INDIRECT TAXES ON INTERNATIONAL AVIATION

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Abstract: Over the last year or so there has been much (heated) discussion of the possible use of internationally coordinated indirect taxes on international aviation as a source of finance for development assistance, culminating (so far) in the recent commitment by 14 countries to apply such a tax. Abstracting from issues concerning the use to which the revenues that it would raise might be put, this paper considers the strengths and weaknesses of the leading candidate instruments of this kind. It argues that, on both policy and administration grounds, the case for levying indirect taxes on international aviation is in principle strong: the indirect tax burden on international aviation is currently very low, yet aviation contributes significantly to border-crossing environmental damage, is just as proper an object of taxation as any other commodity, and incipient tax competition is likely to result in these taxes being set at inefficiently low levels. But the form(s) in which such taxes are levied matters. A tax on aviation fuel would address the key border-crossing externalities most directly. A tax on final ticket values would have greater revenue potential, and some distributional advantage. Departure/arrival taxes face the least legal obstacles and have the merit of already being commonplace—but are much blunter instruments. Optimal policy, it is shown, typically requires deploying both a fuel tax and a ticket tax, and the paper explores, both in principle and by simulation, the key considerations and trade-offs involved in designing a suitable indirect tax regime for international aviation. In revenue terms, a fuel tax of 20 US cents per gallon (10 percent, at today's fuel prices)—a fairly conservative estimate of the associated marginal environmental damage—would raise about US$10 billion if imposed worldwide, and USD 3 billion if applied only in Europe. The same amounts would be raised by a ticket tax of about 2.5 percent. Taking account too of standard efficiency considerations, rates and revenue would be significantly higher.

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I. Introduction

There has recently been much discussion of the potential use of global taxes—taxes adopted, that is, by some set of countries on a coordinated basis—as a source of additional finance for development: see in particular the Landau Report (2004), Quadripartite Group (2004), and Atkinson (2005). Prominent among the candidate taxes for such a role is some form of indirect tax on international aviation. Discussion of such aviation taxes, and voluntary levies of similar nature, has been the subject of lively debate within the European Union. And policy initiatives in this area have recently emerged. In March 2006, a group of 14 countries[1] committed themselves to impose aviation departure taxes, earmarked for development financing. For France, Chile and Norway, these will be new taxes;[2] for the U.K., some fraction of existing departure taxes will be earmarked in this way. One estimate is that these taxes will yield around US$260 million annually, with the suggestion that this be earmarked to finance measures to counter AIDS, malaria and tuberculosis.

The purpose of this paper is to explore the public finance of indirect taxes on aviation,[3] which has been little considered. The analysis will largely leave aside the issues that arise from the prospective use of the proceeds to finance development rather than simply to augment national tax revenues (these issues being largely the same for all candidate global taxes).[4] The aim is to identify, analyze and assess the merits of various forms of aviation taxes as tax policy measures in their own right.

The central arguments in favor of enhanced taxation of aviation, especially international, are easily stated. Such taxes are currently low (as will be seen). Yet (as will also be seen) aviation

[1] Brazil, Chile, Republic of Congo, Cyprus, France, Ivory Coast, Jordan, Luxembourg, Madagascar, Mauritius, Nicaragua, Norway, Republic of Korea and the United Kingdom.

[2] The tax in France, to be imposed from July 2006, will be highly differentiated: for economy class the maximum rates will be 1 Euro per departure to destinations within Europe, 4 Euros to elsewhere; for business- and first-class travelers, 10 and 40 Euros respectively. The tax in Chile, implemented from the start of 2006, is a US$2 departure tax on all international travelers. The rate of the tax in Norway, to be implemented from 2007, remains unclear; this will be a new tax on aviation, but with a revenue-offsetting reduction in carbon taxes.

[3] Airlines are of course subject to corporate tax on their earnings by standard rules of international taxation: typically, under reciprocal arrangements they are taxed only in their country of residence. Direct taxes are not considered here, and for brevity the unqualified term ‘aviation taxes’ refers in what follows only to indirect taxes.

[4] There is however one point worth noting. A key question with any candidate global tax for development finance is that of additionality: the extent to which the additional finance from such a source would be offset by reductions in other forms of support. On this, see World Bank (2005), Boadway and Keen (2006), and Zee (2006). Broadly speaking, viewing foreign assistance as a Samuelsonian public good to those who finance it, there is additionality from a coordinated tax reform amongst them only in so far as this increases the overall efficiency of their tax systems (with its extent then depending on the degree to which the associated increase in real income generates an increase in giving). In this respect, the stronger is the case for expecting efficiency gains from increased indirect taxation of international aviation, the stronger too is the case for using the proceeds for development finance.

causes significant border-crossing environmental damage, including air pollution (to a large extent on the macro, regional or global scale) and noise (largely on the micro scale, depending on the location of airports). There may also be a case for a corrective tax on aviation to address greenhouse effects—emissions related to international aviation are, notably, excluded from the Kyoto protocol. Even apart from border-crossing environmental harm, however, taxes on international aviation may be inefficiently low as a result of tax competition, with countries acting independently choosing to set taxes lower than they would if they behaved in concert, so as to avoid jeopardizing domestic carriers and/or tourist sectors.

These generalities leave many important issues of detail to address. One key issue is which of several possible forms such a tax might take. It might be levied, in particular, on fuel use, as a tax on tickets, and/or as a departure/arrival tax on each trip. Several questions then arise, and are the focus here. Should several of these indirect tax instruments be used, or just one? If only one, which should it be? What would be the appropriate rates of such taxes, and how much revenue would they raise? Are they consistent with existing international aviation law and custom? Could they be administered and complied with at reasonable cost? Do the factors that have kept such taxes low in the past mean that it is unlikely to be possible to raise them in the future? Not least: if taxes on international aviation are clearly too low, why have they not been raised before?

The plan of the paper is as follows. Section II takes a first look at the various forms of aviation tax and the main border-crossing externalities arising from international aviation. Section III develops basic principles for aviation taxes, formally in a stylized theoretical model and then considering informally the implications of other potential distortions in the aviation market. Section IV considers the appropriate rates of aviation taxes, and the revenue they would yield. Section V considers practical issues of administration and compliance. Section VI concludes.

II. Background

This section outlines issues and experience with the main types of indirect taxes on aviation and reviews the environmental externalities associated with international aviation.

A. Types of Aviation Taxes

There are three main possible types of indirect tax on aviation: [5] [6]

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[5] Taxes might also be levied on local air pollution, noise, or the use of airspace. While well-targeted to particular difficulties, they have not featured prominently in recent discussion and none appears to be in current in use (except for a noise tax at airports in Switzerland).

[6] Aviation is also subject to a wide range of fees and charges. Most—such as airport landing charges, passenger security charges, and route facility charges imposed by air navigation services—are essentially user fees.

- An **excise tax**—meaning one that (unlike, in particular, the VAT) is not creditable or refundable to business users—**on aviation fuel**, which, for brevity, it is assumed throughout would be levied in specific form (that is, as a fixed amount per gallon).[7]

- A **ticket tax**, by which will be meant an ad valorem charge on sales of passenger tickets and cargo waybills (whether as VAT or a non-creditable excise—there being, as will be seen, important differences between the two).

- A **trip tax**, meaning a charge that is levied on passengers as a fixed amount per trip, and at a common rate for all trips within some wide class—the familiar departure tax is the leading example.

There are important similarities between the three types of tax. Under perfect competition for a homogeneous product of unchanging characteristics, for instance, ad valorem and specific taxes have precisely the same effects: thus a ticket tax levied as a non-creditable excise would be equivalent to a trip tax levied in the same monetary amount. If, further, there were no possibility of changing fuel efficiency, then they would also be equivalent to a tax on aviation fuel.

But there are also important differences between these instruments. Critically, aviation fuel is an intermediate input (as is business cargo and, at least to some degree, business travel). Under conditions that are strong but provide a useful first guide to policy formation, the Diamond and Mirrlees (1971a, b) theorem on production efficiency implies that—in the absence of externalities—such items should not be taxed. Thus the fundamental rationale for taxing aviation fuel and business travel and freight is the environmental damage referred to above, and explored more fully below. Passenger travel, in contrast, is a final consumption item and so is potentially a proper target for final commodity taxation. More generally, differences between these types of tax arise from the potential differentiation (under a VAT-type ticket tax) between business and final use, substitution possibilities in the use of fuel, and from the heterogeneity of the product (both across flights—so that the ad valorem equivalent of a fixed trip charge will vary—and across classes of travel for a given flight).

With this in mind, we now look at current practice in respect of these three forms of indirect tax:

Taxes on Aviation Fuel

Domestic aviation fuel is generally subject to VAT. However, since aviation fuel is typically a business input this component of tax will (in principle at least) be fully credited to registered taxpayers, and so have little economic impact. More relevant to the concerns here, many

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[7] Specific taxation is the norm for fuel excises. This reflects a variety of considerations, including the relative constancy of revenues that it implies, given relatively inelastic demand, in the face of variable oil prices.

countries also charge excises on aviation fuel used for domestic flights, sometimes at rates differentiated between propeller planes (which use aviation gasoline) and jets (which use kerosene).

Systematic data on aviation fuel taxes are hard to come by. Table 1 reports the rates recently applied to domestic aviation fuel in a selection of countries. In the United States, domestic aviation fuel is taxed at the state level, with rates varying across them (and no tax in some).[8] Table 1 reports both the specific amount and the ad valorem equivalent. The rates are in many cases similar for aviation gasoline and jet fuel, but where they differ the jet fuel tax (the more important in practice) is the lower. Among OECD countries, Norway has had a domestic aviation fuel tax since 1999 (currently equivalent to US$0.16 per gallon).[9] The Netherlands and Japan have recently imposed higher domestic aviation fuel taxes (respectively 0.20 and 0.24 Euro per liter).

Under the VAT, items related to international transport are generally zero-rated (meaning that no tax is charged on sales, and any tax paid on inputs is refunded). In sharp contrast to the high excise rates that are often charged on other fuels, no country appears to levy either an excise of VAT on fuel used for international flights.

This exemption of international aviation fuel is to a large degree enshrined in the legal framework of international aviation:

- Article 24 of the 1944 Convention on International Civil Aviation (the 'Chicago Convention'[10]), requires that: "Fuel, lubricating oils [and other items] on board an aircraft of a contracting State, on arrival in the territory of another contracting State and retained on board on leaving the territory of that State, shall be exempt from customs duty, inspection fees or similar national or local duties and charges."[11] The Chicago Convention does not, however, prevent countries from taxing fuel purchased for international flights in their own jurisdictions; nor from taxing aviation fuel used on purely domestic flights, even if tanked abroad. But it does mean that they cannot undo any incentive for carriers to fuel flights from that country by tanking in lower tax jurisdictions.

[8] Some states provide airlines with guarantees as to the maximum amount of fuel tax they will pay.

[9] See ECON (2005) for a further discussion of the Norwegian aviation tax regime and its development.

[10] The Chicago Convention provides the legal framework for international civil aviation, and establishes the International Civil Aviation Organization (ICAO). Its 188 signatories include those countries most prominent in civil aviation.

[11] The interpretation of this article is clarified in a 1999 resolution of the International Civil Aviation Organization, spelling out for instance that it is intended to apply to local as well as national taxes, and to non-scheduled as well as scheduled flights (ICAO, 2000).

