Airline Fuel Usage and Carbon Emissions

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Overview

With growing concerns about climate change, carbon emissions by airlines are receiving more attention.

ICAO recently announced the CORSIA program, under which airlines will be required to purchase carbon offsets for emissions growth beyond a 2020 baseline.

Has same effect as purchase of emission allowances in the EU's emission trading system (ETS)

Overview

How will airlines respond to the increasing cost of emissions?

One way is to purchase more fuel-efficient planes.

Other way is to save fuel through operational changes.

This talk explores both avenues.

Modeling the purchase of more fuel-efficient planes

Anming Zhang and I developed a model where airline trades off fuel-cost saving and higher capital cost in choosing aircraft fuel efficiency.

$$
\begin{aligned}
r &= \text{fuel price per gallon} \\
s &= \text{number of seats per plane} \\
e &= \text{fuel usage per seat} \\
res &= \text{fuel cost per flight} \\
g\underbrace{(e,\ s)}_{-\ +} &= \text{aircraft capital cost per flight}
\end{aligned}
$$

Then, letting f denote the number of flights

$$
profit = revenue - f[res + g(e, s)]
$$

Modeling the purchase of more fuel-efficient planes

Optimality condition for e is

$$\underbrace{rs}_{\text{saved fuel cost when e falls}} = \underbrace{-\partial g/\partial e}_{\text{extra capital cost when e falls}}$$

Analysis of model showed that

$$r \uparrow \implies e \downarrow,\ f \downarrow,\ \mathit{fare} \uparrow,\ s \rightarrow$$

With higher fuel prices (or emission charges), airlines buy more fuel-efficient planes, fly less, and charger higher fares.

Operational changes to save fuel

With their fleet and thus fuel efficiency fixed, airlines can cut fuel usage through operational changes.

Cutting reserve fuel to save weight, taxiing on one engine, flying slower.

Analyzed by Ryerson et al. (2015), Hao et al. (2016), Kahn and Nickelburg (2016).

Will discuss later, but first consider aggregate impact of such changes.

Measuring overall operational effect of higher fuel prices

My paper with Abreu regressed log(FUEL_USE) at airline level on

log(ATM)	+	more flying raises fuel use
AVG_SEATS	−	bigger planes are more fuel efficient
AVG_STAGELN	−	long flights use less fuel per mile
AVG_LOADFC	+	fuller planes use more fuel
AVG_VINTAGE	−	later build-year reduces fuel use
PCT_DELAY	+	more delays raise fuel use
FUELPR	−	higher fuel price reduces use

Fuel price effect holds fleet characteristics fixed and thus reflects operational changes.

Measuring overall operational effect of fuel prices

In follow up paper, we ran same regression using observations at the airline $\times$ aircraft-model level rather than at the airline level.

Estimated fuel price impact was nearly identical to airline-level one.

Results show that emission charges, by raising effective fuel price, will reduce fuel usage through operational changes.

Imposing socially optimal \$0.39/gallon emission charge on jet fuel would reduce fuel use by 2.2%.

Annual environmental gain is \$117 million.

Potential sources of operational gain

Ryerson et al. (2015) show that weight reduction from cutting reserve fuel to required level would reduce fuel usage by about 1%.

Hao et al. (2016) quote American Airlines' fuel-savings estimate of two million gallon/yr from taxiing on one engine.

Potential sources of operational gain

Kahn and Nickelsburg (2016) use USDOT data to compute average aircraft speed by dividing a carrier's aggregate miles flown by aggregate flying time.

They regress speed on fuel cost per passenger mile, finding an elasticity of -0.054 and -0.12.

So raising fuel price by 10% reduces speed by 0.5 – 1.0%.

Conclusion

Reductions in airline fuel usage come from two sources: buying more fuel-efficient aircraft and using existing ones more efficiently.

We've seen manufacturers build more-efficient planes as airlines have demanded them.

Airlines trade off fuel savings vs. greater aircraft cost.

But airlines can also save fuel through operational changes.

Both avenues will be followed in the coming years in response to emissions charges (or offset requirements).