Efficiency improvements observed in the UK aviation fleet

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1 Introduction

Previously government policy and the Climate Change Committee report on Aviation[1] have both assumed rates of fleet fuel efficiency improvement of around 1% per annum (the CCC gave 0.8-1.5% for future improvements to 2050).

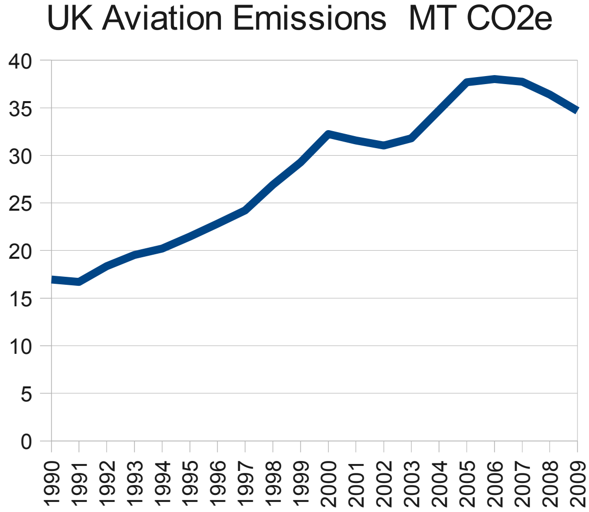
The CCC state that technological (engine and airframe) improvements by 2025 might deliver 35-45% fuel efficiency gain but it does not emphasise that this is comparing a new aircraft of 2025 with one of 2005. A 35% gain over 20 years is equivalent to a compound 1.5% improvement per year. From this we can see that the assumption of the whole fleet improving at 0.8% per year implies that 50% of the whole fleet changes over to the state of the art aircraft in 2025. To achieve 1.5% average improvement requires the whole fleet to change to the state of the art of 2025. As aircraft have a fleet life of 25 years or more it is implausible that all aircraft of 2005 will be replaced by 2025 unless some policy measure (or extreme rise in fuel costs) forces this to happen. In addition some of the existing fleet will be replaced at dates before 2025 and will thus only gain the benefits of improvements up to the date of purchase. As several of the measures that make up the 35% or more improvement will not be available until near 2025, this means that the overall gain cannot be near an average rate of 1.5% per year.

The issue that is ignored by policy, and largely not analysed by the CCC, is at what rate fleets actually turn over and hence at what rate fuel efficiency improvement for the fleet is actually delivered. This paper tries to address this gap.

This paper is submitted as part of the consultation on sustainable aviation policy.

2 Emissions

The Department for Climate Change publishes tables covering the basket of greenhouse gases emitted by the UK including domestic aviation, and with these it estimates the emissions from international aviation and shipping using bunker sales[2].

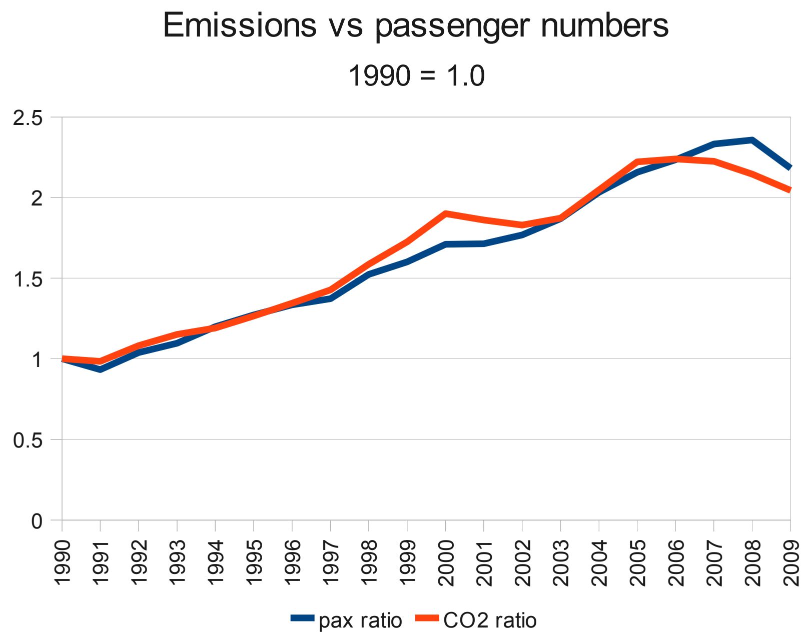


1 “Meeting the UK aviation target – options for reducing emissions to 2050”, CCC December 2009

2 http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/data/data.aspx

The above graph shows millions of tonnes of CO2 equivalent from UK aviation (total domestic and international, ignoring other greenhouse gases) from 1990 to 2009. As can be seen, the total rose by 128% between 1990 and 2006 and it is now 109% above 1990 levels.