- Bilateral air service agreements also typically include a mutual agreement not to tax aviation fuel. In the EU, however, there is now no direct legal impediment to the taxation, by mutual agreement, of aviation fuels used on intra-EU flights.[12]

The rationale for these legal undertakings is by no means clear. They may reflect a sense, in the early days of the industry, that international air travel conveyed beneficial externalities, and ought to be positively encouraged. In any event, they place significant obstacles to the taxation of international aviation fuel.[13] Renegotiating the Chicago Convention seems out of the question. Air service agreements could be renegotiated bilaterally, and are to that extent perhaps a lesser obstacle; but their sheer number (there are several thousand) would likely make this a painstaking process.

Even in the absence of legal restrictions, international tax competition might lead to inefficiently low levels of fuel taxation. To the extent that planes are technically able to do so (a Boeing 747, for example, can in principle travel from New York to London and back on a single tank of fuel)—and to the extent that safety rules allow them to do so—high fuel taxes in any country could then be avoided by tanking in lower tax jurisdictions. Each country acting in isolation might well be inclined to set a low or zero rate in order to maintain its attractiveness relative to other destinations, or as hubs in airlines' operation patterns, even though collectively all would benefit from a mutual increase in tax rates. Collective action in rate-setting would then be required.

Ticket Taxes

Ad valorem taxes—proportional to the price charged—may also be levied on tickets issued to passengers and prices charged for cargo (waybills). These too may take the form of either a VAT or a non-creditable excise; and again treatment commonly varies between domestic and international travel. Here the role of the VAT is rather different, and potentially more significant, than in the case of aviation fuel: although the tax will typically be credited when charged on business-related travel, it will be final for purchases by final consumers.

Domestic air travel is quite widely subject to VAT, as shown in the first column of Table 2 for selected high income countries and the first column of Table 3 for selected developing and emerging market economies. In the EU, all member states except Denmark, Ireland and the United Kingdom charge VAT on domestic aviation services, although (except for Germany and the Netherlands) they do so at a rate lower than their standard.

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[12] This reflects Directive 2003/96 on energy taxation: see European Commission (2005a). Note too that the EU is regarded as a single state for purposes of the Chicago convention.

[13] For further discussion, see for instance Sledsens (1998).

Tables 2 and 3 also show non-creditable ad valorem ticket taxes imposed on domestic aviation. These are quite rare in high-income countries, being charged only by a few that do not levy VAT. The 7.5 percent charge in the U.S. is an earmarked security charge.[14]

International travel, on the other hand, is typically zero-rated under the VAT.[15] This is the case for all high-income countries in Table 2; a few developing and emerging market countries, however—notably in Latin America—do impose VAT on international travel. Ad valorem ticket taxes on international travel are also largely confined to developing and emerging market countries; and where levied they are generally at lower rates than apply domestically. Of the countries for which we have information, only Argentina levies both VAT and an ad valorem ticket tax on international travel. Note also that in the rather few cases in which international ticket taxes are levied, this is typically only for tickets sold in the country.[16]

Many countries—including for example Denmark, Hong Kong, Ireland, Israel, Singapore and the United Kingdom, and Brazil, China, Indonesia, Malaysia, Russia, Saudi Arabia, Turkey and Ukraine in the lower-income group--have no ticket taxes whatsoever.

Departure and Other Trip Charges

Tables 4 and 5 report per passenger charges, for high-income and developing/emerging-market economies respectively. While the IATA data used here distinguish between airport charges (which usually accrue to the airport authority) and arrival/departure taxes (which usually accrue to government), it is in many cases unclear to which of these two categories the charge should be allocated. Attention is thus best focused on the sum of the two, shown in the rightmost columns.

Per-passenger charges are evidently commonplace, though the detail varies (some differentiated by citizenship, for example, and some by class of travel). In some high-income countries, charges are substantial (highest in the U.K., at US$109 for first-class travelers to destinations outside the EU). Most important for present concerns, charges are typically higher for international than for domestic travel.[17] In some emerging market and developing countries

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[14] This includes a fixed charge of US$3.20 per segment for domestic air travel and US$14.10 per takeoff and landing for international travel (‘domestic’ includes a zone 225 miles north and south of the border): NBAA (2005)..

[15] All EU members except Sweden zero-rate international aviation activity, including flights among members. Sweden has an option to tax intra EU flights, as a derogation from 6th VAT Directive.

[16] In Argentina and Costa Rica, which have the most significant such taxes, travel beginning abroad is exempt, as are tickets sold outside Argentina to non-Argentines.

[17] Interestingly, this pattern in trip taxes runs counter to the impression formed above that the ticket taxes levied in low income countries are commonly higher for domestic than for international travel. It may be that trip taxes are a better-targeted way of taxing non-residents likely to have bought their tickets abroad.

(such as Colombia, Mexico, Pakistan, and Peru) charges for international travelers are near the highest levels found in high-income countries.

This differentially heavier taxation of international trips will tend to offset, to some degree and in some countries, the inefficiencies implied by the relatively advantageous treatment of international aviation in respect of ticket taxes and aviation fuel. Most of the countries with particularly high trip taxes account, however, for a relatively small part of global aviation. Those emerging markets that are larger in international aviation markets tend to have low rates (such as China, India, and several East Asian countries). And in high-income countries the offset is small except for a few that are, however, important in international aviation: Japan, the U.K., and, to some degree, the U.S.

B. Environmental Externalities

A key argument in favor of taxing aviation is that it generates adverse environmental externalities, creating a case for purely corrective taxation. Since the concern here is with taxing international aviation, it is only border-crossing externalities that are at issue: purely domestic damage from domestic aviation can in principle be dealt with, at least for the most part, by countries unilaterally, even given the legal obligations described above.

Air pollution

The main pollutants in the emissions from burning aviation fuel are NO_x, carbon monoxide, hydrocarbons, sulphates, and soot aerosols. A complicating factor is that some of these emissions, such as NO_x, affect the concentrations of other substances such as ozone and methane (pollutants and greenhouse gases) through complex chemical processes. And while NO_x increases ozone, other aviation emissions reduce it, with uncertain net effect. Air pollution effects from aircraft are more damaging in more populated areas, and emissions relative to distance traveled are greater in the vicinity of airports. Since many more international than domestic flights are long and over sea or deserted land areas, international aviation on average involves less air pollution (per unit of burned fuel) than domestic.

Global warming

Aviation fuels contribute to global warming through greenhouse effects due to emission of carbon dioxide.[18] At present, aviation accounts for only 3–4 percent of global carbon emissions, but the share is growing.: on one assessment,[19] by 2050 aviation will contribute at least 5 percent of carbon emissions, and possibly as much as 15 percent, with absolute effect 3.8 times the 1992 value. Other pollutants emitted by airplanes (nitrogen oxides, methane, water vapor,

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[18] Note that NO_x also has greenhouse gas effects when emitted at high atmospheric altitudes, through its interaction with ozone. This effect is less well studied than that of CO_2, but likely to be relatively minor.

[19] This estimate is from IPCC (1999), as are the others in the paragraphs that follow.

sulfates, and soot) may also contribute to global warming, although the effects and often even their signs are uncertain.

Noise

Most aviation noise arises near or at airports, with damage varying greatly by airport location and nearby population density. Noise problems far from airports are small, at least for (subsonic) jet flight at 10–12 km (Pearce and Pearce, 2002).[20] Noise pollution is thus essentially local, which implies that it in principle can be dealt with at the country level.

Pollution and congestion at airports

Pollution at airports (apart from that caused by fuels) includes local and groundwater contamination due to use of de-icing fluids, local oil spills, and other substances used for clearing or cleaning runways. Congestion at airports has two components. First, the air transport system may be congested, in runways and airspace. Secondly, there may be congestion in terminals, airport transport systems, and parking. This problem is usually of a peak-load character, and may be particularly serious when scaling-up airport size (in terms of terminal, parking and runway space) is difficult. With a single monopoly provider of air services, congestion externalities will tend to be fully internalized.[21] When several airlines operate at a given airport, however, inefficiency is liable to remain, so that congestion charges should be levied, typically at higher rates the more intense is the competition.[22] In practice, there are relatively few cases in which a single provider (or cooperating provider group) is fully dominant; so that internalization cannot generally be presumed. Again, however, this is generally a domestic rather than border-crossing matter.

Congestion due to passenger overcrowding at or near airports is also of little relevance to the case for international aviation taxes, since it can be corrected by purely domestic means, such as road user charges. In principle, local airport administrations should deal with externality costs arising at airports by charging such costs to users (airlines and/or passengers) through take-off and landing fees (preferably graduated by airplane size, fuel consumption and local noise created by airplanes) and other congestion-related charges (such as fees for local parking and for the use of terminals charged to passengers, and peak-load fees charged to airlines). Most airports do indeed charge substantial fees. Only the fees in excess of costs of constructing and

[20] Supersonic transport creates local noise problems similar to those of subsonic transport, but far greater non-local noise problems over populated land areas.

[21] Acemoglu and Ozdaglar (2005), Brueckner (2002).

[22] In Brueckner (2002), with airlines operating as Cournot oligopolists, the optimal toll equals the congestion cost from an extra flight multiplied by one minus the carrier’s flight share at the airport.

operating airports, however, can serve to correct for externalities: it is unclear whether these are set at such a level, and this may vary across countries and airports.[23]

Estimates of environmental harm from aviation

There have been few attempts to quantify the external damages associated with aviation. A careful study by Pearce and Pearce (2002) estimates overall marginal air and noise externalities from aviation for the U.K. to be about GBP0.07 per liter of aviation fuel, or about US$0.45 per gallon (varying somewhat across aircraft types): see Table 6. The great bulk of this comes from air pollution; and about half of that is from CO_2 emissions (with central estimate, quite widely used, of US$50 per ton, or about 20 US cents per gallon of aviation fuel).

Externalities from aviation may be higher in the UK than elsewhere, since incomes and population densities are relatively high. And noise pollution is more a matter for local and national policy, as noted above, than for international. On the other hand, the Pearce and Pearce estimates exclude the cost of some air pollution compounds (notably carbon monoxide and volatile organic compounds).[24]

In the discussion below, we therefore focus for brevity on two possible values of marginal environmental damage: US$0.4 per gallon, as a plausible estimate for higher income countries, and particularly within Europe; and US$0.2 per gallon, effectively valuing only CO_2 emissions and so corresponding to something of a lower bound.

III Optimal Indirect Taxes on Aviation

This section explores a simple model—capturing the key distinction between taxes on aviation fuel inputs, and ticket (or trip) taxes as a tax on final consumption—that enables a basic analysis and, later, simulation, of optimal indirect taxes on aviation.

A. No Cross-Border Damage

For clarity, we start (but will not end) with the case in which environmental damage does not cross borders, and in which there is no international mobility of the tax base. This means that the optimal policy of each country can be examined in isolation.

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[23] ICAO (2001) data suggest that, for most airports, fees and charges are lower than construction and operation costs. On the other hand, IATA (2005b) concludes that in the U.K., Germany and France the overall level of charges and taxes on passengers and airlines exceeds infrastructure costs.

[24] Looking forward, it is not clear whether marginal damage is likely to be higher or lower in the future: greater population densities and incomes will tend to increase it, while more fuel efficient and silent aircraft will tend to reduce it.

Denote output of the aviation sector—thought of passenger miles traveled—by *X*. This is taxed at specific (per unit) rate of τ; the market is assumed to be perfectly competitive (we return to this below), so that this is equivalent to (but algebraically less messy than) an ad valorem tax. For brevity, τ is referred to as a ticket tax, though it is clear that in the present simple setting—with only one, fixed type of journey—it is equivalent to a trip tax. There are constant returns, with unit cost denoted by $c(p+t)$, where *p* denotes the tax exclusive price of fuel (taken to be exogenous) and *t* a fuel tax in specific form. By standard results, the cost function *c* is convex, the use of fuel per unit output, *f*, is given by

$$c'(p+t) = f \ , \qquad (1)$$

and the curvature $c'' \leq 0$ indicates the ease of substitution between fuel and other inputs. The consumer price of the final output is $Q \equiv \tau + c(p+t)$.

