three different forms: water vapour, line-shaped contrails and cirrus clouds. Water vapour emissions from air transport are small, but effects of contrails and cirrus clouds are very significant. However, there is still much uncertainty as to the real magnitude of their impact on climate change. Moreover, their occurrence is strongly dependent on local variables such as air temperature, pressure and winds, creating legal barriers to the attribution of environmental impact liability to airlines (Wit et al, 2002, p.23).

Sulphur oxides (SO_xO) and sulphuric acid (H_2SO_4) are produced by chemical reactions involving the small quantities of sulphur present in aircraft fuel. However, in addition to being very small, this negative effect is counterbalanced by the positive radiative forcing of soot aerosols, produced by incomplete combustion in aircraft engines.

Table 1 presents a summary of the global radiative forcing (in W/m^2) due to air transport, along with estimates for individual impacts for each type of emission.

Table 1: Relative impact of aviation emissions in terms of radiative forcing (quantities in W/m^2)

Emission	1992 (middle estimate)	2050 (projected)
CO_2	+0.018	+0.074
O_3 (from NO_x)	+0.023	+0.060
CH_4	-0.014	-0.045
Stratospheric H_2O	+0.002	+0.004
Contrails	+0.02	+0.10
Cirrus	0-0.04	0-0.16
Sulphate aerosols	-0.003	-0.009
Soot aerosols	+0.003	+0.009
Total	**+0.049 + cirrus**	**+0.193 + cirrus**

Source: Wit et al (2002, p.23, based on data from IPCC, 1999)

It is clear that the most significant impacts from air transport on climate are due to emissions of CO_2, NO_x and H_2O. However, given the relatively poor level of scientific understanding of H_2O, as well as the problems arising in determining the liability for these effects, the emissions most likely to be addressed by an economic instrument would be CO_2 and NO_x.

In relative terms, the impact of aviation corresponds to 3.5% of the total radiative forcing by all anthropogenic activities. According to NASA projections (reported in IPCC, 1999, chapter 6 summary), the growth in the global aircraft fleet alone would lead to an aircraft-induced radiative forcing of 0.11 Wm^{-2} in 2015, about 5% of all anthropogenic activity in that year. Longer-term projections made by the IPCC suggest that the aircraft-induced radiative forcing in 2050 could amount to anywhere from 2.6 to 11 times the value in 1992 (IPCC, 1999, summary section 4.8).

This impact, combined with the accrued public visibility of the sector (Thompson, 2006, pp.1-2), has led air transport to be regarded as a very environmentally unfriendly activity in recent years. Environmental lobbying groups (EFTE, 2001; Gazzard, 2004), specialised (Thompson, 2006) and popular media (BBC News, 2004; Joarder, 2004; Walters, 2002), policy makers (EAC, 2003), and even airlines themselves (British Airways, 2005) have expressed their concerns over the environmental impact of aviation. Airlines and air transport organisations are without a doubt aware of this situation (Thompson, 2006, p.1-2).

2.1 The externality in Europe

From an economic perspective, greenhouse gas emissions from aircraft are regarded as a negative externality, thus resulting in social welfare losses. In order to estimate the magnitude of this externality, data on the number of flights departing from the EU 15 countries were obtained from Eurostat for the years 2003 and 2004 (Eurostat, 2006). The data include the number of domestic, international intra-EU and international extra-EU flights divided into 67 aircraft categories. Most of these categories have corresponding EMEP generic aircraft types (EEA, 2005, annex of chapter B851), which allow the use of CORINAIR emission factors in estimating CO_2 emissions for both landing and take-off (LTO) and climb, cruise and descent (CCD) cycles. In some cases, finer estimates, obtained using the PIANO model (EEA, 2005, annex of chapter B851), were available. For those aircraft categories where both EMEP aircraft type and PIANO output were lacking, emission factors for similar-sized aircraft were used. For categories where only the manufacturer of the aircraft was specified, emission factors corresponding to a representative aircraft of the manufacturer were used.

For each flight category – domestic, international intra-EU and international extra-EU flights – an average mission length was calculated. This average length was obtained from aggregated data on EU flights from Eurocontrol (Wit et al, 2005, pp.240-243), which contain the total number of flights and kilometres flown for each flight category. A summary of the results is shown in Table 2 for the EU 15 countries.

Table 2: CO_2 emissions from flights departing from the EU 15 and the EU 25 (in thousands of tonnes)

	2003		2004	
	EU 15	**EU 25**	**EU 15**	**EU 25**
Domestic flights	10,594	10,711	10,892	11,089
International intra-EU	41,119	42,969	45,321	48,603
International extra-EU	52,404	55,205	52,243	54,768
Total	**104,118**	**108,886**	**108,456**	**114,460**
Monetary equivalent (€)	**3,157,886,224**	**3,302,502,658**	**3,415,269,976**	**3,604,349,688**

Source: Calculations using Eurostat data, Eurocontrol information on aggregate volume of activity from Wit et al (2005, pp.240-243), and estimates on the social cost of carbon from Clarkson and Deyes (2002)

The choice of "emissions from flights departing from the EU" as a proxy for the size of the externality in Europe is a somewhat arbitrary one. However, it is a very reasonable solution, since it results in the greatest possible coverage of emissions without the occurrence of double counting, should other regions be included in the calculations. In addition, it is crucial to note that the estimates obtained with this very simple method take into account only the aircraft type and straight-line flight distance. Other influential parameters, such as flight paths and levels, atmospheric conditions at flight altitude, fuel quality and suboptimal air traffic management (ATM) procedures (e.g. flight holding and queuing for take-off and/or landing), are not taken into account, since such factors vary greatly from flight to flight and are not included in Eurostat data. Therefore, one might regard these results as underestimates. Nevertheless, these totals are quite consistent with those obtained from more complex models. Eurocontrol (in Wit et al, 2005, pp.240-243), for example, estimates aggregated emissions from flights departing from the EU 15 to have been of 124 million tonnes of CO_2 in 2003 and of 130 million tonnes of CO_2 in 2004, which fall within a margin of less than 20% of the present study's estimates. The totals obtained here were also verified against calculations using outputs from the PIANO model, and the results were highly satisfactory.

