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Tourism Impacts in Southeast Asia from Carbon Pricing

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Abstract

This paper details the construction of a simple model that estimates tourism income impacts for selected APEC member economies of future market-based measures to reduce international aviation emissions. The model was commissioned by the APEC Transport and Tourism Working Groups in order to inform sustainable policy approaches to international aviation emissions.

At its heart, the model uses price elasticities which capture variations between demand responses for visitors from different regions. To make the model operational, we explore key intermediate relationships between emissions pricing and international tourism income. For example, an examination of the nature, magnitude and importance of international aviation movements shows a diversity of aviation flows and levels of dependence on tourism income across sample economies. Furthermore, the relationship between unit passenger costs of aviation, fuel prices and distance flown is found to be complex, with fuel costs per passenger increasing more rapidly than operating costs as distance increases.

Model results suggest that—within sample economies—proposed pricing measures are likely to reduce international aviation demand reductions by a maximum of 5 percent, while GDP is expected to decline by a maximum 0.5 percent as a result.

1. Introduction

GHD Meyrick was commissioned in 2009 by the APEC Transport and Tourism Working Groups to design a pilot model that estimates tourism income impacts of future market-based measures to reduce international aviation emissions. The project was led by Australia, and co-sponsored by New Zealand, Thailand and Singapore. The project focuses on selected APEC member economies: Australia, Brunei Darussalam, Indonesia, Malaysia, New Zealand, Papua New Guinea, Philippines, Singapore, Thailand and Viet Nam.

The growing volumes of international passenger air travel can be viewed as an opportunity or problem depending on one's perspective. Bringing visitors to an economy from distant origins offers large tourism and development opportunities. At the same time, people are increasingly recognising the environmental impacts that aviation can have, both locally with noise and particulate emissions and globally through climate change. The motivation for this study is to better understand broadly how significant the trade-off might be between reducing environmental impacts from aviation and the potential loss of tourism income.

In the relatively short time available, it was necessary to create a model that is as robust as possible without being excessively difficult to compile or operate. As in any modelling exercise, the approach has required a number of simplifying assumptions and perspectives.

The model constructed is not a forecasting model in that it does not capture all of the determinants of current and future tourism demand to make predictions. Instead we apply "what if" scenarios to "current" tourism demand to see what this demand would look like with and without the market-based measures to mitigate climate change.

In creating the model, the overall philosophy has been to build in flexibility so that the model can be used to test a range of inputs, rather than spend excessive resources on compiling a "definitive" set of expected parameter values.

The paper's structure broadly follows the logical development of the modelling and its data requirements. Section 2 provides an overview of aviation's contribution to climate change as well as the likely pricing of emissions. Section 3 describes the modelling approach to air distances and current aviation passenger flows. Section 4 explains the approach to estimation of air service cost increases associated with market-based measures. Section 5 explains how the demand for international aviation to APEC sample economies under the market-based measures scenarios is estimated. Section 6 examines potential income and employment implications of the estimated reduction in aviation demand. Section 7 discusses the limitations of – and potential improvements to – the modelling, while section 8 provides concluding remarks.

2. Greenhouse gases and aviation

The human-induced component of climate change can be thought of as an enhanced 'greenhouse effect'. Here, additional gases in the atmosphere (such as carbon dioxide) work to trap more heat from sunlight than would be the case without human-induced emissions (Garnaut, 2008). While warming is the most obvious impact of the process, many other aspects of the climate system are ultimately affected, such as rainfall and the frequency of severe weather events.

2.1 Aviation impacts on climate

There are several ways in which flights can contribute to climate change (Sausen et al., 2005): (i) Regular carbon dioxide (CO_2) emissions from burning fuel, (ii) localised effects of Nitrogen oxide emissions from burning fuel (IPCC, 1999), (iii) water vapour, sulphate and soot emissions from emissions made in the upper troposphere and lower stratosphere associated with the formation of condensation trails, and (iv) cirrus cloud formation.

Taken together, these aviation contributions represent 2 to 4 times the impacts on climate than are suggested by aviation-related CO_2 emissions alone. However, in this study, only the CO_2 emissions are considered under policy responses to climate change.

2.2 Potential responses to aviation impacts on climate

Much work has been done to coordinate a global response to attempt to restrict the extent of climate change ('mitigation') as well as the impacts of 'locked-in' climate change ('adaptation'). The United Nations Framework Convention on Climate Change (UNFCCC) has the objective to stabilise "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous … interference with the climate system" (UN, 1992, p. 4). Stabilisation of atmospheric greenhouse gas concentrations generally requires that the rate of global emissions is reduced at some point in the future. In general, the lower the concentration targets, the more rapid and larger the reductions in emissions must be.

For the present study, the task is to analyse the potential impacts of policy interventions that use market-based measures to mitigate the impacts of emissions from international aviation. Such measures require firms to pay additional costs (either through taxation or requiring permits), therefore raising the cost of supplying aviation services. The quantity of greenhouse gases emitted is generally decreased by airlines passing on cost increases through higher airfares which has the effect of encouraging lower use of aviation relative to non-polluting goods and services. It is only because of the negative side effects of aviation that these extra costs (and reduction in demand) would be seen as socially desirable.

Among the market-based measures available (e.g. carbon taxes), the most likely policy to be implemented around the world is emissions trading, requiring emitters to hold and then surrender permits for all of their greenhouse gas emissions.

