The Effect of Adopting NextGen Air Transportation System on Flight Travel Time and Jet Fuel Consumption: Evidence from High-frequency Air Traffic Data

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NBER Energy Use in Transportation

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Motivation

Government (and airlines) spend billions dollars on air transportation system

- Century of Aviation Reauthorization Act in 2003: Federal Aviation Administration (FAA) received $7 billions on NextGen from 2004–2014 and has projected spending $21 billions through 2030.
- The appeal: Investing in NextGen may pay for itself

Private benefits from **time-saving** (passenger and airlines) and **fuel-saving**

- Reduce delay (frequency and length)
- Reduce cruising time (by allowing planes to fly closer & take straighter routes)
- Reduce waiting time on the runway (very fuel-intensive!)
- Reducing taxi-in/taxi-out time (by allowing airports to coordinate better)

Social benefits as well, e.g., pollution and GHG emissions

Main Question on Private Benefits

How have adopting NextGen affected **flight travel time** and **fuel consumption**?

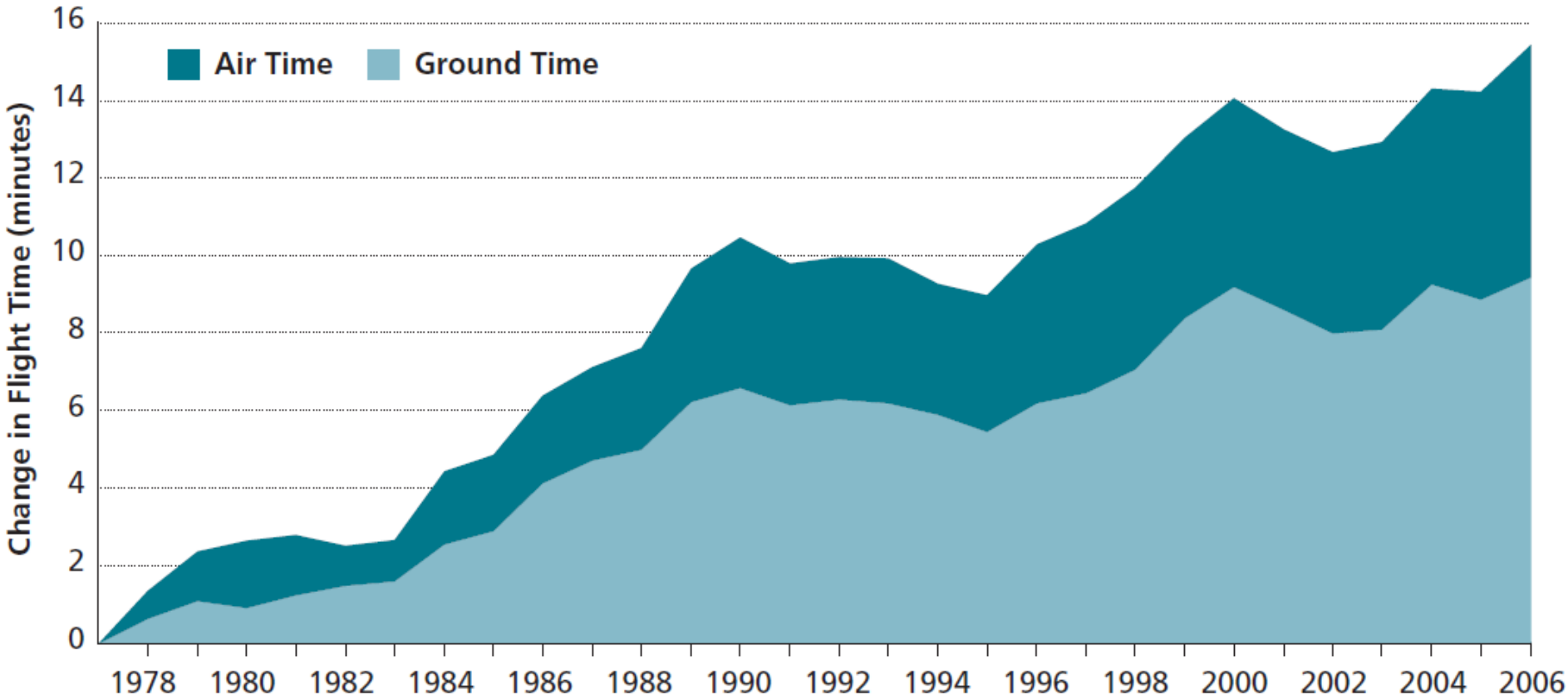
- Infer: What were the **private benefits** of adopting NextGen?
- Relates to the broad question of the private benefits of policies improving energy efficiency
- Use FAA daily flight-level data from 2009 to 2017