Obtaining a monetary estimate of the magnitude of the externality requires the use of the social cost of CO_2. In recent years there have been a number of studies on the subject

(Nordhaus, 1991; Cline, 1993; Fankhauser, 1993; Maddison, 1994; Nordhaus, 1994; Eyre et al, 1999; Tol, 1999; Tol and Downing, 2000) and estimates differ greatly. A recent review of these studies by Clarkson and Deyes (2002) suggests a value of £70 for the social cost of carbon in the year 2000. This result, actualised according to the method recommended by the authors, yields €30.33 and €31.49 as the social cost of CO_2 in 2003 and 2004[2], respectively. In this way, aircraft CO_2 emissions from flights departing from the EU 15 countries can be valued at €3,157,886,224 for 2003 and €3,415,269,976 for 2004, both representing approximately 0.03% of the EU 15 gross domestic product for the years considered.

The calculation was repeated with the inclusion of the ten new members of the European Union[3] using data for the 25 countries available from Eurostat (Eurostat, 2006). Monetary estimates calculated using the same method also suggest a negligible economic relevance for these emissions, as their value remains at approximately at 0.03% of the EU 25 GDP. A summary of these results is also given in Table 2.

The values obtained for the estimates of the externality in monetary terms are surprisingly small, and contrast with the relatively high amount of radiative forcing caused by aircraft emissions. In addition, considering the ample negative repercussions of air transport emissions in the views of public opinion, one would expect them to represent a more significant share of the region's GDP.

The validity of these estimates could perhaps be disputed on the grounds that non-CO_2 emissions from aviation were ignored. Although this is true, calculations show that even if non-

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[2] The original result from Clarkson and Deyes (2002) suggests a social cost of 70 pounds per tonne of elementary carbon for the year 2000. Estimates for subsequent years are obtained by adding 1 pound per year and by using the EU GDP growth as an actualisation factor. In order to obtain the estimate for the social cost of carbon dioxide in euros per tonne of CO_2, a stoichiometric conversion factor of $12/44 = 0.2727$ and the 2005 average exchange rate between British pounds and euros (Eurostat, 2006) were used.

[3] In fact, only 24 countries are taken into account, as no data for Lithuania was available from Eurostat.

CO_2 emissions were converted to their CO_2 equivalent using radiative forcing as a metric, total emissions would represent 0.09% of the EU GDP.

3. Policy options for mitigating greenhouse gas emissions

In recent years, many studies have proposed and discussed different alternatives for tackling the environmental impact of emissions from air transport (Bleijenberg and Wit, 1998; Carlsson and Hammar, 2002; Dings et al, 2003; Mendes de León et al, 1997; Tsai and Petsonk, 2000; Wit et al, 2002; Wit et al, 2005). Typically, these policy options can be divided into command-and-control (CAC) and incentive based (IB) regulations (Carlsson and Hammar, 2002, p.365; Tietenberg, 1990) and the latter tend to be more efficient than the former (Baumol and Oates, 1988). Incentive-based mechanisms can be further categorised into two main types of approaches: price and quantity controls.

Price controls, such as emission charges, are the simplest incarnation of the "polluter pays" principle and one of the most widely used types of economic instrument in environmental policy. However, their lack of flexibility often makes it a less favoured option by the industry (Carlsson and Hammar, 2002, p.365; Pizer, 2002, p.441; Thompson, 2006, p.1).

Quantity controls generally assume the form of emissions trading schemes, also known as cap-and-trade systems. In contrast to CAC systems, where a fixed limit of emissions is imposed for each individual agent, the tradability of allowances causes for reductions to occur where abatement costs are lower. The possibility of flexibly allocating rents associated with emission rights, the room for windfall profits and the flexibility of design also give such a system considerable support from the industry (Pizer, 2002, p.409; Carlsson and Hammar, 2002, p.368).

There are a number of possible initial allocation methods, such as grandfathering, benchmarking and auctioning (Goulder, 1999; Tietenberg, 2002, p.10). Auctioning is technically the best allocation method, as it reduces barriers to entry, increases regulation stringency and generates revenues that can be recycled for environmental purposes. However, it

finds very little support in the industry. Grandfathering, on the other hand, is a more widely accepted option, but does not apply the "polluter pays" principle in full[4].

3.1 The European Union Emissions Trading Scheme (EU ETS)

In this study, the European Union Emissions Trading Scheme (EU ETS), set up in 2003, is used as the model for an emissions trading scheme. The EU ETS is the European initiative to implementing a Kyoto-oriented economic instrument to mitigate aggregated greenhouse gas emissions in its Member States. For the first two trading periods, 2005-2007 and 2008-2012, aggregated emission caps were imposed on the most energy-intensive sectors, namely cement, glass, ceramics, paper, steel and iron, as well as the power sector (EC, 2003, Annex I). In this way, the EU ETS covered over 11,000 installations and more than half of EU CO_2 emissions from 2005 to 2007 (EC, 2005a, p.5). Allocation is made by grandfathering combined with a very small percentage of auctioning (5% and 10% at most, for the first and second periods, respectively). Allocation decisions are made at EU level, based on each country's National Allocation Plan (NAP) (EC, 2000, p.18).

According to Olivia Hartridge, Administrator of International Policy and EU ETS at the DG Environment of the European Commission, in a presentation at the CarbonExpo 2006 conference (10/05/2006, Cologne, Germany), the European Commission is determined to take the necessary measures to reinforce the position of the EU ETS as a long-term system and ensure its continuity even after the deadline of the Kyoto Protocol targets (Hartridge, 2006).

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[4] A priori, having allowances distributed free of charge might lead to the conclusion that the "polluter pays" principle is not applied at all. However, one must consider the opportunity costs that come with the use of allowances: by emitting one tonne of CO_2, the polluter is giving up the earning he would make by selling one allowance – which was distributed gratis – at the market price. The incentive, however, is smaller than in the case of auctioned allowances, where the polluters must pay upfront for allowances.

3.2 A brief history of environmental policy in civil aviation

Regardless of the significance of aircraft emissions to climate change and the negative environmental image of air transport in the eyes of public opinion (Thompson, 2006, p.1), the air transport industry enjoys a considerable lack of regulation in terms of environmental policy (Whitelegg and Cambridge, 2004). Inertia marks politicians' attitudes towards environmental policy in air transport and, and in the specific case of the EU, the only country to tax the fuel used in domestic aviation is Holland (EC, 2005a, p.6). In addition, under the United Nations Framework Convention on Climate Change, international aviation is never dealt with directly, as the Kyoto Protocol states that emissions from this mode of transport should be addressed by the ICAO (United Nations, 1998, paragraph 2.2).