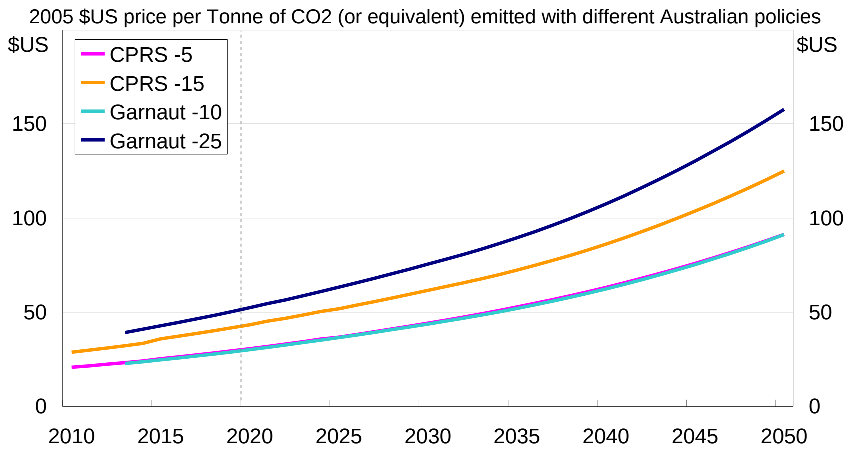
2.3 Expected magnitude of carbon price

For our purposes, we need to know near-term prices of emissions under such trading so we can establish how large the airfare change will be for a given route. We therefore require two things: (1) the likely global emissions target, and (2) a permit price consistent with that emissions level. These will not be known until the magnitude of any global agreement beyond 2012 (as well as the likelihood of including aviation emissions) is agreed.

In the meantime, scenarios for both emissions projections and the economic situation have been performed that provide some guidance for the *likely* price level for emissions trading permits. One such forecasting exercise was performed by the Australian Treasury (2008) for the Garnaut Review (2008). Treasury modelled four emissions scenarios which related Australia's emissions targets to global emissions scenarios consistent with those targets.

Under these scenarios permit prices were estimated between 2010 and 2050. Larger reductions in emissions are associated with higher emissions permit prices, with the largest (Australian) reduction scenario of 25% reduction in emissions from 2000 levels by 2020 associated with a carbon price of around US$40/Tonne in 2013 and a little over US$50/Tonne by 2020 (Figure 1). Less ambitious global emission reduction agreements are associated with prices between US$20 and US$30/Tonne.

Figure 1: Potential Carbon Prices



Source: Australian Treasury modelling (2008)

3. Current aviation routes and usage

This section explores the nature and extent of international aviation flows. The primary aim of doing so is to generate estimates of distances and baseline demand associated with international air travel to sample economies in the APEC region.

3.1 Approach

International aviation flows do not easily lend themselves to economic modelling. A key source of complexity is the route possibilities between two countries; on longer flights, passengers typically have one or more options for a stopover en route. A further source of complexity, which we ignore here, is the domestic leg of an international journey.

To deal fully with the possibility of stopovers on each route, a detailed examination of current flight schedules would be required. Instead the approach taken here was simply to assume that all flights go direct from one country to another. To examine the potential size of distance and CO_2 emission errors with this approach, we studied the actual flight routes for services between Auckland and Ho Chi Minh City. This found possible divergences between the distances and emissions of the direct versus actual flight paths of up to 50 percent.

Overall, the approach used here is to (1) isolate the domestic leg of the travel and exclude it from consideration of the international journey, and (2) assume that all international travel takes place directly via each country's most trafficked international airport.

3.2 Aviation distances

A simplified matrix of 'great circle distances', which measure the shortest surface distances between two points (going 'around' rather than through the earth), was created using an online calculator. These are direct distances between each economy's most trafficked international airport. In characterising the distance of routes, we use a cut-off point between short- and long-haul of 4,000 km based on literature search.

3.3 Aviation flows

Data on international aviation flows are available from a range of national and international sources. For this pilot model, the decision has been made to rely on national sources in light of the relatively small sample of destination economies. More detailed and geographically comprehensive (though expensive) data could be obtained from IATA if a more detailed modelling exercise were to be undertaken.

National data on international arrivals is typically gathered from border control arrival cards. For each sample economy, we require total arrivals split down by mode (separating air from land/sea arrivals) and by country of origin (nationality is used as a proxy for this). As expected, though, many sample economies are not able to provide such detailed arrivals data since it is often not collated from the raw arrival cards. Estimations were made in these cases based on data available.

The full matrix of (estimated) aviation arrivals to each destination in the sample economies is utilised in the pilot model. This matrix contains estimated numbers of aviation passengers that have originated from each economy (up to 120 origins for one destination in the most detailed data series). These figures relate to the latest available year for which most economies have records, 2007 or 2008, though some data relates to earlier years. Due to the size of the total matrix, only a summary can be displayed in Table 1.

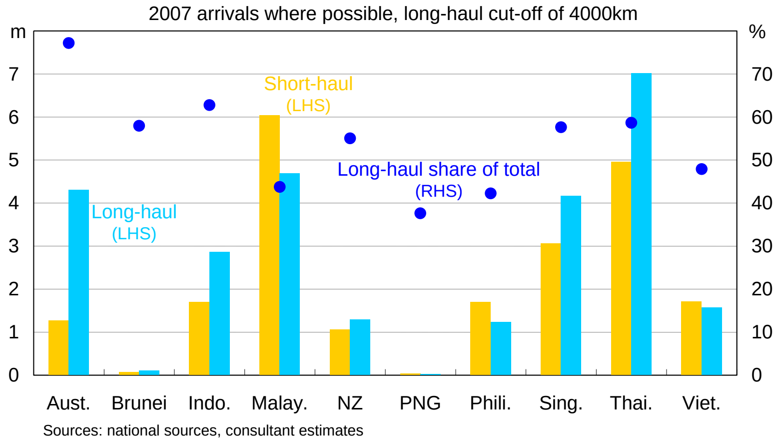
Table 1: Aviation arrivals by origin region, thousands, 2007/8 (where available)*