The object of policy is then to choose the two tax rates, τ and *t*, to maximize welfare, given by[25]

$$W \equiv V(Q) + \delta[\tau X(Q) + tX(Q)c'(p+t)] - E(X(Q)c'(p+t)) \qquad (2)$$

where the indirect utility function *V* captures utility from private consumption, and environmental damage *E* is taken to be increasing and convex in aviation fuel use Xc'. The parameter δ represents the marginal social cost of raising revenue (to which the marginal benefit of public expenditure will optimally be equated), and enables one to capture in convenient summary form the extent of the deadweight losses associated with a wider tax system that is not explicitly modeled.[26] With lump sum taxation, there are no such distortions and $\delta = 1$. More generally, to the extent that distorting taxes must be used, δ > 1: if this were not the case, it would be socially preferable to raise no tax revenue at all.

The necessary conditions for this problem are:

$$\frac{\partial W}{\partial \tau} = -X + \delta(X + \tau X' + tc'X') - E'c'X' = 0 \qquad (3)$$

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[25] There is in the background a numeraire good taken (by normalization) to be untaxed. Preferences are quasi-linear, with all income effects concentrated on the numeraire. Note too that it is assumed throughout that each country may tax only the travel of its own citizens (which abstracts from a range of issues in tax exporting and tax competition likely to be significant to some tourist destinations) and that the load factor is 100 percent (abstracting from some issues of convenience and peak loading).

[26] For present purposes (since we shall be more concerned with characterizing tax policies than with their comparative statics) there is no real loss in treating the marginal value of public expenditure as a constant: the same characterizations would apply if revenue were valued by an increasing concave function with marginal value δ(.).

$$\frac{\partial W}{\partial t} = -c'X + \delta[\tau c'X' + c'X + tc''X + t(c')^2 X'] - E'(c')^2 X' - E'c''X = 0\,, \qquad (4)$$

use being made of Roy's identity (with the marginal utility of income normalized to unity). The system (3)-(4) has determinant $XX'c''$, and so has no unique solution when $c'' = 0$: in this case there is no substitution between fuel and other inputs, then a ticket (or trip) tax and a fuel tax are clearly equivalent in this framework. In the more relevant case in which $c'' < 0$, the optimal fuel and ticket taxes (both expressed as tax-inclusive ad valorem equivalents) are characterized by:

$$\frac{t}{p+t} = \frac{E'}{\delta(p+t)} \qquad (5)$$

$$\frac{\tau}{Q} = \left(\frac{\delta - 1}{\delta}\right)\frac{1}{\varepsilon(Q)} \qquad (6)$$

where $\varepsilon(Q) \equiv -X'Q/X > 0$ denotes the price elasticity of final demand (assumed throughout to be strictly positive in absolute value).

The importance of (5)-(6) is in showing a clear separation in the roles of the two types of tax: environmental damage enters only the characterization of the fuel tax, and revenue considerations drive the ticket tax (which has the standard form of a Ramsey tax in the absence of externalities). To see this separation most clearly, suppose that $\delta = 1$, so that there is no revenue-raising motive. Then it is optimal to set the fuel tax at the Pigovian level and not to tax tickets at all. At the opposite extreme, when there is no environmental damage ($E' = 0$), it is optimal to use only the ticket tax, setting the fuel tax to zero. The intuition behind these observations is straightforward. Aviation fuel is an intermediate input. As noted earlier, the Diamond-Mirrlees theorem then implies that in the absence of externalities it should not be taxed at all if there are no constraints on the taxation (through the ticket tax) of final consumption.[27] When there is no environmental damage, the distortion of input choices caused by a fuel tax would serve no socially useful purpose, and indeed would create an inefficiency in input choice that erodes potential tax revenues.

There is indeed an important trade-off to be faced between environmental and revenue concerns. This emerges clearly on noting that, it is easily shown, it is always possible to raise

[27] More generally, the result requires that there be no constraints on the ability to tax pure profits or to deploy a full range of distorting tax instruments.

more revenue with a ticket tax than with a fuel tax.[28] By the same token, whenever $\delta > 1$ the (second-best efficient) correction of the externality is in an important sense incomplete: unless lump sum taxation is available, the environmental charge is set below the Pigovian level. This is a standard result with a straightforward intuition: increasing the fuel tax towards the Pigovian level would lead to a reduction in the tax base, and hence revenues, that more than offsets the benefit derived from a reduction in external damage.[29] Thus the fuel tax component tends to be lower the greater is the need for revenue (that is, the higher is δ), whereas the ticket tax is increasing in δ.[30]

Given the evident difficulty of implementing any indirect tax on international aviation, let alone two, the case in which only one can be levied is of natural interest. The optimal levels of each tax when used in isolation are readily derived from (3) and (4) above, being

$$\frac{\tau}{Q} = \left(\frac{\delta - 1}{\delta}\right)\frac{1}{\varepsilon} + \frac{E'c'}{\delta Q} \tag{7}$$

for the ticket tax, and

$$\frac{t}{p+t} = \left(\frac{\delta - 1}{\delta}\right)\frac{1}{(1-\alpha)\sigma + \alpha\varepsilon} + \frac{E'}{\delta(p+t)} \tag{8}$$

for the fuel tax, where $\sigma \equiv (p+t)c.c''/c'.(c - c'(p+t))$ denotes the elasticity of substitution in production between fuel and a composite other input, and α the share of fuel in total costs.

As one would expect, (7)-(8) imply that the neat separation of roles found when both tax instruments can be used is lost: each is shaped by both revenue and environmental concerns, and the two possess the same additive structure.[31] The key structural difference is that whereas the optimal stand-alone ticket tax depends on the elasticity of demand, the optimal stand-alone fuel tax depends on a weighted average of that elasticity and the elasticity of substitution in production. If there is no possibility of substituting away from fuel use $(\sigma = 0)$, then the optimal

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[28] This follows from noting that the necessary conditions for maximizing revenue $T = \tau X(Q) + tX(Q)c'(p+t)$ are $X + \tau X' + tX'c' = 0$ and $\tau c'X' + c'X + t(c')^2 X' + tc''X' = 0$, which together imply $tc''X = 0$, and therefore that $t = 0$ so long as $c'' < 0$.

[29] For a fuller treatment of this issue in the more complex case in which aviation is not the only taxed good, see Strand (2005).

[30] It is assumed in this informal discussion, but not in the algebra, that marginal environmental damage and the elasticity of demand are both constants.

[31] This echoes Sandmo's (1975) result on the additivity of Ramsey and environmental terms in optimal taxes on final products.

stand-alone fuel tax (per unit of final output), tc', is identical to the stand-alone ticket tax, τ. In contrast, when $\sigma > 0$ the fuel tax is lower, by an extent that increases with the strength of substitution in production and decreases with the elasticity of final demand.

If then only one of these tax instruments can be used—a ticket tax or a fuel tax—which should it be? From the discussion above, it is clear that the answer hinges on the relative importance of environmental and revenue concerns. All else equal, the ticket tax is more likely to be preferred, the greater is the need for revenue and the lower is marginal environmental damage. The practical significance of this point, and others raised by the formal analysis in this section, are explored by simulation in Section IV.

B. Implications of Cross-Border Damage

A large part of the interest in taxes on indirect taxes on international aviation stems from the perception that it causes significant and at present largely uncorrected border-crossing environmental damage, as discussed above. So suppose now that there are (for simplicity, only) two countries, with the harm suffered by country i =1, 2 being, in obvious notation, $E_i(X_1 f_1 + X_2 f_2)$. Welfare in country i thus becomes:

$$W_i \equiv V_i(Q_i) + \delta_i[\tau_i X_i(Q_i) + t_i X_i(Q_i)c_i'(p+t_i)] - E_i(X_1(Q_1)c_1'(p+t_1) + X_2(Q_2)c_2'(p+t_2)) \quad (9)$$

where, note, the countries may differ in preferences and/or technology.

Cooperative taxation

Consider first the case in which countries cooperate in setting their tax rates, in the sense that each seeks to maximize $W_1 + W_2$. Each thus takes account of the impact of its tax choices on the environmental harm suffered by the other. It is easily seen that the optimally coordinated taxes are given by:[32]

$$\frac{t_i}{p+t_i} = \frac{E'}{\delta_i(p+t_i)} \quad (10)$$

$$\frac{\tau_i}{Q_i} = \left(\frac{\delta_i - 1}{\delta_i}\right)\frac{1}{\varepsilon_i} \quad (11)$$

where $E' \equiv E_1' + E_2'$ denotes the global damage from a unit increase in international travel.

[32] We abstract from considerations of cross-country equity by taking the marginal utility of income (normalized to unity) to be the same in each.

As one might expect, the ticket tax optimally differs across countries, reflecting differences in both the elasticity of demand and the strength of the need for revenue. Rather less obviously—and running counter to the notion that efficiency requires taxes on items that damage the collective commons to be uniform across countries—the optimal fuel tax also typically varies across countries. The point here is that even though the Pigovian marginal social damage that enters the optimal fuel tax expression is the same in the two countries—because it reflects their collective harm—the second-best considerations discussed above means that the optimal fuel tax is typically is lower in the country with the higher marginal cost of public funds: when δ_i is high, the environmental component is lower to mitigate the impact through pre-existing distortions, with the greater need for revenue reflected instead in a higher tax on the final product.[33]

Thus even when countries cooperate fully—and even in the absence of explicit concerns with international distribution of real income—it will typically be optimal for them to set different taxes, on both tickets and fuel, both to exploit differences in elasticity of demand and in reflection of their differing needs for government revenue.

Noncooperative taxation

Now suppose—more plausibly, at least at present—that countries do not cooperate in tax-setting but rather look to their own national interest: country *i* simply maximizes W_i. With each country taking as given the tax rates set by others, the Nash equilibrium non-cooperative tax rates are:

$$\frac{t_i}{p+t_i} = \frac{E_i'}{\delta_i(p+t_i)} \tag{12}$$

$$\frac{\tau_i}{Q_i} = \left(\frac{\delta_i - 1}{\delta_i}\right)\frac{1}{\varepsilon_i} \tag{13}$$

When both taxes are used in the pursuit of national rather than collective interest, equilibrium fuel taxes thus reflect only the harm that each country perceives for itself, and so are set lower than in the cooperative outcome. The characterization of the ticket tax, on the other hand, remains exactly as in the cooperative case.[34]

That the neglect of harm suffered abroad leads to fuel taxes being set at inefficiently low levels is evident enough, and easily verified: starting from a non-cooperative equilibrium, both

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[33] One would expect the same to be true even if the revenue is instead used to purchase a global public good, since the marginal valuation of that good is likely to vary across countries.

[34] The precise value will differ, reflecting the impact of the different level of the fuel tax on producer prices and hence, in principle, on the elasticity of demand.

countries would benefit from a coordinated increase in fuel taxes.[35] It is also readily shown that ticket taxes tend to be set too low in non-cooperative equilibrium.[36] The existence of this inefficiency in ticket taxes may seem strange, given that the characterization of these taxes in the non-cooperative equilibrium (equation (13)) is exactly the same as in the cooperative solution (11)—indeed if the elasticity of demand is constant, the numerical level of the ticket tax is precisely the same in the non-cooperative equilibrium as under full cooperation. The key point, however, is that unless fuel taxes are set to deal appropriately with environmental damage then moving ticket taxes away from the cooperative rule (or even level) may be desirable as a second-best means of reducing emissions.