However, apart from the establishment of engine emission and noise standards and restrictions on flight movements (Carlsson and Hammar, 2002, p.365; IPCC, 1999, summary section 6.4) no significant action has been taken by the ICAO. Since the entry into force of the Kyoto Protocol in 1998, the ICAO has set up a committee to analyse the implementation of different incentive-based alternatives for mitigating emissions from aviation at a global scale, but it has so far been unable to provide a concrete proposal. This is somewhat understandable, given the complexity of proceedings inside the ICAO: any policy it endorses must be agreed by its 188 member countries, some of which have radically different positions towards climate change policy.

Finally, there are many treaties and bilateral agreements between countries to prevent aviation fuel from being taxed (ICAO, 1996). Since the level of CO_2 emissions from an aircraft is inextricably linked to fuel consumption (EEA, 2005), there might be controversy as to whether imposing an environmental levy would lead to non-compliance with these treaties and agreements (Wit et al, 2002, p.81). In 1996 the ICAO Council declared that it would endorse the concept of an international emissions trading scheme (ICAO, 1996), and that it would not be opposed to an environmental levy, provided that it is implemented as a charge and not a tax.

Conscious of the obstacles faced by the ICAO in proposing a solution at a global scale, and considering itself "a major player in global aviation" (EC, 2005a, p.5), the European Union announced that it would itself undertake effective policy measures regarding aviation emissions if no action were agreed upon by the ICAO by 2002 (EC, 2005a, p.5). More recently, it has indicated its intention to include aviation in the EU ETS as a form of taking the first step towards the participation of global aviation in the carbon markets (EC, 2005a, p.5; Hartridge, 2006, slide 10; Zapfel, 2006, slide 19). Upon request of the European Commission, CE Delft has elaborated a feasibility study (Wit et al, 2005), and ICF International has produced a detailed analysis of the impact of such inclusion on EU ETS allowance prices (ICF, 2006). An Aviation Working Group (AWG) has been set up under the European Climate Change Program (ECCP) to study the details of the process, and the European Parliament is expected to have a legislative proposal by the end of 2006 (EC, 2005a, p.11).

4. Potential impacts from different policies

If indeed the air transport sector were to be covered by a EU-wide type of IB environmental regulation, be it in the form of an emissions trading scheme or emission charges, emissions abatement would consist of demand and supply-side reactions to the economic incentive of the policy. Both types of effects are assessed in this section, in the scope of the European Union. This seems reasonable given that the EU is responsible for more than half of the world's air transport volume (EC, 2005a, p.5) and that it is the only region where a concrete proposal for an emissions trading scheme for aviation exists.

However, it should be emphasised that there are a number of aspects of the possible inclusion of aviation in the EU ETS that have not yet been clarified, such as the coverage of emissions (CO_2 and NO_x, CO_2 only, etc.), aircraft models to be included, the geographical scope of flights to be covered, definition of trading entities, details of the allocation process and the monitoring method to be used (EC, 2005a, p.12; Wit et al, 2005). Therefore, a number of assumptions were necessary. These assumptions are based on indications from recent public

presentations by officers of the European Commission (such as those by Olivia Hartridge and Peter Zapfel at the CarbonExpo 2006, in Cologne, Germany) and documents from the ECCP AWG meetings as to what decisions are likely to be taken regarding aviation and the EU ETS.

Carbon dioxide (CO_2) will be assumed to be the only type of emission to be covered. This is without a doubt a suboptimal solution, but difficulties in measuring levels of NO_x emissions and uncertainties regarding the magnitude of contrails and cirrus clouds impacts make mitigating such emissions via a wide-ranging emissions trading scheme or charge an unfeasible task in the foreseeable future[5].

The assumption of aircraft operators as trading entities is likely to be the most efficient choice, given that individual sources of emissions tend to be better informed about their abatement costs (Zhang and Nentjes, 1998). Since it is impossible to predict what the price of EU ETS allowances will be in the post-2012 period, three historically coherent price levels will be used: €7, €15 and €30 per tonne of CO_2 (Capoor and Ambrosi, 2006, pp.14-15). All assumptions are presented in Table 3.

Table 3: Assumptions for policy configurations used for analysis

	EU ETS	Emission charge
Allowance price / levy	€7/tCO$_2$ €15/tCO$_2$ €30/tCO$_2$	€42/tCO$_2$
Geographic scope	Flights departing from the EU	Flights departing from the EU
Trading entities	Aircraft operators	Aircraft operators
Allocation decision	EU Level	EU Level
Reduction targets	2012 Baseline	Social efficiency
Allocation method	Grandfathering Auctioning	

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[5] The European Commission has considered the use of a multiplier to account for the impact of aircraft NO_x emissions. In this way, NO_x emissions would be converted to their equivalent in CO_2 emissions in terms of radiative forcing (or other metric) and treated as such in the EU ETS. However, this solution is highly unsatisfactory for two reasons: firstly, NO_x emissions are not directly linked to fuel consumption, and therefore to CO_2 emissions; secondly, such a strategy would encourage CO_2-NO_x trade-offs in turbofan engine configurations (ECCP, 2006, pp.5-6).

In the discussion of an emission charge as the choice of economic instrument, it will be assumed that it is set approximately at the social cost of CO_2. Using the results from Clarkson and Deyes (2002) for the social cost of carbon in the year 2000 and the actualisation method recommended by the authors, it is estimated at approximately €42/tCO_2 in the year 2012.[6] In theory, such a charge would lead the level of activity to its social optimum.

4.1 Supply-side abatement

Whereas demand-side emissions reductions generated by IB regulation are simply a reflex to a possible increase in prices, supply-side effects include a much broader range of measures to be implemented or influenced by aircraft operators. The least costly of these measures appears to be the optimisation of flight speeds and Air Traffic Management (ATM) to minimise fuel consumption. As they stand, national and international ATM systems are a source of inefficient routings, holding (airborne aircraft waiting for permission to land), and suboptimal flight profiles, which result in excess fuel consumption and, consequently, excess CO_2 emissions. It is estimated that improvements in ATM could potentially reduce aviation emissions by between 6% and 12% (IPCC, 1999, summary section 6.3). Regarding the optimisation of flight speeds, it has been shown that flying at a minimum-emissions speed leads to a reduction of 15% to 25% in CO_2 emissions, compared to the maximum-emissions speed, for any given aircraft and route (Wit et al, 2002)

Other supply-side measures include: technical adaptations (e.g. retrofitting of winglets and riblets), greater efficiency or reduction in use of auxiliary power, shorter taxiing times, acceleration in fleet renewal, shift in new aircraft sales towards cleaner aircraft, and network and frequency changes to increase load factors (IPCC, 1999, summary sections 6.1-6.3; Wit et al, 2005, pp.126-127).