Destination Economy / Origin Region	**Aust-ralia**	**Bru-nei**	**Indo-nesia**	**Malay-sia**	**NZ**	**PNG**	**Philip-pines**	**Sing-apore**	**Thai-land**	**Viet Nam**
Asia, *of which:*	2,209	96	3,127	8,012	450	17	1,739	4,799	6,607	2,215
- Sample Asia	*704*	*60*	*1,534*	*5,220*	*87*	*8*	*251*	*1,995*	*1,456*	*536*
- Other Asia	*1,505*	*36*	*1,593*	*2,792*	*363*	*8*	*1,488*	*2,804*	*5,151*	*1,679*
Oceania, *of which:*	1,272	12	398	532	1,084	41	178	845	730	301
- Aust/NZ	*1,113*	*12*	*340*	*483*	*976*	*39*	*135*	*831*	*714*	*301*
- Other Oceania	*159*	*0*	*57*	*49*	*108*	*3*	*43*	*14*	*15*	*0*
Europe	1,358	36	797	1,666	511	4	325	1,097	3,667	233
Americas	644	42	220	301	294	6	698	416	850	534
Africa	101	0	28	222	28	0	4	76	122	0
Total	**5,586**	**185**	**4,570**	**10,734**	**2,366**	**68**	**2,944**	**7,233**	**11,975**	**3,283**

Sources: national sources, consultant estimates and interpolations

A summary measure of the composition of international visitors to each of the sample economies is the share of visitors arriving by long- and short-haul flights. The available data suggest that more than half of air arrivals visiting Australia, Brunei, Indonesia, New Zealand, Singapore and Thailand are long-haul; with the remaining sample economies having short-haul air arrivals dominating (Figure 2). This analysis also gives a broad idea of which economies will have relatively high emissions intensity of their international tourism income.

Figure 2: Distance composition of international visitor arrivals



4. Aviation costs and fare changes

This section explores the likely impact of carbon pricing on airline costs and airfares. Establishing this impact requires an understanding of the cost structure of typical airline operations, especially the fuel component.

4.1 Aviation fares and costs

There are two potential approaches to establishing how great the percentage change in airfares is likely to be in response to a price being placed on emissions:

- Market **prices** – this approach involves choosing a type of ticket, length of stay, and time horizon for travel and surveying fares on a flight booking website (e.g. Tol, 2007). Fare increases can be calculated using the carbon price and emissions per flight on the route pair (via an engineering approach or online emissions calculator). While an easily understood approach, it is not likely to yield particularly stable results.
- Airline **cost** increments – under the assumption that over longer periods airfares will actually reflect operating costs, with knowledge of the operating cost structure of airlines it is possible to calculate the likely percentage change in fares resulting from the carbon price. *Modelling here uses a cost approach for reasons of computational simplicity and robustness.*

4.2 Cost structure

The percentage change in operating costs with the inclusion of a price on carbon dioxide emissions can be defined in terms of a number of variables:

$$\begin{aligned}\%\Delta OpCost_{ij} &= \frac{\Delta OpCost_j}{OpCost}\times 100 \\ &= \frac{CP_i \cdot k}{FP_j}\cdot\left(\frac{FCost}{OpCost}\right)_j\times 100 \quad , \qquad (1)\end{aligned}$$

where *OpCost* is the operating cost attributable to each passenger on a specific route, CP_i is the carbon price ($US per tonne) in scenario *i*, *k* is a constant reflecting the CO_2 content of a litre of jet fuel, FP_j is the fuel price in scenario *j*, $(FCost/OpCost)_j$ is the share of operating costs accounted by fuel costs in fuel scenario *j*. The first half of this expression contains terms that are either selectable in the model according to scenarios (i.e. CP_i and FP_j) or are known constants (*k* = 2.53 Kg/L, EIA n.d.). The main difficulty is understanding how large a share fuel costs account for in total operating costs.

IATA (2007) reviewed company reports of 45 international passenger airlines to estimate the shares of each major expense in airline operating costs. The results indicate that the two major line items are labour and fuel expenses (Table 2). While labour shares tend to vary by region (due to wage differences in each economy), they are relatively stable across time, accounting for around 25 percent of operating expenses. The fuel price share is much more volatile across time, due in large part to the volatility in aviation fuel prices.

Table 2: Percentage Share of Airline Operating Costs, by Region of Airline Registration

	North America		Europe		Asia Pacific		All Major Airlines	
	2001	*2006*	*2001*	*2006*	*2001*	*2006*	*2001*	*2006*
Labour	36.2	25.2	27.2	25.8	17.2	17.2	28.3	23.3
Fuel	13.4	26.6	12.2	20.5	15.7	30.4	13.6	25.5
Aircraft Rentals	5.5	3.7	2.9	3.1	6.3	2.4	5.0	3.5
Depreciation /Amortisation	6.0	4.9	7.1	6.7	7.4	7.3	6.7	6.0
Other	38.9	39.6	50.6	43.9	53.4	42.7	46.4	41.7

Source: IATA (2007)

Given the volatility in the fuel share of operating costs, we include scenario-based estimates for this variable in the model (Table 3). Estimates correspond to a 'low', 'moderate' and 'high' aviation fuel price in the US (Figure 3) based on a broad relationship between these prices and the cost shares in Table 2.

Figure 3: Aviation fuel prices

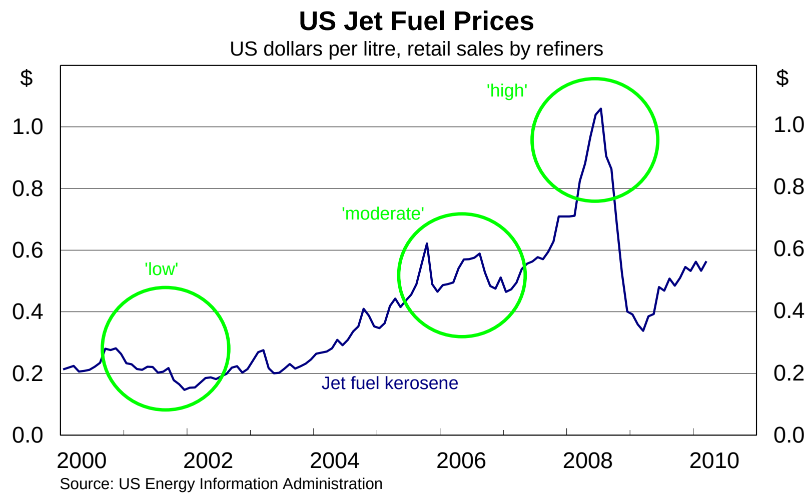


Table 3: Fuel Share Scenarios

Fuel Price Scenario	Fuel Price ($US/L)	Reference Year	Fuel Share (% of total operating costs)
Low	0.20	2001	15
Moderate	0.53	2006	30
High	0.80	2008	40

Source: IATA (2007), consultant estimates, US Energy Information Administration (2009)

Equation (1) does not encompass percentage changes in operating costs that vary across distances. This variability is likely to be present in the (*FCost/OpCost*)$_j$ term. Consider the two parts of this term: fuel cost and operating costs. Each of these costs will increase with increasing distance flown. However, they may not increase at exactly the same rate.