If we look at how this corresponds to passenger numbers (as gathered through the CAA annual returns) we get this result:



This shows that the overall emissions trend has closely followed the number of passengers, but has deviated with a kink between 2000 and 2003, and has fallen away more quickly than passenger numbers since 2007. Clearly some other factors are at work here.

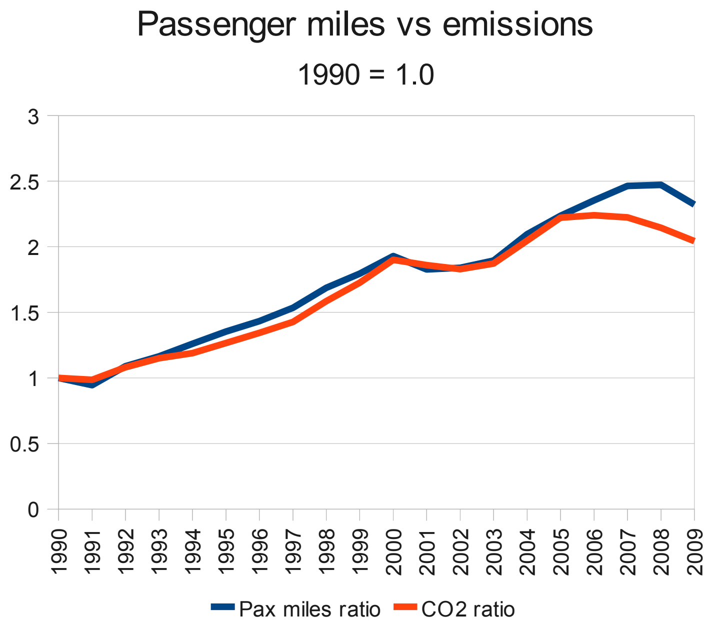
The complicating factors could be a change in fleet composition and a change in journey length (short-haul versus long-haul). There was a phasing out of older aircraft due to regulations on noise, this meant that “Chapter 2” aircraft started to phase-out in 1995 and were either upgraded or replaced by April 2002[3]. This will have removed older and less efficient planes from the fleet. Note that there is no planned future phase-out of “Chapter 3” aircraft for noise reasons, and certainly none for emissions reasons[4].

3 Fleet mix versus flight length

To help untangle these factors, we have created a computer program that can work out the total air miles flown by passengers on the commercial fleet operating from the UK. This uses the detailed CAA returns data[5] for each UK airport which gives the airport for both ends of the flight and the number of passengers on that route per year. Using this data along with the latitude and longitude of the airports involved[6] it is possible to calculate the great circle shortest distance between the airports involved, and hence the total passenger miles. This will be a slight underestimate due to routing, and this will have more of an effect on short-haul flights than long-haul ones, but this is not believed to invalidate the results given below.

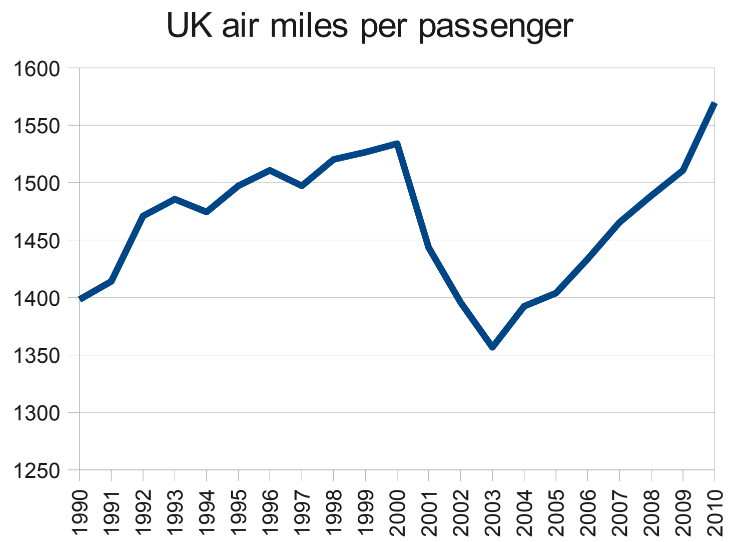
3 *www.boeing.com/commercial/noise/eu_**phaseout**.pdf*
4 http://www.flightglobal.com/articles/2001/01/23/125097/chapter-3-phase-out-talks-fail.html
5 http://www.caa.co.uk/default.aspx?catid=80&pagetype=88&pageid=3&sglid=3 annual data tables 12.1 and 12.2
6 From http://gc.kls2.com/