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[6] The year 2012 is of particular interest since it is the most likely date for the EU to include aviation in its environmental policy framework. The exact value obtained for the social cost of CO_2 in 2012 is €41.84/tCO_2.

The use of a more environmentally friendly fuel is unfortunately not an option in the air transport industry for the next few decades, since at the present state of technology jet-powered aircraft require high energy density fuels. Hydrogen might become available as a long term alternative (IPCC, 1999, summary section 6.2), but it would demand major structural changes in aircraft and airport facilities. It should be noted that although the use of hydrogen would literally eliminate emissions of carbon dioxide from aviation, it would increase emissions of water vapour, which is the only by-product of hydrogen oxidisation.

It is clear that multiple sources for emission abatement exist in aviation. However, a consensus exists that these opportunities are significantly more expensive than those in other sectors (EC, 2000, p.27; IATA, 2001, p.26; ICF, 2006, p.9; Wit et al, 2005, p.85), which may lead aircraft operators to simply absorb the costs of any IB environmental policy applied to the sector or, if possible, just pass them on to customers. Unless drastic changes take place in the cap set by the EU on the trading sectors of the EU ETS, the conclusion that prices will remain at present levels, and therefore that short-term abatement from aviation is highly unlikely to occur, is a very plausible one. ICF (2006) and Wit et al (2005) show that, given current levels of allocation, the inclusion of aviation in the EU ETS is not expected to induce increases in allowance prices. It is important to highlight that this reasoning is built on the hypothesis that aircraft operators will be able to pass policy costs on to customers.

4.2 Demand-side effects

Price increases in air travel would be the natural consequence of the implementation of an IB policy in civil aviation, should airlines and aircraft operators decide to pass the policy costs to customers. This is very likely to happen, especially regarding charter and low-cost airlines, which allegedly operate on very small profit margins (Oxera, 2003; Wit et al 2005, p.132). Research on scheduled carriers also suggests that increasing fares might be one of their dominant responses (Alamdari and Brewer, 1994, *in Wit et al 2005, p.132*; EC, 2005b, executive summary). In this case, substitution for other modes of transport, notably rail and

coach travel, would be encouraged. However, the scope of this substitution is limited to short-haul routes only, where road or rail links are available. According to the IPCC (1999, summary section 6.4) up to 10% of intra-European travel could be transferred from air transport to rail.

In order to estimate the impact of environmental policies on air travel demand, a number of illustrative flights have been used. Since air travel prices are very hard to pin down (they depend on season, carrier, class, date of purchase, amongst other things), a price range has been used for each of the flights considered, corresponding to typical round trip fares of scheduled carriers. The impact on low cost air travel is not assessed, as there is still much uncertainty regarding the demand price elasticities for this market segment. Occupancy rate is assumed to be 70%, which is historically coherent with data from the ICAO Digest of Statistics (ICAO, 2002) for national and international flights from the European Union countries. Values of demand price elasticity for business and leisure air travel for short and long haul were obtained from Gillen et al (2004, chapter 4). These levels are widely accepted and coherent with other studies (Agarwall and Talley, 1985; Dargay and Hanly, 2002; Ippolito, 1981; Jorge-Calderón, 1997; Pickrell, 1984; Talley and Schwarz-Miller, 1988). A summary of the illustrative flights considered is shown in Table 4.

Estimates of CO_2 emissions for each flight were obtained using landing and take-off (LTO) and climb, cruise and descent (CCD) emission factors from the CORINAIR database (EEA, 2005, annex of chapter B851), subsequently verified against PIANO simulation outputs. Treating LTO and CCD emissions separately increases the estimates' reliability, and proceeding otherwise would lead to an underestimation of fuel consumption in short haul flights. Nonetheless, the method used here remains fairly straightforward and presents few shortcomings, the most important of which is the fact that flight paths are not detailed and flight levels are not taken into account.

One important assumption made in this study is that only flights departing from the EU are subject to the policies considered. The reasons for this assumption are (a) as of 2006 it has become clear that any policy targeted at reducing the emissions from aviation would need to be

implemented in a sub-group of countries, as opposed to all the 188 countries which are members of the ICAO. As explained in Section 3.2 the ICAO has so far been unable to propose and commit to any incentive-based policy for mitigating emissions from aviation at a global scale; (b) the EU is responsible for more than half of the world's air transport volume (EC, 2005a, p.5); (c) the EU is the region where a concrete proposal for an emissions trading scheme for aviation exists and should this scheme evolve into a world-wide system, the charging of flights at departure would naturally evolve into the charging of all flights without double-charging; (d) flights arriving from outside the EU eventually leave the EU and would be charged; and (e) the Eurocontrol database for flights leaving the EU is readily available, whereas no equivalent data base exists for all the flights worldwide.

The assumption that only emissions from flights departing from the EU are subject to the two policies considered means that whereas the price of a London-Tokyo round trip will only be covered by the policies on the flight from London to Tokyo, the price of a Paris-London round trip ticket will suffer a dual impact.

Table 4: Summary of illustrative flights used in demand impact calculations

Origin	Destination	Length (km)	Aircraft type	Emissions (t CO_2)	Price range (2006 Euros)	Price elasticity Business	Leisure
Paris	London	346	A320	13.1248	€100-200	-0.730	-1.520
			B737	12.2054	€100-200	-0.730	-1.520
Madrid	Berlin	1850	A321	38.0337	€200-400	-0.730	-1.520
			B757	52.9837	€200-400	-0.730	-1.520
Lisbon	New York	5420	A330	117.2803	€900-1600	-0.265	-0.993
			B767	92.1445	€900-1600	-0.265	-0.993
London	Tokyo	9589	A340	222.9469	€1200-2000	-0.265	-0.993
			B777	242.4531	€1200-2000	-0.265	-0.993
			B744	345.2611	€1200-2000	-0.265	-0.993

Source: Emissions calculated using CORINAIR emission factors, verified against PIANO simulations. Elasticities compiled by Gillen et al (2004) for different flight categories

The first policy alternative considered was an environmental charge of €42 per tonne of CO_2 and the results of this exercise are presented in Table 5. In spite of the diversity in assumptions

and methods of calculation, the impact on prices obtained are in general consistent with values found in the literature (e.g. Bleijenberg and Wit, 1998; Dings et al, 2003; INFRAS, 2004; Pearce and Pearce, 2000).