While the analysis thus points to potential coordination gains, in the presence of border-crossing environmental damage, in respect of both fuel and ticket and taxes, those in respect of the former are in an important sense more fundamental and a more appropriate focus of policy: increasing ticket taxes from their non-cooperative level may convey a mutual benefit for the reason just noted, but is also likely to move those taxes away from their appropriate cooperative levels. Increasing fuel taxes from their non-cooperative levels, on the other hand, is likely to bring them closer to their cooperative levels, in the process eliminating any gain from ticket tax coordination and moving the combination of instruments towards the efficient outcome.

The magnitude of the coordination gains will depend on the nature and extent of asymmetries between the countries. It is likely to be greater the more similar are the countries: for if, in contrast, one country causes a large share of overall externalities, then it will to a large degree internalize these in its own decision-making.

C. Treatment of Business and Economy Travel

The analysis above treats air travelers as a homogeneous group. In reality the aviation market is highly segmented, between (and within) first, business and economy class. In terms of aviation fuel taxes it is likely to be impractical to distinguish between them—and also undesirable, if the sole purpose of the tax is to address externalities associated with fuel use. The question is whether it is desirable to distinguish between them in terms of ticket or trip taxes.

Clearly the elasticity of demand ε is likely to differ across these segments, and hence so too are optimal ticket and trip tax rates. A recent survey[37] confirms the natural presumption that business travel is indeed typically far less price-sensitive than economy or tourist travel: central

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[35] For example, a small increase in t_1 from the non-cooperative equilibrium has no effect on W_1 (as an envelope property) but increases W_2 by $-E_2'(X_1'(c_1')^2 + X_1 c_1'')dt_1 > 0$.

[36] Along similar lines to the preceding footnote, a small increase in country 1's ticket tax τ_1, for example, has no first-order effect on welfare in country 1 but increases welfare in country 2 by $-E_2' X_1' c_1' d\tau > 0$.

[37] Gillen, Morrison, and Stewart (2004).

estimates of the demand elasticity for business travel are around 0.25 for long-haul international travel, and around 0.6 for short-haul domestic travel; for economy-class travel they are around 1.0 and 1.3, respectively.[38] The analysis above would thus point to substantially higher ticket or trip taxes on business than on economy-class travel.

There are though other considerations that may serve to modify this conclusion. In particular:

- Interactions with the wider tax system are potentially important. When this leads consumers to take to excessive leisure (in the broad sense of time out of the labor market), optimal tax design involves counteracting this effect by taxing more heavily items that are more complementary with leisure. To the extent that economy travel tends to be for leisure, and business travel for business, this points in the opposite direction—a lower tax on business- than economy class travel.[39]

- To the extent that business class travel is a production input, the Diamond-Mirrlees theorem implies that it should be untaxed, so long as fuel is properly taxed. Even if fuel is not appropriately taxed, the point has potential force: taxing business travel may lead to such a reduction in aggregate output that any revenue gained by the tax itself would be more than offset by a reduction in the revenue that could be raised by other taxes (such as those on salaries, profits or final sales).

Where the balance of these considerations lies is not clear-cut. Not all economy-class travel is for leisure, and business travel may to some degree serve as final consumption. A reasonable conclusion appears to be that there is no overwhelming reason to differentiate between business and economy travel, and that the best form of ticket tax would in principle be a VAT, creditable to registered taxpayers (and of course subject to controls intended to deny credit for private use).

D. International Tax Competition

Countries are likely to be unwilling unilaterally to levy aviation taxes at levels that they fear will reduce their competitiveness—the market share of their own airlines and airports, or of their tourism industries—given the taxes charged by others. It is possible, for example, for parts of the airline business to change their location, in particular for air routes with more than one leg, by rescheduling routes and altering the hub structure in response to differential taxes between countries and individual airports. In the case of fuel taxes, bunkering in lower tax jurisdictions could emerge as a significant problem when fuel tax rates differ substantially. All this again points—for reasons familiar, for example, in relation to the taxation of internationally

[38] European Commission (2005a,b) takes a central estimate of -0.5. Earlier work by the ICAO (1985) implies a demand elasticity for leisure trips of -1.1 for short-haul and -0.8 for long-haul.

[39] Strand (2005a) develops this argument in detail.

mobile capital[40]—to non-cooperative taxes on international aviation being set at inefficiently low levels, with scope for mutually beneficial gains from a coordinated increase. This, it should be stressed, is a source of gain from cooperative taxation quite distinct from that relating to border-crossing externalities discussed above.

There are some qualifications to this presumption of mutual gain from coordination. First, there may be countervailing incentives to set tax rates higher than is in the collective interest, in order to exploit power in world markets. Countries with strong appeal to tourists, or with major airports serving as hubs, may to some degree exploit these advantages by 'tax exporting,' imposing high taxes on foreigners whose welfare is presumably valued less than that of domestic residents. Indeed that is presumably to some degree the rationale for the heavier departure taxes on international travel described above, at least for some lower-income countries.

Second, the interests of countries diverge, and it is possible that coordinated tax increases can be made beneficial to all only if some of the revenue raised is used to compensate those who would otherwise lose. Indeed, coordinated tax increases by a subset of countries may increase the benefits of non-cooperation to other countries.[41]

Moreover, most flight activity cannot be readily rescheduled on a large scale, as it must serve the populations naturally catered for by the respective airports. Strategic international fuel tanking is likely to be a problem only given very high aviation fuel taxes, not with the moderate taxes currently under discussion.[42] In Norway, for example, when an aviation fuel tax at a rate of 16 US cents per gallon was first proposed (not far from the likely damage from CO_2 emissions), major airlines threatened to purchase substantial amounts of aviation fuel abroad. Such a fuel tax was enacted in 1999, and has since been increased moderately, to about 18 US cents per gallon. And in fact little or no such excess fueling has taken place. ECON (2005), discussing this case, concludes that the level of the tax was low enough to make excess tanking abroad uneconomical, due to resulting increased plane weight. Nevertheless, experience in relation to tanking of commercial diesel fuel in the EU—for which there is significant evidence of tax competition (Evers, de Mooij and Vollebeergh (2004))—suggests that this could become a real issue at the higher of the levels of international fuel tax that have been proposed.

[40] A classic reference is Zodrow and Miezkowski (1986).

[41] On these points—not specific to the aviation context—see K anbur and Keen (1993) on the possibility of Pareto gains from harmonization or the adoption of a minimum tax rate, and Konrad and Schjelderup (1998) on the possibility of a subset of countries gaining from coordination in which others do not participate.

[42] For a fuel tax at the (high) rate of USD 1 per gallon, Edmondson et al (2005) calculate that 50 percent or more of the fuel tax base may be lost for inter-EU air traffic. European Commission (1999), however, concludes that the loss of the aviation fuel tax base would be only in the range 5-10 percent for tax rates in this range.

E. Distortions in Competing Modes of Transport

Distortions in transport markets that provide substitutes for air travel may also impact the optimal structure of aviation taxes. In particular, since short-haul air travel often competes with road or rail transport, any over- or under-pricing in these sectors (taking account of any externalities associated with their usage) should in principle—to the extent that it cannot be addressed directly—be factored into aviation tax design. The extent of the proper adjustment depends on both the cross-elasticity of demand between aviation and these other modes and the direction of the distortion in the latter. To the extent that a competing mode is inappropriately subsidized, for example (and the subsidies cannot be removed), the optimal aviation tax will be lower than otherwise, in order to counteract the tendency towards socially excessive use of the alternative.

This consideration is potentially important in both North America and Europe. In much of North America, short-haul air transport competes mainly with car travel (though there are cases, notably on the eastern seaboard, in which it competes with rail); in Europe, air transport competes with both cars and rail. Recent work suggests that road transport is overtaxed in Europe, and under-taxed in the U.S. and other countries where road vehicle fuel taxes are low (at least in urban areas where most airports are located).[43] If higher road traffic taxes in the U.S. are ruled out, then second-best aviation taxes will be lower there relative to the benchmark Pigovian case (though this is of course a matter for domestic tax policy rather than internationally coordinated taxes). In Europe, on the other hand, second best considerations relative to road transport point to higher aviation taxes than would otherwise be the case (including on international flights within the region). Pointing in the opposite direction, however, rail transport is heavily subsidized in some European countries, such as France, Germany, the U.K. and the Benelux.[44] There is thus no clear-cut conclusion, with the appropriate pattern of aviation taxes on intra-EU flights depend on the strength of substitutability between road, rail and air transport and the extent of taxes/subsidies on the alternatives to air travel. Indeed the implications for aviation taxation might well, in principle, be route-specific. In the absence of firmer quantitative evidence, and given too that the better response is to address directly any inefficiencies related to the alternative modes, the safest position for the moment—and this is clearly an area that will merit closer study if aviation taxation continues to move up the policy agenda—seems to be to consider aviation taxes independently of potential interactions across competing modes.

F. Other Considerations

There are several additional considerations that are in principle relevant for aviation tax design, but on which direct evidence is at present again scant. One is possible imperfect competition in

[43] See Parry (2002), Parry and Bento (2001), and Parry and Small (2004).

[44] IATA (2005b) documents substantial rail subsidies for Britain, France and Germany.

the aviation sector. With homogenous product monopoly or Cournot competition, first-best policy—leaving revenue and environmental considerations aside for the present—is an output subsidy set so as to induce marginal cost pricing, together with lump sum transfers to firms, if necessary, to ensure non-zero profits. Combined with revenue and environmental concerns, the implication is that optimal taxes will be lower than would otherwise be the case.[45] Assessing the extent of imperfect competition in the aviation industry is not easy, however.

A key issue is whether there is free entry and exit. This has been studied widely for domestic U.S. aviation, the general conclusion being that net long run profits tend to zero and entry/exit is relatively free, at least in the economy-class segments.[46] Both formal and informal barriers (due, for example, to national airline subsidies) have also been substantially reduced since the 1980s, at least in North America and Europe.[47] Ease of entry/exit has been less studied for international aviation. Stronger legal restrictions on entry (for example on the North Atlantic) suggest that—while there is clearly considerable variation by route—monopolistic output restrictions are here more likely. It seems, however, that private international carriers do not systematically earn supernormal profits.[48]

Analysis of this and other aspects of the airline industry is complicated too by the heterogeneity of its products, notably as between economy, business and first class travel. These products are differentiated by flexibility of booking, availability at short notice, travel and airport comfort, food and entertainment service, connection availability, and timing. The potential importance of such differentiation is illustrated by the pricing structure of a fairly typical trans-Atlantic flight, shown in Table 7. Only 9 percent of passengers were in first or club (business) class, but they accounted for about half of revenues. There was wide price differentiation even within the traveler (economy) class segment. Differentiation has likely increased since then, by place of ticket issue, by whether the ticket is sold through a travel agency, via the Internet or directly from the airline.[49] Some part of these differentials reflects cost differences, but others are clearly due to price differentiation between passenger segments.

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[45] See for instance Kolstad (2000), pp. 129-132.

[46] See, for instance, Transportation Research Board (1999), Hanlon (1999), Borenstein (1989, 1991, 1992), Borenstein and Rose (1994), Evans and Kessides (1993), Hurdle et al (1989), Mayer and Sinai (2003), Morrison (2001) and Whinston and Collins (1992).