Establishing aircraft fuel cost and operating cost models is a significant exercise in itself and is beyond the scope of this project. Instead, a literature review was undertaken in order to gauge the likely forms of the fuel cost and operating cost relationships with distance flown. The ICAO (2008) calculator attributes emissions to each economy-class air passenger by examining fuel use when flying between linked origins and destinations. These calculations are made according to average loadings, splits between freight and passengers, and the various classes of passengers; it also considers the characteristics of the aircraft actually flown on each route. The final stage of ICAO's calculation converts fuel burn to CO_2 emissions per passenger by multiplying by a constant factor (3.157) which represents the "number of tonnes of CO_2 produced by burning a tonne of aviation fuel" (ICAO, 2008, p. 6). An exercise of generating a table of CO_2 emissions per passenger versus distances between (directly linked) origins and destinations within our sample reveals a broadly linear relationship between fuel burn per passenger and distance travelled (Figure 4).

Figure 4: Emissions relationship with distance implied by ICAO calculator

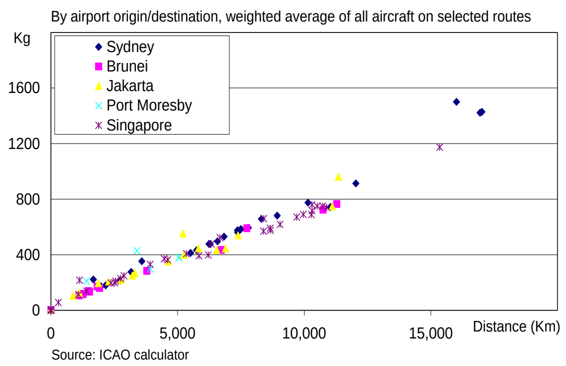
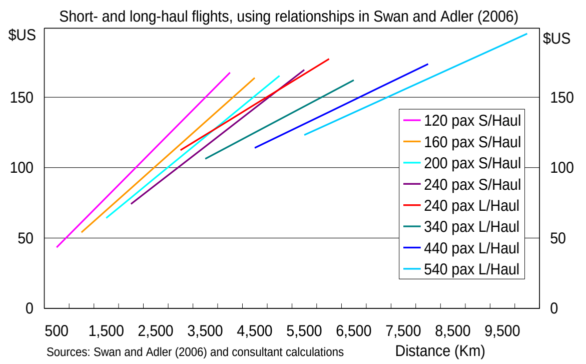


Figure 5: Operating cost relationship with distance



Swan and Adler (2006) generate aircraft operating cost functions for short- and long-haul flights for a range of aircraft based upon both the capacity of the aircraft and the distance flown. Application of the results suggests that operating costs per passenger increase at a decreasing rate as distances flown increase – i.e. a non-linear relationship. This is due to two factors: the greater increase in costs per passenger with increasing distance associated with short-haul (compared to long-haul), and the move towards larger aircraft at longer distances that can harness lower average costs (Swan and Adler, 2006). Graphing the examples according to the relationships in Swan and Adler's (2006) work shows that as distances increase, the switch to larger aircraft and from short- to long-haul cost factors results in a less-than linear overall relationship (Figure 5).

Combining this information about the 'shapes' of the relationships between fuel cost and distance, and operating costs and distance, we can suggest that the joint ratio (i.e. (*FCost/OpCost*)$_j$) will not be constant across distance. Instead, the evidence suggests that the ratio will increase with increasing distance. The exact scale of this relationship is not known, since we would have to be able to calibrate the fuel-price-dependent *FCost/OpCost*$_j$s in Table 3 across distances. This would require full specification of fuel cost functions (possible from the ICAO calculator) and operating cost functions (extremely difficult) that depend upon fuel prices *and* distance. Instead, a simplifying assumption is made that the *FCost/OpCost*$_j$ ratio values in Table 3 represent an average of each of short-haul or long-haul flights. Therefore, we take the stylised increasing *FCost/OpCost*$_j$ function to mean that the fuel cost ratio is higher than average for long-haul flights and lower than average for short-haul flights. The degree to which the *FCost/OpCost*$_j$ ratios will be higher than the means in Table 3 for long-haul (and similarly the degree to which this will be lower for short-haul flights) is controlled by a single (symmetrical) parameter, termed the 'fuel price sensitivity' in the pilot model.

4.3 Cost increases under a carbon price

As is clear from the preceding section, projecting increases in cost per passenger under a carbon price will depend a great deal on the scenario expected for the fuel price and the carbon price. These costs per passenger will clearly vary between origin and destination pairs in our sample. To give some indication of the magnitude of this impact, an average of estimated cost increases across all origin-destination pairs in the sample is provided for a range of fuel prices and carbon prices (Table 4).

Table 4: Average percentage change in costs per passenger among sample-economy-destined flights*

Carbon Price	Fuel Price (US$/L)		
(US$/Tonne)	0.20	0.53	0.80
10	2.1	1.6	1.4
30	6.2	4.7	4.1
50	10.4	7.8	6.9

*Assumes fuel cost share sensitivity = +/- 15% and long haul cut off = 4000km

These calculations demonstrate the intuitive result that higher carbon prices will imply a greater increase in operator costs than lower carbon prices. They also show that with higher (pre-tax) fuel prices, the impact of a given carbon price will be relatively low since the carbon price accounts for a relatively small share to fuel and total operating costs. Results suggest the magnitude of the once-off operating cost change is 10 percent or less for most feasible short-term values for both the carbon price and fuel price.