The second policy alternative is the inclusion of aviation in the EU ETS in a scenario of 100% auctioning. This means that for every tonne of CO_2 emitted by an operator's flight, one allowance must be bought and surrendered. Therefore, the impact on the ticket price will depend on the price at which the allowance is auctioned just as it depends on the level of an environmental charge in the first scenario. Impacts have been estimated for auction clearing prices of €7, €15 and €30 and are shown in Table 6.

The third policy option considered is actually the most plausible one for the 2013-2017 trading period: it consists of including aviation in the EU ETS and of grandfathering allowances to operators. The allowances are grandfathered according to the operators' 2012 emissions, which means that for all emissions exceeding the 2012 baseline, allowances will have to be bought at market price. An exogenous growth rate of 4% in aviation emissions is used, which is consistent with the range of growth scenarios used by the IPCC (in IPCC, 1999, summary section 3). Under these assumptions, in 2017, operators would be obliged to buy allowances for approximately 21.67% of their emissions. The impact of the costs of buying these allowances in the market at different price levels is shown in Table 7. It is assumed that the opportunity costs of using the grandfathered allowances as opposed to selling them at market price is not passed on to customers.

The total policy costs column in Tables 6 to 8 is computed as tonnes of CO_2 emissions for the relevant flight multiplied by the emissions charge or allowance price expressed in €/tCO_2. For the case of intra-European flights this is also multiplied by 2, as both departures (for way-out and for way-in) would be from the EU and would be subject to the emissions charge or the ETS.

Since it is assumed that airlines would pass the whole cost of the policy on to their customers, the column corresponding to the impact on ticket price in all three tables is

computed as the total policy cost imposed on a given flight divided by the number of passengers in that flight, which was in turn computed using 70% as the seat occupancy rate for the relevant aircraft.

As Tables 5 and 6 indicate, estimated percentage reductions in demand are very small, but this magnitude is also in line with other studies in the literature (Wit et al, 2002, p.39; Wit et al, 2005, p.136; MVW, 2002, p.76). Simulations using the proprietary AERO Modelling System for example show that a fuel tax of US$ 0.20 per kilogram of fuel (approximately the equivalent of an emissions charge of €50 per tonne of CO_2) would only reduce global passenger demand by 7.5% (MVW, 2002, p.76).[7]

The most significant impacts occur in leisure travel, given the higher values of demand price elasticity for this market segment, and are stronger for short-haul flights. The reason for this can be found in the very high fuel consumption during the LTO cycle compared to CCD stages, making short-haul flights more fuel-intensive. However, whether the impact on demand is sufficiently strong to induce a decrease in the number of flights remains unclear. In fact, an airline's decision to reduce flights is a very complex one, and is likely to involve many other factors, such as long term airline strategy, historical occupancy rate and aircraft property costs. It is probable, on the other hand, that the reduction in demand would provide airlines with an additional incentive to reallocate aircraft and optimise passenger load factors in their flight network. It should be highlighted that longer term reactions from the industry are not being taken into account in the calculations.

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[7] Although the AERO model simulates impacts worldwide, it allows the simulation of instruments implemented at EU level only. The same instruments used in this study were simulated with AERO and although the results refer to worldwide impacts, they are modest. The environmental charge of €42/tCO_2 on all flights leaving from the EU gives the largest percentage reductions in fuel consumption and aircraft-km. These however never exceed 10% with respect to the base level, with the exception of EU-Asia routes, which would experience a reduction in fuel consumption of 12%.

Table 5: Effects on passenger demand of an environmental charge set at €42 per tonne of CO_2

Flight	Aircraft	Total policy costs	Impact on ticket price	Impact on demand *Business*	*Leisure*
Paris-London	A320	€548.22	€5.22	1.91-3.81%	3.97-7.94%
	B737	€512.63	€4.88	1.78-3.56%	3.71-7.42%
Madrid-Berlin	A321	€1,597.42	€12.34	2.25-4.50%	4.69-9.37%
	B757	€2,225.32	€15.90	2.90-5.80%	6.04-12.08%
Lisbon-NY	B767	€3,870.07	€29.10	0.48-0.86%	1.81-3.21%
	A332	€4,925.77	€23.85	0.40-0.70%	1.48-2.63%
London-Tokyo	B744	€14,500.97	€49.32	0.65-1.09%	2.45-4.08%
	A346	€9,363.77	€35.20	0.47-0.78%	1.75-2.91%
	B773	€10,183.03	€42.29	0.56-0.93%	2.10-3.50%

Source: Impacts calculated using emissions obtained with CORINAIR emission factors, verified against PIANO simulations. Elasticities compiled by Gillen et al (2004) for different flight categories

Results also suggest that, *ceteris paribus*, demand for flights will suffer a greater impact in flights where "kilometres flown per Euro paid for an air ticket" are higher. This conclusion, however, is based on the assumption of constant demand price elasticities, which might be regarded as an oversimplification.

This conclusion, however, is non-trivial. Any hope of reducing emissions as a consequence of demand reduction would be placed on a reduction of leisure trips in the first place, and, within that group, in short-haul trips. The link between demand reduction and flights suppressed is missing and it cannot be established based on readily available information. The final reduction in the number of flights would partly determine the reduction in emissions from aviation. Cairns and Newson (2006, Figure 3.1, p.24) report that over 50% of all trips arriving or leaving from UK airports are for leisure purposes. If this share prevailed in the whole of the EU, then there would be a serious possibility of reducing emissions through the use of a charge, provided the number of flights were reduced in response to the reduction of passenger demand for leisure trips. Unfortunately there are no data available on the distribution of trip purposes for flights departing from different EU airports.

Taking into consideration the different levels of CO_2 emitted by older (B757, B767) and newer (A321, A332) aircraft, it is reasonable to assume that the use of newer aircraft in a given

flight would lead to smaller reductions in demand for that flight, since the impact of emissions on prices would be lower. This would suggest at first that economic instruments should provide airlines with an additional incentive for fleet renewal and should strengthen fuel-efficiency as a decision factor in aircraft purchase. However, it is unclear whether this difference in demand reduction is large enough for this incentive to be significant in the short term. Furthermore, it has been suggested (Wit et al, 2005, p.132) that airlines could make use of cross-subsidisation to balance the negative effects that the older share of their fleet might have on demand.