[47] See Transportation Research Board (1999). Government-controlled European airlines still received more than US$11 billion in (accumulated) subsidies in the 1990s, and private airlines more than US$3 billion.

[48] See Pearce (2006) for an overview of airline industry profits over the last 10 years: they have generally been small.

[49] Kesharwani (2001) distinguishes three "standard" ticket classes (restricted economy, unrestricted economy, and premium) rather than the two usually identified (economy and premium), and also documents substantial further price differentiation within the restricted economy-class segment. (In Table 8, the APEX and Promotion tickets both belong to the restricted economy-class tickets).

Imperfect competition and product heterogeneity could also affect the choice between specific and ad valorem forms of aviation taxes. With perfect competition and homogenous products, ad valorem and specific taxes are equivalent; under imperfect competition they are not, and it is a fairly robust result that ad valorem taxes are then socially preferable.[50] Further complications and ambiguities arise, however, from the heterogeneity and endogeneity of product characteristics. Ad valorem taxation, for example, tends to induce airlines to compete in part by offering lower quality products, since recovering the cost of a quality improvement that costs say US$1 will require increasing the consumer price by more than US$1. Thus heavy reliance on ad valorem ticket taxes (rather than, say, per passenger charges) is likely to imply, for example, reduced in-flight service, and fewer flights with higher load factors (and hence less flexibility in booking). What this implies for the balance between specific and ad valorem taxation depends on how quality enters consumers' preferences, the general principle being that it should be chosen to minimize the distortion of quality decisions.[51] This may point to a preference for specific ticket taxes, though this may be more than offset by the distributional appeal of ad valorem taxation.[52]

Network externalities—the beneficial 'Mohring effect' that arises when a larger air traffic volume expands passengers' air route choices[53]—may also affect the appropriate indirect taxation of aviation. Betancor and Nombela (2002) find that the average travel time between two European capitals fell between 1990 and 1998 by 20 minutes, due to more extensive and frequent flights. The time reduction was largest for the routes with the lowest initial densities, with no gains for routes with traffic exceeding 150,000 passengers per year. Most airlines, however, limit own ticket issues to routes covered by the airline (including in some cases a limited range of cooperating partners), and effectively exclude other airlines operating on the same airport. This serves to limit the scope for positive network externalities from greater traffic loads. In principle, the presence of Mohring effects for airports of smaller sizes might indicate a case for lower than otherwise aviation taxes for traffic to and from such airports; but not for traffic at major airports. But the empirical significance of such externalities in international air travel is uncertain.

Finally, input price distortions may arise when aircraft production and operation are subsidized by producing and operating countries' governments. To the extent that such subsidies are significant—a continued matter of contention between Airbus and Boeing—they point to

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[50] See for instance Delipalla and Keen (1992); Keen (1998) shows that this is also true in the Dixit-Stiglitz (1977) model of horizontal quality competition.

[51] Delipalla and Keen (2006).

[52] Product quality and distributional concerns are less of an issue with aviation fuel; given too the revenue stability concern noted earlier, the established preference for specific taxation is uncontentious.

[53] This effect, due to Mohring (1972), was originally discussed for bus networks.

relatively high aviation taxes. Implicit taxes or subsidies also arise when airport fees and charges differ from appropriate marginal cost levels. The limited evidence suggests, tentatively and with exceptions, a broad tendency for high-income countries to subsidize such activities—pointing to higher aviation taxes—and for lower-income countries to tax them. To the extent that this is the case, it is an argument for generally lighter aviation taxation in low-income countries than in high-income ones.

With these various considerations pointing in different directions, and very little evidence on the quantitative importance, it appears, somewhat frustratingly, that the safest approach for policy design, at least for the present, is to suppose that they net out to zero.

IV. Tax Rates, Revenues and Incidence

This section considers the rates at which internationally coordinated aviation taxes might be set, the revenue they could raise, and who would bear the burden they impose.

A. Optimal Tax Rates

How high might optimal indirect taxes on aviation be, and how much revenue might they raise? To provide a first sense of the likely answers, this section and the next report some simple calculations based on the analysis above.

The conceptual framework for these calculations is that of section III.A, in which there is assumed to be no cross-border spillover of environmental harm. Thus the analysis is best thought of corresponding to the case of globally coordinated tax design, with all countries assumed to be identical. The analysis of further and perhaps more interesting cases is left to future work.

For the purposes of these illustrative calculations the elasticity of demand ε is assumed to be constant, taking alternative values of unity and 0.5, broadly reflecting the estimates for leisure and business travel reported above. The elasticity of substitution in production σ is also taken to be constant, with values of unity or 0.5,[54]and the factor share for aviation fuel, α, assumed to be 0.25 in the absence of aviation taxes (corresponding broadly to its global factor share in 2005).[55]

[54] We have no estimates of the strength of substitution between fuel and other inputs, but there is certainly evidence that it can be quite marked, even in the short term: for instance, a 16 percent increase in aviation fuel prices in 2002–03 was associated with a 3 percent reduction in fuel use per passenger mile traveled. Margins on which aviation fuel efficiency can be improved include closing routes with low average load factors and/or reducing seat space (or even eliminating seating (*New York Times* (2006)). For the longer term, Sledsens (1998), for example, discusses how more efficient airplane design is phased in when fuel prices increase.

[55] IATA figures for 2005 are not yet available, but the *Economist* (2005) reports fuel expenses at US$97 billion, implying a fuel share of about 25 percent

The marginal cost of public funds δ ranges from unity (corresponding to the case in which lump sum taxation is available) to a fairly moderate 1.5. The appropriate value of marginal environmental damage E' remains an open question, but the discussion above suggested a reasonable order of magnitude, particularly in contexts like the European, to be E'=US$0.40 per gallon of aviation fuel.

Table 8 reports optimal (tax-inclusive, ad valorem) ticket tax rates, and fuel tax rates (in US$ per gallon), for the case in which the elasticity of demand is unity. The two first columns show ticket and fuel tax rates when both instruments are optimally deployed. In this case, the calculations are straightforward: recalling (5) and (6), the optimal fuel tax is E'/δ while the optimal ticket tax is in this case simply (1-δ)/δ. The results are thus easily anticipated, but provide a useful reminder that the optimal fuel tax decreases with the marginal cost of public funds: taking the central case in which $E' = 0.40$, it decreases from around 20 percent when δ is unity to 13 percent at δ = 1.5. Perhaps more interestingly, the last three columns in Table 8 show optimal tax rates when only one tax instrument may be deployed (as in (7) and (8)), recognizing too that in this case the optimal fuel tax depends on the elasticity of substitution in production. As one would expect, each tax in isolation is now optimally set higher than it would be if the other tax were also available; and the optimal stand-alone fuel tax is higher at the lower elasticity of substitution. Beyond this, three points stand out. First, the optimal stand-alone fuel tax increases with the marginal cost of public funds, reflecting the impact of an intensified revenue need. Second, the optimal ticket tax becomes highly sensitive to the marginal social cost of public funds: again taking the central case in which $E' = 0.40$ it increases from 5 percent when lump sum taxes are available—in which case the ticket tax is being used only as an inferior corrective device—to 35 percent when δ = 1.5. Third, the elasticity of substitution in production matters: halving it more than doubles the optimal stand-alone fuel tax at the higher level of δ. The intuition, evident from (8), is that at higher levels of δ the revenue motive becomes more dominant, further emphasizing the role that the elasticity of substitution plays (analogous to that of the demand elasticity in the Ramsey rule).

Table 9 repeats the exercise for a demand elasticity of 0.5. Broadly the same qualitative pattern emerges, with the tendency towards a higher rate associated with the Ramsey component being evident—except in the case of the fuel tax when both instruments are optimally deployed, since that instrument is then independent of the elasticity of demand.

The final columns of Tables 8 and 9 explore which of the two taxes is preferred (indicated in bold) when only one can be used. As the discussion above indicated, the fuel tax is more likely to be preferred the lower is the marginal cost of public funds δ and the higher is the marginal environmental damage E'. Less obviously, the calculations also show that the issue is a real one, in that neither tax dominates the other within the plausible range of parameter values: at $E' = 0.40$, for example, the fuel tax, which is evidently preferred when lump sum taxes are available, becomes inferior to the ticket tax when δ rises to the quite moderate level of 1.25. It also emerges that the choice between the instruments is potentially quite sensitive to the elasticity of substitution, with the fuel tax more likely to be preferred the lower it is—for the lower is σ the less is the erosion of the tax base, and hence the jeopardy to the revenue objective, from taxing fuel.

Table 10 provides some sense of the likely welfare losses in using only instrument rather than two (compared to using only the better of the latter), and in then choosing the wrong one. The first two columns suggest that there may be relatively little harm in using only one instrument: the largest policy gain in moving to two instruments is less than one percent of turnover. (It is greater, as one would expect, the higher is the elasticity of substitution in production: in the limiting case in which $\sigma = 0$, recall, the two instruments are equivalent). The gain in choosing the better of the single instruments tends to be somewhat larger, but is still relatively modest: when there is no environmental damage, for example, inappropriately deploying a fuel tax leads to a welfare loss of about 2 percent of expenditure. These calculations thus suggest that there may be relatively little loss in using one instrument, even if not the best choice available, rather than two.

B. The Revenue Potential of Aviation Taxes

As a natural benchmark, consider first the case in which only a fuel tax alone is deployed, and set at its average worldwide Pigovian level. This level is unknown, but the considerations discussed at the end of Section II suggest it may be lower than the benchmark of $E' = 0.40$ taken in the simulations above. Suppose instead that the fuel tax were set at half this level, corresponding roughly, as noted earlier, to the damage from carbon emissions alone, and so something of a lower bound. With worldwide aviation fuel consumption of 50 billion gallons in 2003 (the latest year for which data are available: IATA (2004)), this would raise—assuming for the moment no behavioral response to imposition of the tax—around US$10 billion per annum. Given aviation sector turnover of US$400 billion, such a fuel tax would be roughly equivalent to a modest 2.5 percent non-creditable ticket tax,[56] and would add roughly US$6 to an average air fare (about US$25 for business/first-class tickets, and US$4 for economy tickets). This is a fairly modest price increase: recall, for instance, that the homeland security charge in the United States is 7.5 percent. With about 1.7 billion passengers carried in 2005 (of whom about 1.5 billion in economy class), the same tax revenue would be collected through a US$5 departure tax on economy-class passengers, and a US$15 departure tax on business- and first-class passengers, applied both internationally and domestically.

Applied only to international aviation—which accounted for about two-thirds of aviation fuel use in 2003[57]—a fuel tax of US$0.2 would raise about US$6.5 billion. Applied only in Europe (encompassing the EU and current non-EU members in Western and Eastern Europe, including

[56] It is assumed throughout this section that any ticket tax would function as an excise, rather than a VAT, so that the revenue raised would not be diminished by refund to registered taxpayers.

[57] This is the proportionate usage for airlines that reported the breakdown to IATA (IATA, 2004).

Russia, and covering both domestic and international flights), it would raise about US$3 billion. Revenue patterns under a ticket tax of about 2.5 percent would be similar.[58]

Behavioral responses are potentially important, of course, tending to reduce the revenue raised from any combination of ticket and fuel tax through an induced reduction in final demand and/or increase in fuel efficiency. And of course the fuel tax may not be the only, or best, tax instrument to be deployed. To provide some sense of the likely importance of these further considerations, Table 11 reports the revenue associated with the welfare-maximizing tax rates reported in Table 8 above, expressed relative to total final expenditure on aviation services. For brevity, we consider only the case of unitary demand elasticity.[59] Note that this implies that total final expenditure is the same in all cases considered, so that comparisons in the level of revenue can also be directly read from the table. As a rough calibration, the overall level of airline revenues in 2003 was around US$400 billion (IATA, 2004).