5. Aviation demand under a carbon price

This section pulls together the strands from previous chapters to estimate the expected demand impact of applying market-based measures to international aviation emissions.

5.1 Factors influencing aviation demand

This section focuses on the influence that price has over people's demand for international aviation. In practice, several factors will influence demand, such as (Brons, et al. 2002):

- Travel time (in-'vehicle' time plus access time, waiting, frequency, etc.) relative to other modes where available. Some international passenger travel can be done by non-aviation modes, such as rail, road or sea in similar amounts of time.
- Airfares relative to other costs of other modes where available. The impact of the inclusion of a carbon price may be complicated by price changes of substitutes.
- Comfort relative to other modes if available.
- Incomes will also determine how much international travel can be consumed.
- Types of travel – such as business versus personal.

This model assumes that the current conditions (e.g. for country incomes) will remain broadly unchanged in the modelled scenario.

5.2 Price elasticity of demand for aviation

This study takes a relatively simple approach to modelling demand responses based on the economic concept of elasticity. In short, an elasticity measures the specific responsiveness of demand to a percentage change in another variable (often a price), while all other variables are held constant. In this instance, we use a (own) price elasticity of demand, which is given by:

$$\varepsilon_p = \frac{\%\Delta Q}{\%\Delta P}, \qquad (2)$$

where $\%\Delta Q$ is the percentage change in international aviation and $\%\Delta P$ is the percentage change in international airfares. Rearranging equation (2) shows that with suitable estimates of the price elasticity of international aviation demand will allow the calculation of the percentage change in aviation demand from price rises associated with market-based measures for international aviation emissions.

A recent elasticity study for IATA estimates region-specific elasticities to account for the factors affecting the price elasticiticy of demand for air travel, including an adjustment factor to account for higher elasticities of short-haul flights. The estimates used in the present study are found in Table 5.

Table 5: Elasticities for air travel from region-wide fare changes

Region	Short-haul	Long-haul
Intra Asia	-0.63	-0.57
Trans Pacific (N. America – Asia)	-0.40	-0.36
Europe – Asia	-0.59	-0.54

Source: InterVISTAS (2007)

5.3 Estimated changes in aviation flows under a carbon price

The elasticities are applied to the percentage changes in fuel prices implied by certain fuel prices (which are in turn influenced by the base fuel price and the 'fuel price sensitivity' defined in section 4.2) to estimate percentage changes in aviation demand for relevant market segments (Table 6). Results indicate, that with 'moderate' base fuel prices, the once-off change in international aviation demand to sample APEC economies under a carbon price of around US$50/Tonne is likely to be between 3 and 5 percent. While this estimate is based on a range of realistic assumptions, it is important to clarify that this is a static model that does not allow for the input mix to change. The low-cost carrier experience shows that airlines are prepared to alter the existing input mix in order to deliver more competitive services. This dynamic response may dampen the effect shown here.

Table 6: Representative percentage changes in aviation demand with various carbon prices*

Region	Short-haul				Long-haul			
Carbon Price: ($US/Tonne)	10	30	50	100	10	30	50	100
Intra Asia	-0.8	-2.3	-3.8	-7.7	-0.9	-2.8	-4.7	-9.4
Trans Pacific (N. America – Asia)	na	na	na	na	-0.6	-1.8	-3.0	-5.9
Europe – Asia	na	na	na	na	-0.9	-2.7	-4.4	-8.9

* Assumes that fuel price is 'moderate' at $US0.53/litre and fuel price sensitivity is +/- 15%

In any case, these calculations suggest that the aggregate impacts for economic activities associated with international aviation are not likely to be transformative. Within this overall figure, lower demand responses from more distant origins (particularly North America) reflect a lack of alternative travel modes and relatively high incomes.[1]

6. Impact of a carbon price on tourism income

6.1 Tourism in context

To give a sense of the importance of the international tourism industry to the sample economies, statistics about tourism arrivals and income have been collected and estimated. These indicate that many of the economies received over US$5 billion over 2007 (or 2008) (Figure 6). In this same time period, over 10 million tourists arrived by air to Thailand and Malaysia, with most other economies receiving between 2 and 7 million aviation arrivals.

Perhaps more instructive still on the importance of tourism to people in the sample economies is the share of GDP that tourism accounts for, as well as the income per person that the industry provides. The former measure illustrates that Malaysia, Singapore, Thailand and Viet Nam all receive greater than 5 percent of their income from tourism (Figure 7). In absolute terms though, Australia, New Zealand, Singapore and Malaysia are the only economies where on average per capita receipts from tourism are greater than $500 per annum.

Figure 6: Tourism arrivals and income

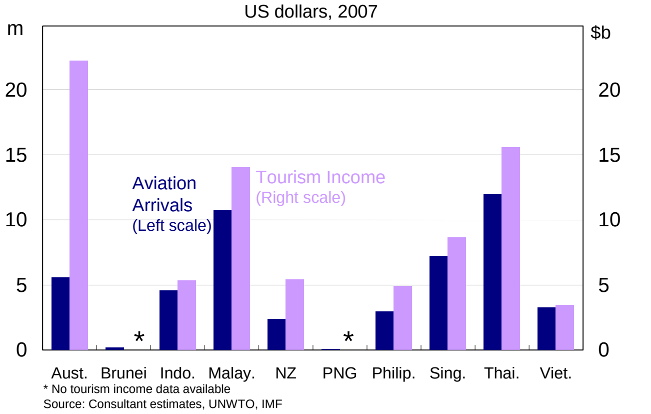
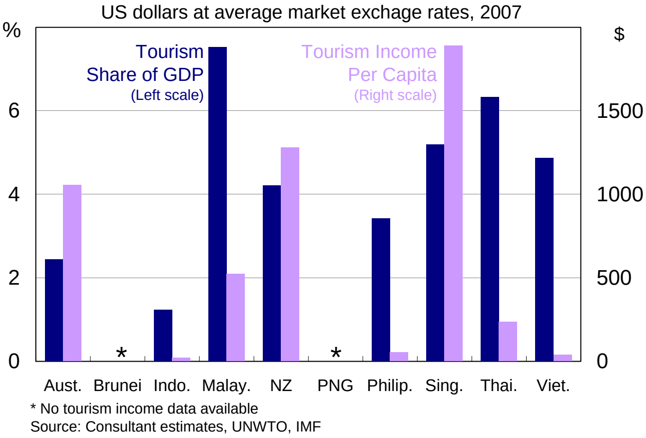