First we plot the total passenger miles and emissions against time to show that they largely track each other:



Again this shows a high degree of correlation, and perhaps the pulling apart between 1995 and 2000 reflects the Chapter 2 phase-out. The very close tracking 2001 to 2006 might imply that the fleet mix stayed relatively constant over that period.

However this view is complicated by not knowing the mixture of short and long haul flights. We can try to eliminate this element by looking at the miles flown per passenger:



A major drop in long-haul flight occurred after 2001, probably due to the events of 9/11 in the US. A sharp increase in flight length has occurred after 2008 due to the weakening of the pound versus the euro, making it more expensive to holiday in Europe and thus driving a section of passengers to travel beyond the eurozone (although the total number of passengers has fallen considerably, and hence emissions overall have fallen even though emissions per passenger will have risen).

This curve allows us to look at improvements in fleet efficiency whilst trying to eliminate the element of flight length. By choosing two years where the air miles per passenger are nearly the same we can then see how the emissions per passenger (or per passenger mile) have changed.

Year	Miles per passenger	gCO2/per pax mile	Rate of improvement %/year
1990	1398.3	118.5	
2002	1395.8	117.8	0.05
2004	1392.3	115.7	0.89
1996	1510.8	111	
2009	1510.7	104.3	0.48

So for the period during which we know a fleet phase-out occurred (up to 2002) the average compound rate of improvement in fuel efficiency was only 0.05%[7]. Over the longer period to 2004 a larger rate is seen and this might be due to a secondary effect of a drop in long-haul flight in that although the average passenger flight length stayed the same, this was made from a lot more flights near the average rather than a few long-haul flights and a lot of short-haul ones. This would need a more detailed analysis of the actual flight schedules to determine.

Another correspondence between 1996 and 2009 shows an average rate of improvement of 0.48%.

4 Drivers for change

The forces that might accelerate improvements in fleet efficiency are if there was some form of legislated phase-out of older aircraft, some form of compulsion driving radical technological improvements so that when planes are replaced they have a significant improvement in efficiency (ie faster than the historic average rate of improvement) , or a radical increase in the cost of fuel that would compensate for the cost of early replacement of a plane in a commercially attractive time.

Currently the no-frills fleets are made of aircraft near the state of the art, and the only way for them to reach a lower fuel cost per passenger mile would be to buy much bigger aircraft. This does not fit with their business model of minimising the variety of planes within their fleet. Unless new planes with a much lower fuel burn but similar other characteristics were introduced, it is hard to see the case for no-fills operators changing over rapidly.

Although the A380 may be 25% more efficient than an older B747, but it is neither usable in the no-frills short haul fleets, nor at their target airports, and it is very much larger so the routes it may work on are limited. But in addition to this, the average compound rate of improvement over time that it represents over the 747 is very close to 1%, which means switching to it does not increase the average rate of improvement, it merely follows the trend.

7We are limiting ourselves to calendar years here for convenience, but we could choose any rolling twelve months in order to find a closer match for miles per passenger between two periods.
Note that this value is quite sensitive to the match in “miles per passenger” because the emissions per mile for short-haul are generally quite a lot higher than for long-haul, both because the planes are smaller so the overhead of the plane is a larger part of the load being moved, and because the take-off/landing section is a larger proportion of the total flight.

5 Conclusion

The analysis performed above indicates that the actual rate of improvement in fuel efficiency of the UK fleet observed over the last 20 years is lower than the rate assumed by both Government policy and the CCC, even though there has been a phasing-out of old aircraft and a switch of business model from older full-service fleets to largely new no-frills fleets, both of which are savings unlikely to be repeated. Fuel prices have also increased considerably which would tend to drive switching out less efficient planes.

The actual compound rate of improvement seems to be well below 1% per year, and it seems likely from this, and the lack of external pressures to make the future situation significantly different in terms of rate of technical improvement and rate of fleet turn-over, that the rate of improvement of fuel efficiency of the UK fleet will be closer to 0.5% per year. There is no sign here of 1.5% compound gains in efficiency.