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Notes and comments

Global carbon dioxide emissions scenarios for aviation derived from IPCC storylines: A meta-analysis

Sveinn Vidar Gudmundsson [a,*], Annela Anger [b]

[a] Toulouse Business School, 20 Boulevard Lascrosses, 31068 Toulouse, France
[b] Cambridge Centre for Climate Change Mitigation Research, Department of Land Economy, University of Cambridge, 19 Silver Street, Cambridge CB3 9EP, UK

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ABSTRACT

This research summarises the aviation CO_2 emissions studies that use the Intergovernmental Panel on Climate Change IS92 and Special Report on Emissions Scenarios storylines as GDP growth assumptions to estimate future global carbon dioxide emissions from the aviation sector. The inter-quartile mean and the first and third quartiles are calculated to enable researches studying climate change policies for aviation to use an average global baseline scenario with lower and upper boundaries. We also perform a simple meta-analysis to analyse the assumptions used to derive the baseline scenario and conclude, as expected, that change in revenue-tonne-kilometres and fuel-efficiency are the main drivers behind the baseline scenarios.

1. Introduction

Carbon dioxide (CO_2) is considered the most important greenhouse gas emitted by aircraft and will be included in the EU Emissions Trading System in 2012 with potentially important implication for European air transport (Scheelhaase et al., 2010; Mayor and Tol, 2010). Numerous studies estimating CO_2 from aviation use the Intergovernmental Panel on Climate Change (IPCC) IS92 (Leggett et al., 1992; Pepper et al., 1992) and Special Report on Emissions Scenarios (SRES) (Nakicenovic et al., 2000) storylines, but vary in methodologies and assumptions used to attain estimates of global aviation emissions. Here we to provide a meta-estimate from these different scenarios for aviation CO_2 up to 2050; and isolate through meta-analysis the influence of key macro, moderator, variables on these differences among aviation CO_2 scenarios.

2. Data description

2.1. Characteristics of the studies

We included five studies with 30 scenarios covering global aviation CO_2 emissions using the IPCC storylines (Table 1).

- Eight International Civil Aviation Organisation's Forecasting and Economic Analysis Sub-Group (FESG) scenarios (ICAO/FESG, 1998) that build on the IPCC IS92a to e scenarios (Leggett et al., 1992; Pepper et al., 1992) using traffic growth in Revenue Tonne Kilometres (RTK) for aviation based on GDP growth rates. Two of these scenarios (Fa1H and Fe1H) assume a growing supersonic fleet and have therefore higher CO_2 emissions than scenarios with subsonic fleet only. Three scenarios (Fa2, Fc2 and Fe2) assume emphasis on NOx reducing technologies.

* Corresponding author. Tel.: +33 (0)561294843; fax: +33 (0)561294807.
E-mail address: s.gudmundsson@wanadoo.fr (S.V. Gudmundsson).

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Table 1
Characteristics of the scenario studies included in the meta-analysis.

	Scenario	Base year	Fuel efficiency improvement	Avg. growth GDP	Avg. growth RTK	Year 2000 CO_2	Year 2050 CO_2	Ratio 2050/2000
ICAO (1998)								
FESG	Fa1	1995	1.64	2.50	3.20	664	1439	2.17
	Fa2		1.57	2.50	3.20	–	1489	2.24
	Fc1		1.67	1.40	2.10	–	821	1.24
	Fc2		1.37	1.40	2.10	–	847	1.27
	Fe1		1.51	3.20	4.00	–	2274	3.42
	Fe2		*0.19*	*3.20*	*4.00*	–	*2360*	*3.55*
	Fa1H		1.30	2.50	3.20	–	1702	2.56
	Fe1H		1.27	3.20	4.00	–	2540	3.82
Owen et al. (2010)								
QUANTIFY	A1	2000	0.70	2.90	3.30	667	2382	3.57
	A2		0.53	2.30	2.10	–	1457	2.19
	B1		1.18	2.50	2.60	–	1325	1.99
	B2		0.76	2.20	2.20	–	1352	2.03
	B1ACARE		1.65	2.50	2.50	–	1010	1.51
Berghof et al. (2005)								
CONSAVE	uls(A1G-Fe)	2000	1.50	3.90	4.60	540	2486	4.60
	rpp(A1T-Fa)		1.30	3.80	3.60	–	1684	3.12
	fw(A2-Fc)		0.82	2.40	2.00	–	972	1.80
	dte(B1)		0.59	3.20	1.20	–	732	1.36
	rpp(A1T-Fa)H2		*7.32*	*3.80*	*3.60*	–	*77*	*0.14*
Vedantham and Oppenheimer (1998)								
V&O	IS92a&b Base	1990	0.73	2.30	3.80	614	2766	4.50
	IS92a&b High		0.62	2.30	4.00	950	5029	5.29
	IS92c Base		0.72	1.20	3.20	587	2012	3.43
	IS92c High		0.55	1.20	3.40	894	3688	4.13
	IS92d Base		0.76	2.00	3.50	615	2319	3.77
	IS92d High		0.66	2.00	3.60	950	4051	4.26
	IS92e Base		0.79	3.00	4.00	643	3129	4.87
	IS92e High		0.66	3.00	4.20	978	5532	5.66
	IS92f Base		0.71	2.30	4.00	615	3101	5.05
	IS92f High		0.59	2.30	4.30	950	5839	6.15
Owen and Lee (2006)								
FAST	A1	2000	0.78	2.90	4.00	515	2550	4.95
	B2		–	2.20	3.20	–	1714	3.33

Outliers shown in italics were excluded in the WLS models.

- Ten V&O scenarios (Vedantham and Oppenheimer, 1998) that build on the GDP estimates in IPCC IS92 "a" to "f" scenarios, but assume a base and a high aviation demand growth, for each IPCC scenario used and therefore generate two aviation emissions growth scenarios corresponding to each IPCC IS scenario.
- Two FAST scenarios (Owen and Lee, 2006) that make use of GDP growth rates in the IPCC SRES A1 (globalisation) and the B2 (regional developments) storylines (Nakicenovic et al., 2000) for the period 2020 until 2050. Up to 2020 the ICAO Committee on Aviation Environmental Protection (ICAO/CAEP) traffic forecast is used.
- Five Constrained Scenarios on Aviation and Emissions (CONSAVE) scenarios (Berghof et al., 2005) derived from the IPCC scenarios SRES A1G, A1T, A2 and B1. Aviation technology and capacity-related adjustments were added for the aviation emissions scenarios. The fifth CONSAVE scenario is based on the IPCC A1T storyline, but assumes domination of hydrogen aircraft.
- Five QUANTIFY scenarios (Owen et al., 2010) where demand for air transport is based on GDP growth in the IPCC SRES storylines. Up to 2020 the ICAO/CAEP traffic forecast is used. In addition to two globalisation scenarios (A1B and B1) and two regional development scenarios (A2 and B2). The B1-ACARE scenario has similar growth as B1 but assumes that all technology improvement targets set in the Strategic Research Agenda of the Advisory Council for Aeronautics Research (ACARE) (2002) in Europe will be met.

2.2. Comparability of the studies

By using only studies based on IPCC storylines, commonality (Button and Nijkamp, 1997) can be considered high, enhancing the interpretability of the results. The bulk of the studies use 2050 as the final reporting year and 2000 as a base year,