Amongst different policy options, it is clear that the environmental charge of €42 per tonne of CO_2 has the greatest impact on demand, followed by the ETS scenario with an auction clearing price of €30 per allowance. That being said, one can notice that the use of grandfathering as a method of allocation reduces the intensity of the demand-side effects. In the cases considered, when allowances are grandfathered, the reductions in demand are negligible. Given that all policy costs are passed on to customers and that it is assumed that the purchase of additional allowances is preferred to supply-side abatement measures, it can be concluded that, in this scenario, including aviation in the ETS will have virtually no impact on the emissions of the air transport sector itself.

The case for auctioning is not strong either, since aviation would still be included in a scheme where the price of allowances is determined by demand from all participants, and therefore inextricably linked to abatement costs of every trading sector. Given that abatement measures in air transport are much more expensive than in other sectors, aircraft operators are likely to become mere purchasers of allowances. This idea is further developed in section 5, where theoretical, political and feasibility considerations are taken into account in a broader comparison of the use of price and quantity controls in the air transport sector.

Table 6: Estimated impact of the inclusion of the aviation sector in the EU ETS on ticket prices (100% auctioning scenario)

Flight	Aircraft	Allowances at 7€/tCO₂				Allowances at 15€/tCO₂				Allowances at 30€/tCO₂			
		Total policy costs	Impact on ticket price	Impact on Demand Business	Leisure	Total policy costs	Impact on ticket price	Impact on Demand Business	Leisure	Total policy costs	Impact on ticket price	Impact on Demand Business	Leisure
Paris-London	A320	€91.37	€0.87	0.32-0.64%	0.66-1.32%	€195.79	€1.86	0.68-1.36%	1.42-2.83%	€391.58	€3.73	1.36-2.72%	2.83-5.67%
	B737	€85.44	€0.81	0.30-0.59%	0.62-1.24%	€183.08	€1.74	0,64-1,27%	1.33-2.65%	€366.16	€3.49	1.27-2.55%	2.65-5.30%
Madrid-Berlin	A321	€266.24	€2.06	0.38-0.75%	0.78-1.56%	€570.51	€4.41	0.80-1.61%	1.67-3.35%	€1141.01	€8.81	1.61-3.22%	3.35-6.70%
	B757	€370.89	€2.65	0.48-0.97%	1.01-2.01%	€794.76	€5.68	1.04-2.07%	2.16-4.31%	€1589.51	€11.35	2.07-4.14%	4.31-8.63%
Lisbon-NY	B767	€645.01	€4.85	0.08-0.14%	0.30-0.54%	€1382.17	€10.39	0.17-0.31%	0.64-1.15%	€2764.33	€20.78	0.34-0.64%	1.29-2.29%
	A332	€820.96	€3.98	0.07-0.12%	0.25-0.44%	€1759.20	€8.52	0.14-0.25%	0.53-0.94%	€3518.41	€17.04	0.28-0.50%	1.06-1.88%
London-Tokyo	B744	€2416.83	€8.22	0.11-0.18%	0.41-0.68%	€5178.92	€17.62	0.23-0.39%	0.87-1.46%	€10357.83	€35.23	0.47-0.78%	1.75-2.92%
	A346	€1560.63	€5.87	0.08-0.13%	0.29-0.49%	€3344.20	€12.57	0.17-0.28%	0.62-1.04%	€6688.41	€25.14	0.33-0.56%	1.25-2.08%
	B773	€1697.17	€7.05	0.09-0.16%	0.35-0.58%	€3636.80	€15.10	0.20-0.33%	0.75-1.25%	€7273.59	€30.21	0.40-0.67%	1.50-2.50%

Source: Impacts calculated using emissions obtained with CORINAIR emission factors, verified against PIANO simulations. Elasticities compiled by Gillen et al (2004) for different flight categories.

Table 7: Estimated impact of the inclusion of the aviation sector in the EU ETS on 2017 ticket prices (grandfathering scenario with a 2012 baseline target)

Flight	Aircraft	Allowances at 7€/tCO₂				Allowances at 15€/tCO₂				Allowances at 30€/tCO₂			
		Total policy costs	Impact on ticket price	Impact on Demand Business	Leisure	Total policy costs	Impact on ticket price	Impact on Demand Business	Leisure	Total policy costs	Impact on ticket price	Impact on Demand Business	Leisure
Paris-London	A320	€19.80	€0.19	0.07-0.14%	0.14-0.29%	€42.42	€0.40	0.15-0.29%	0.31-0.61%	€84.84	€0.81	0.29-0.59%	0.61-1.22%
	B737	€18.51	€0.18	0.06-0.13%	0.13-0.27%	€39.66	€0.38	0.14-0.28%	0.29-0.57%	€79.33	€0.76	0.28-0.55%	0.57-1.15%
Madrid-Berlin	A321	€57.68	€0.45	0.08-0.16%	0.17-0.34%	€123.60	€0.95	0.17-0.35%	0.36-0.73%	€247.20	€1.91	0.35-0.70%	0.73-1.45%
	B757	€80.35	€0.57	0.10-0.21%	0.22-0.44%	€172.19	€1.23	0.22-0.45%	0.47-0.93%	€344.37	€2.46	0.45-0.90%	0.93-1.87%
Lisbon-NY	B767	€139.74	€1.05	0.02-0.03%	0.07-0.12%	€299.45	€2.25	0.04-0.07%	0.14-0.25%	€598.90	€4.50	0.07-0.13%	0.28-0.50%
	A332	€177.86	€0.86	0.01-0.03%	0.05-0.10%	€381.14	€1.85	0.03-0.05%	0.11-0.20%	€762.27	€3.69	0.06-0.11%	0.23-0.41%
London-Tokyo	B744	€523.61	€1.78	0.02-0.04%	0.09-0.15%	€1122.03	€3.82	0.05-0.08%	0.19-0.32%	€2244.05	€7.63	0.10-0.17%	0.38-0.63%
	A346	€338.11	€1.27	0.02-0.03%	0.06-0.11%	€724.53	€2.72	0.04-0.06%	0.14-0.23%	€1449.06	€5.45	0.07-0.12%	0.27-0.45%
	B773	€367.70	€1.53	0.02-0.03%	0.08-0.13%	€787.92	€3.27	0.04-0.07%	0.16-0.27%	€1575.85	€6.54	0.09-0.14%	0.32-0.54%

Source: Impacts calculated using emissions obtained with CORINAIR emission factors, verified against PIANO simulations. Elasticities compiled by Gillen et al (2004) for different flight categories.

5. Prices vs. Quantities

A standard result in environmental economics is that even though environmental charges and a system of tradable emission permits are identically efficient in a perfect-information scenario[8], they differ in efficiency under uncertainty (Weitzman, 1974).