Figure 7: Importance of Tourism



The issue of insufficient data detail discussed in section 3.3 means that the numbers of international arrivals coming by air has been estimated from total international arrivals, which are commonly only available on the basis of origin country (or region) rather than mode. This provides a serviceable estimate of aviation arrivals from each origin country. However, it is less easy to apportion income generated from tourism to these *aviation* arrivals from each country.

In the present modelling we make the (extreme) assumption that all tourism income is attributable to visitors who arrive by air and that this income is generated equally per arrival regardless of country of origin. In practice, this means that the impacts on tourism income will likely be overstated in the modelling for two reasons. First, reductions in total tourism

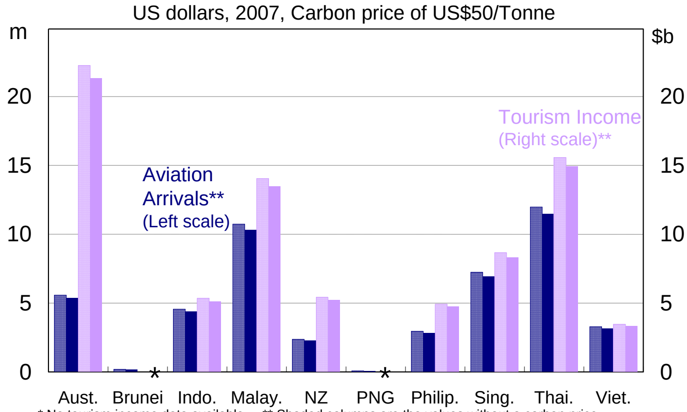
[1] The lower demand response from short-haul compared to long-haul passengers evident in Table 6 is to some extent an artefact of a specific parameter choice. Specifically, the fuel price sensitivity, which measures the degree to which fuel operating costs account for a greater share of operating costs in long-haul flights than in short-haul ones, is set at a higher percentage (15%) than the extent to which elasticities on long-haul flights are smaller than those on short-haul flights (10%). This suggests that improving the accuracy of this parameter would be important in better understanding the relative aviation demand response from various locations.

arrivals are likely to be lower than estimated because some visiting air passengers will be business travellers who tend to have lower responsiveness to price changes (Hensher and Brewer, 2001). Second, income from visitor arrivals by sea and land should be unaffected by the carbon price for aviation emissions.

6.2 Changes in tourism income under a carbon tax

Under the assumption that all tourism income is attributable to visitors who arrive by air, the change in income from tourism is proportional to the change in international aviation arrivals. Examples of the potential changes in international aviation arrivals for a variety carbon prices are shown in Figure 8 as being between -0.5 and -5.0 percent for carbon prices below US$50/Tonne. Figure 8 illustrates the impact that a US$50/Tonne carbon price would have on aviation arrivals and tourism income for sample APEC member economies.

Figure 8: Tourism with a carbon price of US$50/Tonne



* No tourism income data available ** Shaded columns are the values without a carbon price
Assumptions: fuel price = US$0.53/L, fuel cost share sensitivity = +/- 15%, long haul cut off = 4000km
Source: Consultant estimates and model results, UNWTO, IMF

6.3 GDP impacts of carbon price

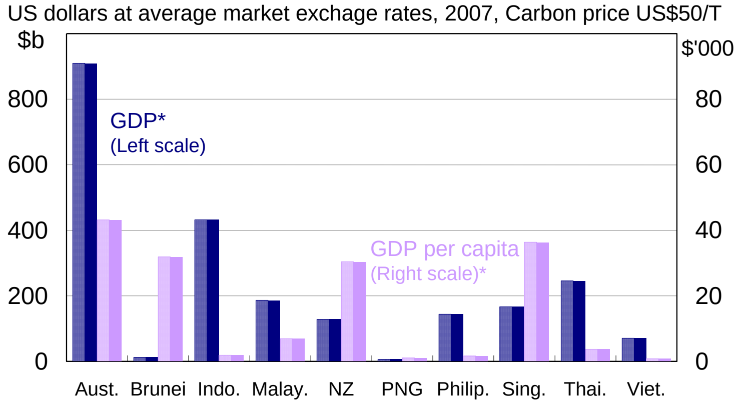
Section 6.1 describes the difference in the importance of tourism to each of the sample APEC economies. Due to these differences, the impact on GDP of changes in tourism income will vary across the economies.

The impact on national income (GDP) from a change in aviation arrivals may exceed the direct impacts captured above for two reasons. First, it is possible that some tourism-related income may not be captured in the UNWTO measures of tourism income used in the model (e.g. purchases of clothing or food that may not be separately reported in national accounting). Second, there is likely to be a multiplier effect of income reduction from a once-off reduction in tourism income. For example, if fewer tourists arriving in Penang meant that fewer people purchased meals from a restaurant then the restaurant vendor would have less to spend on a range of goods and services that might otherwise be consumed. A reduction in income from the reduction in direct tourism income may therefore result in indirect income reductions in other sectors of the economy.

The economic model captures these two factors by including an 'indirect tourism income multiplier', which is a multiple of the direct tourism income that is considered to produce income in excess of that direct tourism income. We use a relatively high multiplier of 1, implying each dollar of (direct) tourism income lost results in a 2 dollar loss of GDP in total.[2] Applying these assumptions to the above information, we see that under a US$50/Tonne carbon price, the reduction in GDP falls with the range of -0.1 to -0.6 percent (Figure 9). A sensitivity analysis on key variables is detailed in the Appendix.