With a fuel tax set at the higher level of US$0.40 per gallon—roughly the level of external damage in the U.K.—the possibility of substituting away from fuel use reduces the revenue yield to US$16.8-18.4 billion (being lower, as one would expect, the greater is the ease of substitution; and of course lower than the US$20 billion that would be raised in the absence of any behavioral response).

The aggregate revenue associated with optimal policy is higher, of course, once a revenue-raising motive is also recognized, and increases with both the marginal cost of public funds and the extent of marginal environmental damage. More to the point, the amounts raised can plausibly be substantial. When, for instance, $\delta = 1.25$ and $E' = 0.4$, global tax revenues are around 23 percent of sector turnover, or US$92 billion. The bulk of this revenue—around US$80 billion—comes from the ticket tax (reflecting the revenue motive). When applied only to international traffic, the figures would be roughly two thirds of these, corresponding to the fraction of international air traffic in total activity.

Two other points emerge from the revenue calculations. First, and perhaps surprisingly, the revenue associated with optimal policy is not necessarily higher when both taxes can be deployed than when only one is available. Second, revenue is in all cases higher—in some cases, very substantially so—when only the ticket tax may be deployed than when only the fuel tax can be used;[60] and this is true, strikingly, even when there is no revenue raising concern, so

[58] These sums, it is worth noting, are substantially more than departure taxes of the kind recently discussed and implemented are likely to raise: a uniform departure tax raising US$10 billion, for example, would require a charge of about US$6 per trip if applied worldwide. A uniform departure tax levied in Europe alone would need, in order to raise US$10 billion, need to be set at US$20, or about 16 Euros.

[59] A lower demand elasticity would of course be associated with higher levels of revenue.

[60] Note that this is not implied by the earlier general result that maximized revenue is higher under the ticket tax than under the fuel tax, since here it is welfare that is being maximized, not revenue.

that the sole purpose of taxation is corrective. Indeed, in all cases revenue when only the ticket tax is used is higher than when both can be deployed, while revenue from a stand alone fuel tax is always lower. While these results do not generalize beyond the circumstances of the simulations,[61] the implications and underlying intuition may be of some importance. At one level, they reiterate the feature of the fuel tax that the distortion of production that it implies—however desirable on environmental grounds—erodes the tax base. They also make the point that using an ill-targeted tax on final consumption (in this case, the ticket tax) to address externality problems arising in production may actually lead to more revenue being raised, rather than less, since the imperfect targeting may call for heavy taxation to choke back the demand for the input generating the problem.

C. Incidence

Who would ultimately bear the burden of aviation taxes depends on details of market structure and adjustment. No detailed study of these issues will be offered here. Instead, and as first pass at the issue, it will simply be assumed that airlines are competitive and operate under constant returns, and that oil supply is elastic in the long run. A tax on aviation fuel will then be fully passed on into airlines' input prices, and the consequent increase in ticket prices fully borne by travelers. Ticket and trip taxes too would be fully passed on.

The incidence of ticket taxes by travel class will then depend on airline revenues from travelers in different classes and the class-specific tax rates. For departure taxes it will depend on class-related traffic volumes and tax rates. Since fuel can best be considered a fixed cost for each entire flight, ascribing fuel cost shares to travel classes is somewhat arbitrary, although airlines may tend to recuperate their increased fuel costs from different passenger segments according to the segment-specific demand elasticities.

Table 12 provides worldwide data on relative traffic volumes, in terms of numbers of passengers and passenger kilometers traveled, and shares of airlines' revenues, classified by economy, business and first class, and by major regions. About 90 percent of all air travel (in passenger numbers or miles) is in economy, about 9 percent in business, and only about one percent in first class. In terms of airline revenues, however, the shares for business and first class are much higher: about 30 percent. About 90 percent of the burden of a departure tax invariant to distance and class of travel, or a fuel tax, would then fall on economy-class travelers. For a uniform ad valorem ticket tax, by contrast, almost 30 percent would fall on premium travelers.

[61] The finding that revenue is higher under a ticket tax than under a fuel tax when only the corrective motive is present, for example, is readily shown to be model-specific: relative revenues in the two cases depend on the curvatures of the cost function and slope of the demand function.

Table 12 also shows the distribution of air travelers by class, for flights originating in the major regions. North America, Latin America, and Asia and the Pacific have similar distributions, while Europe has a higher share of business-class travelers.

Incidence by region has several aspects. The impact on any country's welfare is likely to depend on the direct impact on its own residents (regardless of carrier), on its national carriers (whatever the residence of their passengers), and, for tourist destinations, on the volume of all leisure traffic. And the pattern of regional effects will also potentially differ by type of tax. The available data allow only a few broad statements:

- Allocating the impact of aviation fuel taxes in proportion to passenger kilometers flown,[62] about 36 percent of the burden would fall on North America, 28 percent on Europe, 24 percent on East Asia and the Pacific, and 12 percent on the other regions (South and Central America, Africa, the Middle East and South and Central Asia).

- Since ticket prices per kilometer flown are typically lower for long-haul than for short-haul flights, the burden of ticket taxes would be tilted, compared to fuel taxes, towards regions (such as Europe) in which flights are relatively short and fares high.[63] A ticket tax would also tend to fall more heavily on premium-class use. This also increases the average burden on European compared to other travelers, due to the larger fraction of business-class travelers in Europe (Table 12).

- For departure taxes, the allocation would be proportional to the number of departing passengers, so that the burden would fall rather more on Europe and Asia-Pacific regions and rather less on North America.

- Concern about harm to tourism, important for many low-income countries, has prompted the suggestion of excluding all flights connecting low-income countries. Exempting Latin America, the Caribbean, Africa, and Asia (except Japan and other high-income countries) would eliminate approximately 25 percent of the global tax base (somewhat less for ticket taxes, and somewhat more for fuel taxes). Alternatively, one might exempt only economy-class travel within and from such destinations, with a tax base reduction of about 15 percent. This may have some distributional appeal, but is of course

[62] IATA (2004) data indicate that the three main regions, North America, Europe and the Far East, have broadly similar fuel consumption per passenger kilometer, so that passenger kilometer counts are reasonably good proxies for regional aviation fuel use. (Fuel efficiency is slightly lower in North America and slightly higher in the Far East, compared to Europe, mainly reflecting lower average age of aircraft fleets in the Far East).

[63] Kesharwani (2001) notes that in 2000 the worldwide average fare per kilometer for 16,000-kilometer trips was only 20 percent of that for 250 kilometer trips; while average fares in Europe were 3 times average fares in Asia and the Pacific for 250 kilometer trips (almost all domestic). Shorter flights, however, are only slightly more fuel consuming per kilometer.

unwarranted from an environmental perspective, and requires higher tax rates for a given revenue target.

V. ADMINISTRATION AND COMPLIANCE

There is little technical difficulty in collecting taxes on aviation fuel, on tickets, and/or on departures.

Well-developed procedures for imposing excises on fuels are already in place in almost all countries, with the relatively small number of companies involved in importing and/or refining greatly facilitating control.[64] Indeed levying tax on fuel for international aviation might well facilitate administration, since narrowing the tax differential between fuels used internationally and domestically would reduce the need to identify the use to which fuel is to be put. Ticket and departure taxes are both already commonplace.

More difficult than these technicalities is ensuring appropriate incentives for their collection if—as recent proponents of aviation taxes have in mind—proceeds do not accrue to the collecting country. Collection is in practice likely to be entrusted to participating countries rather than vested in a new supranational tax administration. Incentives to devote scarce resources to the collection of such taxes are then clearly blunted. This effect can be mitigated, but not eliminated, by allowing the collecting authorities to retain some proportion of the receipts (perhaps 10 percent, the share of collected customs duties retained by EU members). Moreover, the same considerations of national self-interest that are likely to lead countries to set inefficiently low levels of taxation in the absence of coordination give them a reason to enforce these taxes less intensively than otherwise. Countries that fear disadvantaging national carriers may be inclined to allow for lengthier payment periods, for example, or delay inflation-adjusting specific taxes.

Participation in such schemes may require that countries be assured that other participants will comply with the commonly agreed rules. This has two implications. First, agreement may need to be reached on quite detailed aspects of design and implementation, concerning not only the rate of the tax but also its precise base, the definition of taxpayers subject to it, and rules on such matters as payment periods, interest, and penalties. Second, countries may wish to have some direct means of verifying implementation by others. This might take a number of forms, such as participation in joint audit activities or the monitoring of aviation activity so as to derive independent estimates of the tax due. The pressures for some such mutual oversight are likely to increase as the set of participating countries, since weaker relations of bilateral trust may be involved and the possibilities for directly observing each others' actions reduced.

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[64] The close monitoring to which international commercial air traffic is subject might also be used to support implementation, providing some potential check on fuel usage.

VI. Conclusions

On pure tax policy grounds, the case for increased indirect taxes on international aviation taxes appears to be strong. The present low rates stand in marked contrast to the quite persuasive evidence of significant cross-border damage from international air travel, which in any event is just as proper an object of indirect taxation as any other commodity, and—even leaving aside environmental issues—there is potentially a coordination problem leading to inefficiently low taxes. In practical terms, such taxes are similar to ones that tax administrations and taxpayers are already well accustomed to. Certainly a novel set of practical issues would arise if the revenue were devoted to other than national purposes; but these are qualitatively no different from (and may be less than) those that any global tax would raise.

Optimal aviation taxation is likely to involve a combination of both an excise on the use of aviation fuel (addressing the principal and most clearly established source of cross-border environmental harm associated with aviation), and a ticket tax (focused on the objective of raising revenue), with the latter best taking the form of a VAT (so as to exclude business use, including through cargo).[65] Which of the two is to be preferred, if only one can be used, is in general unclear for plausible parameter values, but depends on the relative strengths of environmental and revenue concerns. Somewhat reassuringly, however, simulations suggest both that there may be little loss in using only one instrument, or in then choosing the wrong one among the two. Trip charges, such as the departure taxes that have been the subject of recent policy initiatives, are a much blunter instrument, being less capable of variation according to fuel use or the extent of consumption of aviation services.

There are legal obstacles to aviation fuel taxation, in the Chicago convention and under bilateral air service agreements. One might argue that such restrictions, dating from a time when encouraging international aviation travel was an object of policy, have outlived their usefulness. And within the EU, at least, it seems that they can be overcome.[66] If, nevertheless, international aviation fuel taxes are ruled out, the case for ticket taxes clearly becomes stronger. To ensure that environmental costs are reflected in all travel decisions, including business travel and cargo, these should be in the form of a non-creditable excise rather than—or in addition to—a VAT that is better suited to raising revenue.

Even if legal impediments were removed, however, prospective tax competition between countries concerned to protect their national carriers, tourist industries and revenues would likely lead to inefficiently low tax rates. Some degree of coordination in the design and setting of aviation taxes would be required, though since the tax base is less than perfectly mobile—bunkering fuel in low tax jurisdictions is costly, and many destinations have elements of

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[65] Business use of course would, and should, be affected by a fuel excise.

[66] See, for instance, the legal opinion on deployment of domestic aviation fuel taxes in Germany in Pache (2005).

uniqueness—such taxes can clearly have effect even if levied on a regional basis rather than universally.

The calculations reported here suggest that fuel taxes set at US$0.20 per gallon, or 2.5 percent as a ticket tax—corresponding to a fairly conservative estimate of the typical marginal environmental cost of international aviation—would raise a little under US$10 billion if levied worldwide, and a little under US$3 billion if levied in Europe alone. Considerably more could be raised if aviation taxes were set with not only environmental concerns in mind but also with a view to the distortionary impact of the wider tax system.