In the case where the Marginal Abatement Cost (MAC) curve is known with certainty but the Marginal Social Benefit (MSB) curve is not, quantity and price controls will result in welfare losses of equal magnitude. However, if marginal abatement costs are not known with certainty, the performances of both types of instruments differ. Both types of policies result in undesirable effects, but the relative magnitude of these effects for each policy depends on the shapes of the MAC and MSB curves (Baumol and Oates, 1988, p.63). In general, the steeper the slope of the MSB curve relative to the MAC curve, the less severe the magnitude of the distortions caused by tradable permits compared to that caused by charges will be; and the steeper the slope of the MAC curve relative to the MSB curve, the more severe the magnitude of the distortions caused by tradable permits compared to that caused by charges will be.

The first conclusion makes a strong case for the use of emission charges in aviation, given that marginal damage of aviation emissions (and therefore the marginal social benefit derived from their reduction) is fairly constant (Carlsson and Hammar, 2002, p.370). The second conclusion, on the other hand, is not immediately applicable to aviation, mainly because very little is known about MAC curves for this sector.[9] In any case, if the MSB and MAC curves are

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[8] If the optimum amount of permits is made available in the market, their price will be bid up to exactly the level of the optimal Pigouvian tax, provided that social damage and abatement cost functions are perfectly known.

[9] ICF (2006, p.12) has produced curves for the marginal cost of carbon instruments (allowances, credits and abatement measures) as a function of the amounts abated, which suggest that the marginal costs of abating emissions in the aviation sector might be steep. The general shape of the curves obtained allow for three very distinct regions to be identified: one where marginal costs are negative, corresponding to the decision of selling the allowances that were grandfathered to the sector; one where marginal costs are fairly constant in the 10-30 €/t region, corresponding to the sector buying allowances at market prices; and one where the costs per tonne undergo a very sudden convex

assumed to be linear, an emissions charge will be preferable to an emissions trading scheme provided that the absolute value of the slope of the cost curve is greater than that of the marginal benefits curve (Baumol and Oates, p.68). Regarding aviation emissions, this condition on the relative slopes of the MAC and MSB curves is very likely to be satisfied, which would mean, at least theoretically, that price controls are preferable to quantity controls for mitigating emissions from this sector.[10]

5.1 Stakeholder views

Although an emissions charge equal to the social cost of carbon may sound attractive from the point of view of reducing emissions, it would probably not find much consensus within the aviation industry, mainly because of the very high costs of emission abatement, which would leave airlines with no option but to face the cost of their environmental externality.

Amongst airlines and international aviation organisations, emissions trading is by far the preferred instrument to be employed. Open trading with other sectors, allocation of allowances by grandfathering and the coverage of CO_2 alone are defended by most airlines as elements of design of the scheme (British Airways, 2005, p.5; EC, 2005b, p.26*; Thompson, 2006, p.2).

An interesting case is that of Lufthansa: it is one of the few airlines that opposes to the inclusion of aviation in the ETS. According to Karlheinz Haag, Head of Environmental Issues of the company, in a recent presentation at the CarbonExpo 2006 (Cologne, Germany), this measure would bring unacceptable costs and risks to the industry, whereas the environmental impact would be negligible (see Haag, 2006, p.2).

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increase, corresponding to the adoption of abatement measures. The shape of this third region of the curve suggests that the marginal cost of abatement in the sector of aviation might be steep.

[10] This conclusion could be challenged on the grounds that, if abatement measures are indeed assumed to be much too expensive to be considered by operators, this context is equivalent to a perfect information scenario where abatement costs are known, but are prohibitively high. Therefore, Weitzman's conclusions of non-equivalence between price and quantity controls do not apply even if there is some uncertainty on the costs of these measures.

Amongst aircraft manufacturers, the idea of employing any economic instrument to mitigate emissions from aviation does not find much support. Some manufacturers feel that this would have little impact on the reduction of fuel consumption and that the additional burden on airlines could actually slow down fleet renewal (EC, 2005b, p.20).

Other energy intensive sectors currently participating in the EU ETS are strongly opposed to the inclusion of aviation in the scheme. They believe that, since air transport has a very low amount of CO_2 emissions per unit of sales and is perfectly able to pass on the policy costs to customers (as seen in section 4), the position of airlines in the EU ETS would be reduced to that of a net purchaser of allowances (EC, 2005b, p.5). The view of these sectors is that, including aviation would therefore accelerate the increase in allowance price and reduce the amount of allowances available to other sectors, impairing their competitiveness (EC, 2005b, p.27). ICF, (2006) and Wit et al (2005), on the other hand, show that, even if aircraft operators opt not to abate at all, the inclusion of aviation in the EU ETS would have virtually no impact on the price of allowances.

Throughout this study, it has been argued that public opinion has a very negative view of the aviation business concerning the environment. In a recent public consultation by the European Union (EC, 2005b, p.3), 82% of respondents stated that they would fully support the inclusion of air transport in the EU environmental policy framework. Many of them felt that aviation enjoys an unfair advantage in comparison to other modes of travel, since it is exempt from many types of taxes (e.g. VAT and fuel taxes) (EC, 2005b, p.11).

It is also worth noting that there is a widespread belief amongst air transport stakeholders that the impact of aviation emissions on the environment is overestimated by public opinion (Thompson, 2006, p.1). Airlines admit they have very little potential for reducing emissions, but they also recognise the existence of a serious public image issue (Thompson, 2006, p.1). In this context, it appears reasonable that the majority of airlines support the participation of aviation in the EU ETS, as it would help improve their perception by the public while keeping the impact on costs and demand to a minimum. This is why the inclusion of aviation in the EU ETS is

perceived by some as a strategy for the sector to postpone dealing with its impact on climate change, whilst cleaning its image (EC, 2005b, p.27).

5.2 A pragmatic analysis

The choice of a policy instrument is, above all, a political decision. Therefore, it is very unlikely that any choice will be made without regard to more practical aspects, such as transaction, organisation and compliance costs for each of the policy alternatives, barriers to new entrants, pressure and support from the industry and the nature of the reduction targets themselves. This is why, for example, revenue-neutral charges and grandfathering of permits are not at all unrealistic policy options, even if from a theoretical point of view they are much less stringent. It must be highlighted, in addition, that the theoretical comparison between price and quantity controls presented in section 5 limited its analysis to static policy designs. Timely revisions of the economic policy can amend what would otherwise comprise very unsatisfactory policy choices.