[2] Frechtling (1994) provides a table of estimates which shows that a 'doubling' multiplier effect is at the high end of the spectrum of available estimates. These effects appear to diminish with the size and stage of economic development of the region under consideration.

Figure 9: GDP impacts of a US$50/Tonne carbon price



* Shaded columns are the values without a carbon price
Assumptions: fuel price = US$0.53/L, fuel cost share sensitivity = +/- 15%, long haul cut off = 4000km, indirect tourism income multiplier = 1
Source: Consultant estimates and model results, IMF

This analysis considers only the costs of implementing market-based measures to reduce emissions from aviation. A more thorough analysis would need to consider the benefits of such policy action. Specifically, by including emissions from aviation in a global mitigation effort, some degree of climate change impacts (e.g. rising temperatures) may be avoided. Such an outcome should be considered a benefit of the action and compared to the economic costs of these actions. The two main studies that have attempted to compare costs and benefits are the Stern (UK, 2006) and Garnaut (Australia, 2008) reviews, which each found that the benefits of early, significant and collective mitigation action were in excess of the costs of action for each economy. Furthermore, under some proposals for the implementation of market-based measures there would be transfers of revenue to affected economies, further offsetting any negative economic impacts for these economies.[3]

7. Caveats, extensions and sensitivity analysis

The foregoing modelling is clearly capable of further enhancement. Given the detail of the available data and the time available, the overall philosophy of the modelling was to provide sufficient degree of sophistication in order to capture the main relationships and responses that are expected to be relevant in understanding the impacts of market-based measures to reduce aviation emissions.

The implication of this is that while the broad order of magnitude of impacts may be realistic, the specific values for impacts (e.g. the percentage change in GDP) should not be relied upon. There are two reasons for this. First, the quality of the data and low degree of precision possible in the calculations means that there are likely to be wide error bands around estimates. Second, the model relies on the selection (or prediction) of a number of key variables that will be determined elsewhere (such as the prevailing cost of carbon dioxide emissions). Any specific estimate embodies a specific choice of a number of parameters, which are all to some extent uncertain. To highlight the potential impacts of the latter effect, sensitivity analysis has been undertaken and reported in the Appendix.

Potential improvements and extensions are suggested under chapter headings:

- *Greenhouse gases and aviation*: The world carbon price could be improved after the Mexico negotiations in late 2010.
- *Current aviation routes and usage*: Perhaps the most useful extension of the economic model will be to gain more accurate aviation flow data. This could come

[3] See, for example, the "Maldives Proposal" (Müller, 2009).

from either IATA's statistical database on annual international passenger flows or member economies' arrivals information. In calculating flight distances between origins and destinations, greater sophistication could be applied to accounting for stopovers and for indirect routing.

- *Aviation costs and fare changes*: The model results hinge upon several simplifications. The most important simplification is that the FCost/OpCostj ratio varies only with the fuel price (in three increments) and distance (in just two increments). With greater time and resources it would be more accurate to develop direct relationships for each of the components of this ratio.
- *Aviation demand under a carbon price*: The main improvement in this part of the economic model would be to refine the elasticity estimates. This could be done by running a new study that incorporated the detailed origin-destination/price data from IATA.
- *Impact of a carbon price on tourism*: The reductions in aviation arrivals will affect only the tourism income generated from visitors arriving by air, whereas the assumption of the current analysis is that the drop in total income from tourism will be proportional to the drop in the number of arrivals by air. Detailed tourism income information may assist in assigning the correct proportions of total international tourism income to aviation-related tourism income. Improved accounting for 'indirect' tourism income, such as the Australian Bureau of Statistics' Tourism Satellite Accounts, may assist in understanding the full GDP effects that international tourists provide.

8. Conclusion

Climate change is a serious challenge for the world to deal with. Aviation plays a small but growing part of this problem. Based on current proposals, there is some chance the world economies will strike a global agreement for emissions reductions in coming years. This agreement may include international aviation emissions, which have thus far been excluded from the mitigation effort.

Recognising that international aviation flows currently deliver significant mobility and economic opportunities in destination economies, this study has modelled, in broad terms, how large the likely impacts of mitigation policies for aviation might be on tourism numbers, income and GDP for sample APEC member economies.

The effect of carbon pricing on tourism numbers will be very dependent on the actual carbon price, which is as yet unknown. It will also vary between economies, because of factors such as the different mix of short-haul and long-haul travellers and availability of alternative travel modes. But, as a general guide, results indicate, that with 'moderate' base fuel prices, the near-term change in international aviation demand to sample APEC economies under a carbon price of around than US$50/Tonne is likely to be between 3 and 5 percent. Over the medium term the combined impacts of rising carbon prices and efforts of airlines to change technology or input mix are still uncertain.

The combined direct and indirect GDP impacts of this reduction in aviation will be more significant for economies that have a high reliance on tourism. At a carbon price of $US50/tonne, the effect ranges from around -0.1 percent of GDP (Indonesia) to around -0.6 percent (Malaysia).

The simplifications in this study will in general tend to over-estimate rather under-estimate the impact of carbon pricing, and the results should be interpreted as upper bound estimates of the likely impact of the proposed market-based measures. A study that undertook a similar analysis using a much different methodology found smaller (aggregate) impacts from higher carbon prices (Tol, 2007).

At several stages, the accuracy of the modelling has been limited by the availability of sufficiently rich data. In some cases, more detail may make modelling more difficult without delivering significant improvements in accuracy. However, in specific areas, such as visitor arrivals by mode and origin country, better data quality would likely improve modelling accuracy measurably.

The current study is intended as a pilot modelling exercise, and as such has been limited in resources and geographical coverage. This paper demonstrates that a more detailed modelling exercise is both feasible – particularly with more extensive data – and potentially useful using the current modelling framework.