Many countries, including high-income countries with large market shares and smaller, low-income countries heavily reliant on tourism, have expressed strong opposition to indirect taxes on international aviation. And clearly the present circumstance of high and uncertain future fuel prices, with many airlines financially pressed, do not make this the easiest moment to press the case.[67] Nevertheless, the case for strengthening indirect taxation of international aviation seems strong enough to warrant continued attention and closer analysis.

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[67] The general outlook for the aviation industry, however, is not bleak. *The Economist* (2005) reports that international demand for new aircraft has never been stronger, reflecting both the demand for more fuel-efficient planes and anticipated continuing expansion in international travel.

References

Acemoglu, Daron and Ozdaglar, Asuman E., 2005, "Competition and Efficiency in Congested Markets," Working Paper (Massachusetts Institute of Technology).

Ashford, Norman and Moore, Clifton A., 1992, *Airport Finance*. New York: Van Nostrand Reinhold.

Atkinson, Anthony B., 2005, *New Sources of Development Finance* (Oxford University Press: Oxford).

Betancor, Ofelia and Nombela, Gustavo (2002), "Mohring Effects for Air Transport." UNITE Competitive and Sustainable Growth Programme. Work Package 7: Case Study 7. EIET University of Las Palmas, Spain.

Boadway, Robin, and Keen, Michael (2006), "Notes on the Provision of International Public Goods," in preparation.

Borenstein, Severin, 1989, "Hubs and High Fares: Dominance and Market Power in the U.S. Airline Industry," *Rand Journal of Economics*, Vol. 20, pp.344–365.

_____, 1991, "The Dominant-Firm Advantage in Multiproduct Industries: Evidence from the U.S. Airlines," *Quarterly Journal of Economics* **106**, pp.1237-1266.

_____, 1992, "The Evolution of U.S. Airline Competition," *Journal of Economic Perspectives* **6**, pp. 45–73.

_____, and Rose, Nancy L., 1994, "Competition and Price Dispersion in the U.S. Airline Industry," *Journal of Political Economy* **102**, pp. 653–683.

Brueckner, Jan K., 2002, "Airport Congestion when Carriers have Market Power," *American Economic Review,* Vol. 92, pp.1357–1375.

Delipalla, Sofia and Keen, Michael, 1992, "The Comparison Between Ad Valorem and Specific Taxation Under Imperfect Competition," *Journal of Public Economics*, 49, 351–367.

_____, and Keen, Michael, 2006, "Product Quality and the Optimal Tax Structure," *Journal of Public Economic Theory*, forthcoming.

Diamond, Peter A. and Mirrlees, James A., 1971a, "Optimal Taxation and Public Production I: Production Efficiency," *American Economic Review*, 61, 8–27.

_____, 1971b, "Optimal Taxation and Public Production II: Tax Rules," *American Economic Review*, 61, 261–278.

Dixit, Avinash K. and Stiglitz, Joseph E., 1977, "Monopolistic Competition and Optimum Product Diversity," *American Economic Review*, 67, 297–308.

ECON, 2005, Political Economy of the Norwegian Aviation Fuel Tax, ECON Report 2005–017 (Oslo: ECON Analysis).

Economist (2005), "Lining Up for Profits," November 12, 2005, 71-73.

Edmondson, Duncan, Hancox, Richard, Lowe, Steve and Pulles, Hans, 2005, "Quantifying the environmental and economic impacts of market-based instruments to reduce aircraft emissions." Report written for the Civil Aviation Department, the Netherlands.

European Commission, 1999, Resource Analysis (Brussels: European Commission).

_____, 2005a, "A Possible Contribution Based on Airline Tickets as a New Source of Financing Development: Technical Reflections in the Run up to the UN High Level Event," European Commission Staff Working Paper,1067.

_____, 2005b, "New Sources of Financing for Development: A Review of the Options," European Commission Staff Working Paper, 467.

Evans, William N. and Kessides, Ioannis, 1993, "Localized Market Power in the U.S. Airline Industry," *Review of Economics and Statistics*, 75, 66–75.

Evers, de Mooij and Vollebeergh (2004), "Tax Competition under Minimum Rates: The Case of European Diesel Excises," CESifo Working Paper No. 1221.

Friedrich, Rainer and Bickel, Peter (eds.), 2001, *Environmental External Costs of Transport* (Berlin: Springer Publishers).

Gillen, David W., Morrison, William G. and Stewart, Christopher, 2004, "Air Travel Demand Elasticities: Concepts, Issues and Measurement," Report for Department of Finance, Canada.

Hanlon, Pat, 1999, *Global Airlines.* Oxford: Butterworth Heinemann.

Hendricks, Kenneth, Piccione, Michele and Tan, Guofu, 1997, "Entry and Exit in Hub-Spoke Networks," *Rand Journal of Economics*, 28, 291–303.

Hurdle, Gloria J., Johnson, Richard L., Joskow, Andrew S. Werden, Gregory J. and Williams, Michael A., 1989, "Concentration, Potential Entry, and Performance in the Airline Industry," *Journal of Industrial Economics*, 38, 119–139.

IATA, 2004, *World Air Transport Statistics*. Montreal and Geneva: International Air Transport Association.

____, 2005a, *IATA List of Ticket and Airport Taxes and Fees*. Montreal and Geneva: International Air Transport Association.

____, 2005b, "Aviation Taxes and Charges. A Comparison of the Level of the Taxation, Subsidies and Charges for Aviation and for Other Transport Modes in Germany, France and the United Kingdom." Unpublished Report, November.

ICAO, 1985, *Manual on Air Traffic Forecasting*, ICAO Document 8991-HT/772/2.

____, 2000, "ICAO's Policies on Taxation in the Field of International Air Transport." ICAO document 8632.

____, 2001, *Airports and Route Facilities, Financial Data and Summary Statistics*, ICAO Digest of Statistics, No. 509.

IPCC, 1999, "Aviation and the Global Atmosphere," Report, Intergovernmental Panel on Climate Change.

Kanbur, Ravi and Michael Keen, 1993, "Jeux Sans Frontiéres: Tax Competition and Tax Coordination when Countries Differ in Size," *American Economic Review*, **83**, 877–892.

Katz, Michael L. and Shapiro, Karl, 1994, "System Competition and Network Effects." *Journal of Economic Perspectives*, 8, 93–115.

Keen, Michael, 1998, "The Balance Between Specific and Ad Valorem Taxation," *Fiscal Studies*, 19, 1–37.

Kesharwani, Tulsi (2001), "Pricing and Charges in Civil Aviation." Economic issues 5, Asian Institute of Transport Development.

Kolstad, Charles D., 2000, *Environmental Economics* (New York: Oxford University Press).

Konrad, Kai and Guttorm Schjelderup, 1998, "Fortress Building in Global Tax Competition," *Journal of Urban Economics* **46**, 156–167.

('Landau Report') Working on New International Contributions to Finance Development, 2004, Report to President Chirac.

Mayer, Chris and Sinai, Todd, 2003, "Network Effects, Congestion Externalities, and Air Traffic Delays: Or Why Not All Delays are Evil," *American Economic Review*, 93, 1194–1215.

Mohring, H. (1972), "Optimization and Scale Economies in Urban Bus Transportation." *American Economic Review*, 62, 591-604.

Morrison, Steven A., 2001, "Actual, Adjacent, and Potential Competition: Estimating the Full Effect of Southwest Airlines," *Journal of Transport Economics and Policy*, 32, 239–256.

NBAA, 2005, *Federal Excise Tax Handbook* (Washington: National Business Aviation Association).

New York Times, 2006, "One Day, That Economy Ticket May Buy You a Place to Stand," April 25, 2006.

Pache, Eckhard, 2005, Options of Introducing a Tax on Kerosene Consumed on Domestic Flights—Legal Opinion by Order of the Federal Environmental Agency, Note (Würtzburg, Germany).

Parry, Ian W. H., 2002, "Is Gasoline Undertaxed in the United States?" *Resources*, 148, 28–33.

____, and Bento, Antonio M., 2001, "Revenue Recycling and the Welfare Effects of Road Pricing," *Scandinavian Journal of Economics*, 85, 333362.

____, and Small, Kenneth A., 2005, "Does Britain or the United States have the Right Gasoline Tax?" *American Economic Review*, 1276-1289.

Pearce, Brian D., 2006, "Industry Outlook Improving – But Still a Long Way to Go". Industry Forecast Briefing, March 2006, Montreal and Geneva: International Air Transport Association.

Pearce, Brian D. and Pearce, David W., 2002, "Setting Environmental Taxes for Aircraft: A Case Study of the U.K.," Working Paper, Forum for the Future/University College (London).

Pirttilä, Jukka, 2002, "Specific Versus Ad Valorem Taxation and Externalities," *Journal of Economics*, 76,177–187.

Quadripartite Group, 2004, *Report of the Technical Group on Innovative Financing Mechanisms* (Geneva: United Nations).

Sandmo, Agnar, 1975, "Optimal Taxation in the Presence of Externalities." *Swedish Journal of Economics*, 77, 86–98.

Sledsens, T., 1998, *Sustainable Aviation: The Need for an European Environmental Aviation Charge* (Brussels: European Federation for Transport and Environment).

Strand, Jon, 2005, "Optimal Aviation Taxes with Distortive Taxation and Endogenous Labor Supply." (Unpublished: Washington: International Monetary Fund).

Transportation Research Board, 1999, *Entry and Competition in the U.S. Airline Industry*. Special Report No. 255 (Washington: Transportation Research Board).

Whinston, Michael D. and Collins, Susan C., 1992, "Entry and Competitive Structure in Deregulated Airline Markets: An Event Study Analysis of People Express." *Rand Journal of Economics*, 23, 445–462.

World Bank, 2005, *Aid Financing and Aid Effectiveness*, Board Note, SecM2005–0435 (Washington: The World Bank).

Zee, Howell (2006), 'A Note on Global Taxes and Aid for Development,' *Journal of Economic Studies*, 33, 5-11.

Zodrow, George and Peter Mieszkowski, 1986, 'Pigou, Tiebout and the Underprovision of Local Public Goods,' *Journal of Urban Economics*, 19, 356–70.

Appendix: Tables

Table 1: Tax Rates on Domestic Aviation Fuel

(Selected countries, various years)

	Aviation gasoline (US$ per gallon)	Aviation Gasoline, (In percent) 7/	Jet Fuel (US$ per gallon)	Jet Fuel (In percent) 7/
Australia 5/	0.09	8	0.09	8
Bolivia 1/	0.21	9.3	0.21	17.4
Brazil 3/	1.57	40.4	0.06	4.9
Canada 5/	0.06	6	0.06	6
Costa Rica 4/	0.96	38.7	0.58	38.4
Ecuador 1/	0.36	15.8	0.16	15.4
Indonesia 2/	0.02	7.7	0.16	13.2
Japan 5/	1.10	96	1.10	96
Netherlands 5/	0.92	81	0.92	81
Nicaragua 4/	0.91	21.7	0.01	0.7
Norway 5/, 6/	0.16	14	0.16	14
Paraguay 1/	0.32	9.2	0.01	1.1
Peru 4/	0.58	15.9	0.25	16.1
Philippines 5/	n.a.	n.a.	0.30	27.5
Taiwan 1/	0.89	39.4	0.06	3.3
Uruguay 5/	0.09	5.0	0.09	5.0
United States 5/	0.19	18.1	0.22	21.0
Venezuela 2/	0.05	4.4	0.04	5.0

Source: Energy Détente, various issues.