From the regulator's point of view, there is one main advantage of using the EU ETS for the mitigation of emissions from air transport, which is the fact that the effect in terms of emissions reductions is known – a very desirable characteristic in a potentially target-oriented post-2012 scenario. Another argument put forward by the EU is that the addition of more sectors to the trading system helps diluting compliance and transaction costs (EC, 2000, pp.27-28). Nonetheless, the very presence in the EU ETS of other sectors with much cheaper abatement options than those in aviation creates a rather problematic situation: in its current form, emissions trading will not lead to any reduction in air transport emissions in the near future. In fact, despite their plurality in nature (as seen in section 4.1), emission abatement opportunities in aviation appear to be prohibitively costly for any open multi-sector trading scheme to function properly. Since its inclusion in the EU ETS is expected to have little or no impact on allowance prices, airlines will simply choose to buy allowances from other sectors instead of abating their own emissions, as this will be much more cost-effective.

From the perspective of aircraft operators, there are many benefits in participating in the EU ETS as opposed to being subject to emission charges. The main advantage is that, assuming that the allocation method is kept unchanged until 2012, operators are likely to receive most of the allowances they will need for free[11]. Furthermore, as results presented in section 4.2 have shown, airlines would be fully able to pass on the cost of allowances to customers without creating significant negative impacts on demand.

From the point of view of social efficiency, transaction costs comprise an important component that could *a priori* be seen as an argument against the use of emissions trading in aviation. However, these costs are likely to be well absorbed when the trading entities are large companies, whereas a market with numerous small trading entities would be better suited for the implementation of an emissions charge (Tietenberg, 1990, p.30). It is safe to say that the airline market would fit the first category.

6. Conclusions and policy recommendations

Emissions from air transport are a complex issue. They have a significant impact on climate change, representing over 3.5% of all radiative forcing from human activity and yet they represent, in monetary terms, less than 0.03% of the GDP as an externality in the EU, as calculated in section 2.1.

Though widely seen as an environmentally unfriendly activity, aviation has had very little political pressure to curb its emissions in the last decades. Therefore, one might regard the recent proposals to include air transport in the EU environmental policy framework as a big step towards the internalisation of external costs of the sector. However, the conditions through which this is made – the choice of economic instruments, the level of stringency of the

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[11] One should add that, in the event of a severe drop in the level of activity of the aviation sector, aircraft operators would be able to sell unused allowances to other sectors. Since most of these allowances would have been received at no cost, participation in the EU ETS could also be regarded as a form of insurance.

emissions cap or the charge level adopted – are of utmost importance to determine the magnitude of the resulting abatement.

It is clear from the results in section 4 that neither of the policy alternatives considered for the inclusion of aviation in the EU ETS – auctioning or grandfathering – are able to curb emissions from the aviation sector itself. An environmental charge set at the estimated social cost of CO_2 would achieve a reduction if leisure trips, which correspond to flights with relatively higher elasticities, represent an important share in the total number of trips. Data on flight purpose for Europe are not collected, and therefore there is at present no way of estimating the potential reduction in emissions.

From the demand perspective, reductions are proportional to the increase in prices caused by each type of policy, and therefore depend on the real costs imposed on aircraft operators. On the supply side, abatement alternatives are abundant, but simply not worth their price compared to the stringency of any of the instruments at the prices considered. In this context, it can be concluded that the choice of economic instrument within the air transport sector is in fact dependant on the objective of the regulator.

If the objective is to curb emissions from the air transport sector itself, then it is imperative that aviation is treated separately from other sectors. The reason for this is that, in any multi-sector policy, the target pursued by the regulator is an aggregated one, be it in terms of total reductions (quantity controls) or marginal abatement costs (price controls). In this case, the determination of the cap or the charge level will take into account abatement costs from all sectors, and the functioning of economic instruments will cause emissions to be curbed in those sectors where these costs are lower. It should be stressed that it is in fact a desirable characteristic of economic instruments and not an imperfection.

Under this condition, treating the air transport sector separately would allow for its own abatement costs to be the determinant factors of the stringency of the regulation. Two main alternatives could be envisaged, in terms of IB regulation: the implementation of an en-route emissions charge and the creation of an isolated emissions trading scheme for aviation. The first

proposition might be favoured *a priori* due to its theoretical superiority to quantity controls under uncertainty, but one must be aware that the implementation of such a measure would face ferocious resistance from the industry, as explained in section 5. The second proposition would involve greater organisation and transaction costs in its implementation, but the flexibility in many variables of the design of such a scheme could probably be used for bargaining with the sector and therefore obtaining wider support. A proposal to introduce a separate dedicated scheme for aviation emissions was produced by the European Parliament on 4 July 2006 (European Parliament, 2006), on the basis that accounting would be simplified by a separate, closed system. This proposal went further to say that if the aviation sector were eventually incorporated into a wider ETS, a cap on the number of emission allowances it would permitted to buy from the market should be imposed, together with a requirement of minimum emission reduction without trading, before being allowed to buy permits.

If the aviation sector were included in the EU ETS, the addition of this new sector to the scheme would help dilute transaction and organisation costs, and the regulator would have the advantage of knowing the resulting reduction in advance. Even though the use of charges would still be theoretically superior under uncertainty, this would in all likelihood be counterbalanced by the support received from stakeholders.

Should the 2006 proposal by the EU Parliament to impose special conditions on the air transport sector for its inclusion in the EU ETS be actually implemented, the sector would be forced to comply with a minimum required reduction before being able to trade. Once airlines enter trading, Once airlines enter trading, it can be expected that they will become net buyers of allowances, given their high abatement costs relatively to other sectors, and no further emission reductions would be expected from aviation from this point on. This would, however, tighten the aggregate cap for the remaining sectors, thus fulfilling the primary objective of the ETS: to make emission reductions take place where they are the cheapest.

From the perspective of airlines and air transport organisations, the inclusion of aviation in the EU ETS with no special conditions has some very clear advantages. Firstly, given the

current use of grandfathering as the method of initial allocation, it is likely that the inclusion of the sector in the EU ETS will impose much smaller costs on aircraft operators than it would be the case with the adoption of emissions trading under auctioning, emission charges or any type of policy where aviation were treated separately. Secondly, and perhaps most importantly, becoming a participant in the current EU ETS, even if under no special conditions, would represent an excellent opportunity for airlines to improve their public image at very small costs and with little or no reduction of its own emissions. This would explain, at least in part, the support that the majority of these stakeholders have been demonstrating towards the adoption of quantity controls in aviation.

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