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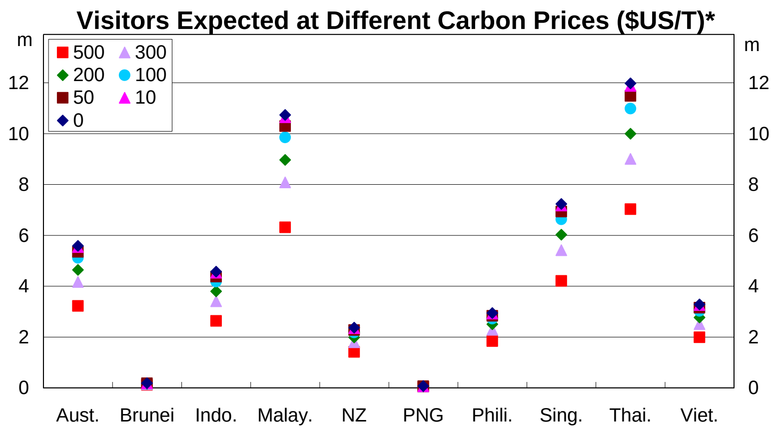
Appendix: Sensitivity analysis

This appendix examines how sensitive the results of the economic modelling are to variations in the parameters used. Of most interest are the impacts of parameter inputs on the visitor numbers expected and GDP changes from the reference scenario. In each case, values of one parameter are varied, while all other parameters are held constant at representative values. Results are presented under headings based on the parameter to be varied.

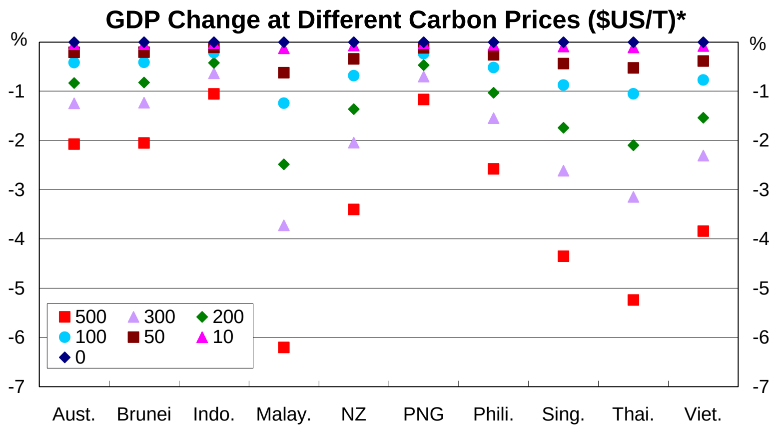
A.1 Carbon price

The changes to international aviation visitor arrivals in response to the application of a carbon price appear relatively muted for carbon prices up to US$100/Tonne (Figure 10). The varying GDP impacts across the sample economies is observed in the second panel, whereby GDP is anticipated to decrease by around 1% in Malaysia, Thailand and Singapore, but the impact is less than -0.5% for Australia, Brunei Darussalam, Indonesia and Papua New Guinea for a carbon price of US$100/Tonne. For much larger carbon prices impacts on aviation arrivals and GDP are proportionally larger, with a carbon price of US$500/Tonne suggesting a near halving of aviation arrivals and GDP impacts of over -2% for many of the sample economies.

Figure 10: Impacts of varying the carbon price



* Millions of international arrivals per year. Assumptions: fuel price = US$0.53/L, fuel cost share sensitivity = +/- 15%, long haul cut off = 4000km, demand responsiveness adjustment = 1



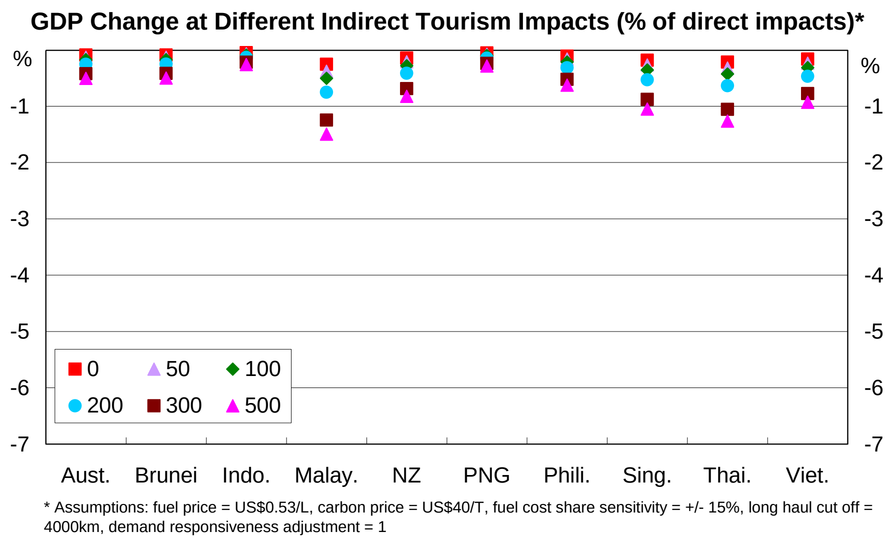
* Assumptions: fuel price = US$0.53/L, fuel cost share sensitivity = +/- 15%, long haul cut off = 4000km, demand responsiveness adjustment = 1, indirect tourism impacts = 100% of direct impacts

A.2 Indirect tourism multiplier

The indirect impacts of tourism income amplify the GDP effects of a given loss of tourism income. As such, the greater the choice of parameter for the indirect impacts, the greater the

GDP impact will be in the model. For example, even with a US$40/Tonne carbon price, if the indirect impacts are 2 to 5 times the original impact of the carbon price, the overall impact can be pronounced, particularly for Malaysia, Singapore and Thailand (Figure 11). If higher indirect tourism impacts were combined with higher carbon prices, the overall impact on GDP would be higher still.

Figure 11: Effect of altering the indirect tourism impacts



A.3 Other parameters

Most other parameter choices do not produce dramatic changes in either visitor arrivals or GDP, even with considerable variation. These variables include the (tax-free) fuel price, the 'fuel price sensitivity', the cut-off distance between short and long-haul flights and an adjustment to the scale of the elasticities.