Notes:

1/ = 2000
2/ = 2001
3/ = 2002
4/ = 2003
5/ = 2004
6/ Also international flights.
7/ In percent of average fuel prices in the respective year, US$1 per gallon worldwide for 2000-2003, US$1.50 per gallon for 2004.

Table 2: Domestic Ad Valorem Ticket Taxes, Selected High-Income Economies, April 2005

(Tax-exclusive rates, in percent)

	VAT	Other Ticket Tax
Australia	10	0
Austria	10	0
Belgium	6	0
Canada	0	7
Finland	8	0
France	5.5	0
Germany	16	0
Greece	8	0
Italy	10	0
Japan	0	5
Netherlands	6	0
New Zealand	12.5	0
Norway	7	0
Spain	7	0
Sweden	6	0
Switzerland	7	0
United States of America	0	7.5

Source: IATA (2005a).

Note: None of these countries charges ticket taxes on international flights.

Table 3: Ad Valorem Aviation Taxes, Selected Emerging Market
and Developing Economies, April 2005

(Tax-exclusive rates, in percent)

Country	Domestic VAT	International VAT	Domestic Ticket Tax	International Ticket Tax
Argentina	10.5	0	14	5
Brazil	0	0	3	0
Colombia	16	8-16	0	0
India	0	0	10	0
Korea	10	0	0	0
Mexico	2.5-10	2.5-4	0	0
Pakistan	0	0	20	1
Peru	19	19	0	0
Poland	7	0	0	0
South Africa	14	0	0	0
Taiwan	5	0	0	0
Thailand	10	7	0	0
Venezuela	0	0	9	1

Source: IATA (2005a).

Table 4: Airport and Trip Charges, Selected High-Income Economies 1/

(US$ per traveler, rates as of April 2005, exchange rates as of June 2005)

Country	Airport Charges Domestic	Airport Charges International	Trip Charges Domestic	Trip Charges International	Total Passenger Charges Domestic	Total Passenger Charges International
Australia	6–22	11–19	30	30	36–52	41–49
Austria	16	16	0	16–17	16	32
Belgium	0	0	0	12–25	0	12–25
Canada	16–20	22–26	0	0	16–20	22–26
Denmark	8–16	20	12	12	20–26	32
Finland	3	3	7	6–12	10	9–15
France	15	9–16	0	0	15	9–16
Germany	13–22	11–19	0	0	13–22	11–19
Greece	29	44	0	0	29	44
Hong Kong	0	0	0	15	0	15
Ireland	4–6	4–6	10	10	14–16	14–16
Israel	12	12	0	8–55	12	20–67
Italy	6	6	7–11	7–11	13–19	13–19
Japan	1–2	11–28	0	0	1–	11–28
Netherlands	40–42	40–42	0	0	40–42	40–42
New Zealand	4	11	0	14–18	4	25–29
Norway	12	17	0	0	12	17
Singapore	0	0	0	10–13	0	10–13
Spain	1	1	4–5	5–8	5–6	6–9
Sweden	11–18	12–25	0	0	11–18	12–25
Switzerland	0	0	6–28 1/	6–28 2/	6–28 2/	6–28
United Kingdom	15–27	18–36	11	9–73 3/	26–38	27–109
United States of America	3	3	19	31	22	34

Source: IATA (2005a)

Notes:
1/ Trip charges include departure charges and in some instances also arrival charges.
2/ Includes a specific noise tax, differentiated by airport.
3/ Rate differentiated by class of travel, and by destination (EU/non-EU).

Table 5: Airport and Trip Charges, Selected Emerging and Developing Economies

(US$ per traveler, rates as of April 2005, exchange rates as of June 2005)

	Airport Charges		Trip Charges		Total Passenger Charges	
	Domestic	International	Domestic	International	Domestic	International
Argentina	1	12	2	18	1	30
Brazil	0	0	2–4	12–36	2–4	12–36
Chile	3–8	8	0	20/50 1/	3–8	8
China	6	11	0	0	6	11
Colombia	0	0	1–4	60–66	1–4	60–66
Costa Rica	1	7	0	26	1	33
India	5.50	5.50	0	3–12	5.50	5.50
Indonesia	2–10	5–10	0	10 2/	12–20	15–20
Korea	4–5	23–27	0	0	4–5	23–27
Malaysia	0	0	2	5–12	2	5–12
Mexico	10	10	15	39	25	49
Nigeria	3	35	0	0	3	35
Pakistan	2	12–25 3/	0	27	2	39–52
Peru	0	0	5	43	5	43 4/
Philippines	2	10	0	23–32 2/	2	33–42
Poland	5–8	10–16	0	0	5–8	10–16
Russia	6	6–14.50	0	15	6	21-29.50
Saudi Arabia	0	0	0	9	0	9
South Africa	7–16	19–21	0	10	7–16	29–31
Taiwan	0	0	0	10	0	10
Thailand	0	0	1–10	12	1–11	12
Turkey	1–3	7–18	0	0	1–3	7–18
Ukraine	1	1–5	2–3	10–15	3–4	11–16
Venezuela	1	0	0	30–37	1	30–37

Source: IATA (2005a)

Notes:
1/ Applies to U.S. and Canadian citizens only.
2/ Applies to domestic citizens only.
3/ Rate differentiated by class of travel.
4/ Includes both arrival and departure tax.

Table 6: Estimated Aviation Fuel Externality Cost, United Kingdom, 2000,

(U.S. cents per gallon)

Airplane Type	Noise	Air Pollution	Total Externality Cost
A310	7	35	42
A340	7	40	47
Bae146	0	35	35
B737-100	42	27	69
B737-400	0	35	35
B747-400	7	44	51
B757	6	38	44
B767-300	6	36	42
B777	0	40	40
F100	0	35	35
MD82	7	38	45
Average	7	38	45

Source: Pearce and Pearce (2002).

Table 7: Illustrative Seat Prices by Type of Ticket

(British Airways 747, London-New York, November 1998)

Travel class	Ticket price round trip, in GBP	Number of seats	Average capacity utilization, percent	Average share of passengers, percent	Average share of revenue, percent
First class	5,234	18	50	3	25
Club class	2,954	25	60	6	24
Unrestricted Traveler class	844	49	80	15	18
APEX class	357	124	85	39	19
Promotion class 1/	187	132	100	49	13
Total	186,813 2/	359	75		

Source: Hanlon (1999).

Notes:
1/ This is a particular low-price ticket sold as part of a time-limited promotion scheme; the capacity utilization rate of 100 percent is assumed.
2/ Total revenue per flight.

Table 8: Optimal Tax Rates with ε=1.

(Ticket tax in tax-inclusive form, percent; fuel tax in US$ per gallon)

Parameters	Both Tax Available		Only One Tax Available 1/		
				Fuel tax	Fuel tax
	Ticket tax	Fuel tax	Ticket tax	σ = 1	σ = 0.5
E′ =0					
δ = 1	0	0	0	0	0
δ = 1.1	0.09	0	**0.09**	0.20	0.34
δ = 1.25	0.2	0	**0.2**	0.50	0.94
δ = 1.5	0.33	0	**0.33**	0.75	2.28
E′ =0.40					
δ = 1	0	0.40	0.05	**0.40**	**0.40**
δ = 1.1	0.09	0.36	**0.13** 2/	0.60	**0.77**
δ = 1.25	0.2	0.32	**0.23**	0.90	1.41
δ = 1.5	0.33	0.27	**0.35**	1.40	2.86

Notes:
1/ Bold type indicates optimal single tax.
2/ Ticket tax optimal when σ=1, fuel tax optimal when σ= 0.5.

Table 9: Optimal Tax Rates with ε = 0.5.

(Ticket tax in tax-inclusive form, percent; fuel tax in US$ per gallon)

Parameters	Combined Optimal Taxes		Single	Single Fuel Tax	
	Ticket tax	Fuel tax	Ticket Tax	σ = 1	σ = 0.5
E′ =0					
δ = 1	0	0	0	0	0
δ = 1.1	0.18	0	**0.18**	0.34	0.44
δ = 1.25	0.4	0	**0.4**	0.94	1.33
δ = 1.5	0.67	0	**0.67**	2.29	4.00
E′ =40					
δ = 1	0	0.40	0.05	**0.40**	**0.40**
δ = 1.1	0.18	0.36	**0.22**	0.76	0.89
δ = 1.25	0.4	0.32	**0.42**	1.41	1.87
δ = 1.5	0.67	0.27	**0.68**	2.86	4.80

Table 10: Policy Gains (with ε=1) from using Two Instruments versus Best Single Instrument and from Ticket Tax versus Fuel Tax

(Gains in percent of total turnover in the aviation sector)

Parameters	Two Taxes over Best Single Tax		Ticket Tax Over Fuel Tax	
	σ = 1	σ = 0.5	σ = 1	σ = 0.5
E' =0				
δ = 1	0	0	0	
δ = 1.1	0	0	0.35	0.22
δ = 1.25	0	0	2.01	1.6
δ = 1.5	0	0	6.84	5.05
E' =40,				
δ = 1	0	0	-0.42	-0.19
δ = 1.1	0.01	0.01	0.02	0.02
δ = 1.25	0.21	0.15	1.8	1.15
δ = 1.5	0.25	0.2	6.94	4.85

Table 11: Tax Revenues (with ε = 1), and Revenue Gain from Deploying Two Taxes Rather than One

(US$ billion)

Parameters	Both Taxes		Only One Tax Available 1/			Revenue Gain from using Two Taxes 2/	
				Fuel tax			
	σ = 1	σ = 0.5	Ticket tax	σ = 1	σ = 0.5	Σ = 1	σ = 0.5
E' =0							
δ = 1	0	0	0	0	0	0	0
δ = 1.1	36.4	36.4	**36.4**	9.2	15.6	0	0
δ = 1.25	80	80	**80**	16.8	31.6	0	0
δ = 1.5	133.2	133.2	**133.2**	25.2	48.0	0	0
E' =40							
δ = 1	16.8	18.4	19.2	**16.8**	**18.4**	0	0
δ = 1.1	50.4	51.6	**52** 3/	23.2	**27.6**	-1.6	24
δ = 1.25	91.2	92	**92.4**	31.2	43.2	-1.2	-0.4
δ = 1.5	141.2	141.6	**142**	41.2	63.2	-0.8	-0.4

Notes:
1/ Bold type indicates welfare-maximizing single tax.
2/ Relative to welfare-maximizing single tax.
3/ Ticket tax optimal when σ = 1, fuel tax optimal when σ = 0.5.

Table 12. Aviation Traffic by Travel Class and Region

(Passenger Miles and Airline Revenue)

Traffic Category	Economy Class, Percent of Traffic 1/	Business Class, Percent of Traffic 1/	First Class, Percent of Traffic 1/	Percent of Total Traffic, Passenger Miles
Originating in Europe	85.0	14.6	0.4	28.4
Originating in North America	89.0	9.3	1.7	35.5
Originating in Latin America	91.1	7.3	1.6	5.0
Originating in Asia and Pacific	90.5	8.7	0.8	23.9
Other regions 2/	92.5	7.0	0.5	7.2
Total traffic 1/	89.6	9.6	0.8	100
Share of total traffic, passenger miles	90.4	8.2	1.4	100
Share of airline revenue	73.1	20.1	6.7	100

Sources: IATA (2004); and Brian Pearce, IATA, personal communication.

Notes:
1/ Number of passengers
2/ Other regions include Africa and the Middle and Near East.