Secondary question: How have adopting NextGen affected GHG emissions? (Simulate GHG emissions using an engineering model)

Flight Travel Time

FIGURE 2

Change in Flight Travel Times, 1977–2006



Sources: Morrison and Winston (2008) Brookings Working Paper

Four Types of NextGen Projects

Table 1. History of NextGen Implementation

NextGen Projects	**Sub-projects** (In parentheses: First quarter of implementation, Number of airports first implemented)
Multiple Runway Operations	Wake Re-categorization (First 2014 Q3, 2 Airports)
	Amend Dependent Runway Separation (First 2017 Q1, 5 Airports)
	Amend Standard for Simultaneous Independent Parallel Approaches (First 2015 Q4)
	Dependent Parallel Operation (First 2015 Q4, 7 Airports)
	Dual Independent Parallel Operations (First 2014 Q3, 1 Airport)
Performance Based Navigation	Metroplex: Improving Traffic Flow at Complex Airspace (First 2015 Q2, 1 Airport)
	Decision Tool: Ground-Based Interval Management (First 2016 Q4, 3 Airports)
	Decision Tool: Integrated Departure Arrival Capacity (First 2016 Q4, 3 Airports)
Surface Operations and Data Sharing	Advanced Electronic Flight Strips (First 2015 Q1, 2 Airports)
	System Wide Information Management (SWIM) and Surface Visualization Tool (First 2015 Q1, 5 Airports)
Data Communication	Departure Clearance Tower Service (First 2015 Q3, 3 Airports)

Which Might Be the Main Private Benefits

Table 13 - Comparison of Annual Business Case Benefit Estimates of Future Improvements Through 2030

	Year of Business Case (Base Case vs. NextGen Case)			
	2012	2013	2014	2015
	(Billions, 2011 $) (2011–2030)	(Billions, 2012 $) (2012–2030)	(Billions, 2013 $) (2013–2030)	(Billions, 2015 $) (2015–2030)
Avoided Delay	$76.9	$154.4	$99.6	$108.1
Reduced Flight Time	$1.7	$5.9	$4.6	$0.4
Fewer Flight Cancellations	$9.6	$3.4	$9.0	$25.3
Reduced CO_2	$1.1	$0.4	$0.4	$0.2
Other Benefits not Modeled in SWAC‡	$16.6	$17.7	$18.9	$13.4
Total	**$105.9**	**$181.8**	**$132.5**	**$147.4**

Sources: FAA(2016) Updates to the Business Cases for NextGen
Notes: ‡SWAC is FAA's fast-time engineering model

How does NextGen affect **flight travel time**? A Diff-in-Diff Design

Flight A1: JetBlue Flight 1446 CLT–BOS, Non-stop, Embraer E-190 Departed at 6pm, April 19, 2015	Flight B1: Another flight LAX–BOS, Non-stop, Embraer E-190 Departed at 6pm, April 19, 2015
Flight A0: Departed at 6pm, April 19, 2013	Flight B0: Departed at 6pm, April 19, 2013

- BOS and CLT finished implementing its first project in 2015 Q1
- LAX has not completed any of the four types of NextGen projects until 2016 Q1
- Timeline: Projects were in the study(S), design(D), and eval.(E) stage before 2013. **Implementation (I)** started in 2014. It took about 3-4 quarters to finish and move to **Post-implementation (P)** stage.
- Control for covariates and extensive fixed effects: Plane model FE, airline FE, origin and destination FE, daily FE, time of day FE, and interactions, weather conditions, *etc.*
- Daily flight-level data and hourly airport-level data from 2009 to 2017

A Diff-in-Diff Design

For flight i at airport pair a and b, on date t during hour(s) block h, we estimate

$$y_{iabth} = \beta_1 d_{at} + \beta_2 d_{bt} + \gamma \boldsymbol{X}_{i,a,b,t,h} + u_{iabth}$$

- y_{iath}: measures of air travel time (ground/runway, air time, total time, delayed time, *etc.*)
- d_{at}, d_{bt}: number of completed NextGen projects at airport a (or b) on date t
- $X_{i,a,b,t,h}$: a variety of possible fixed effects approaches:
  - Flight FEs (i), time FEs (t,h), plane model FE, operating airline FE, airline - hub pair FE
  - Interactions: Flight by hour blocks ($i \times h$), airports by hour blocks ($a \times h$,$b \times h$), airline - hub pair by hour blocks
- Treatment is not randomly assigned: Assume conditional on controls, treatment on a given date is as good as random
- Can extend to ML in selection-on-unobservables: Burlig et al. (2017) construct DiD estimators of the effect of energy efficiency upgrades on school energy consumption from LASSO

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Data: NextGen Schedule and Flight Travel Time

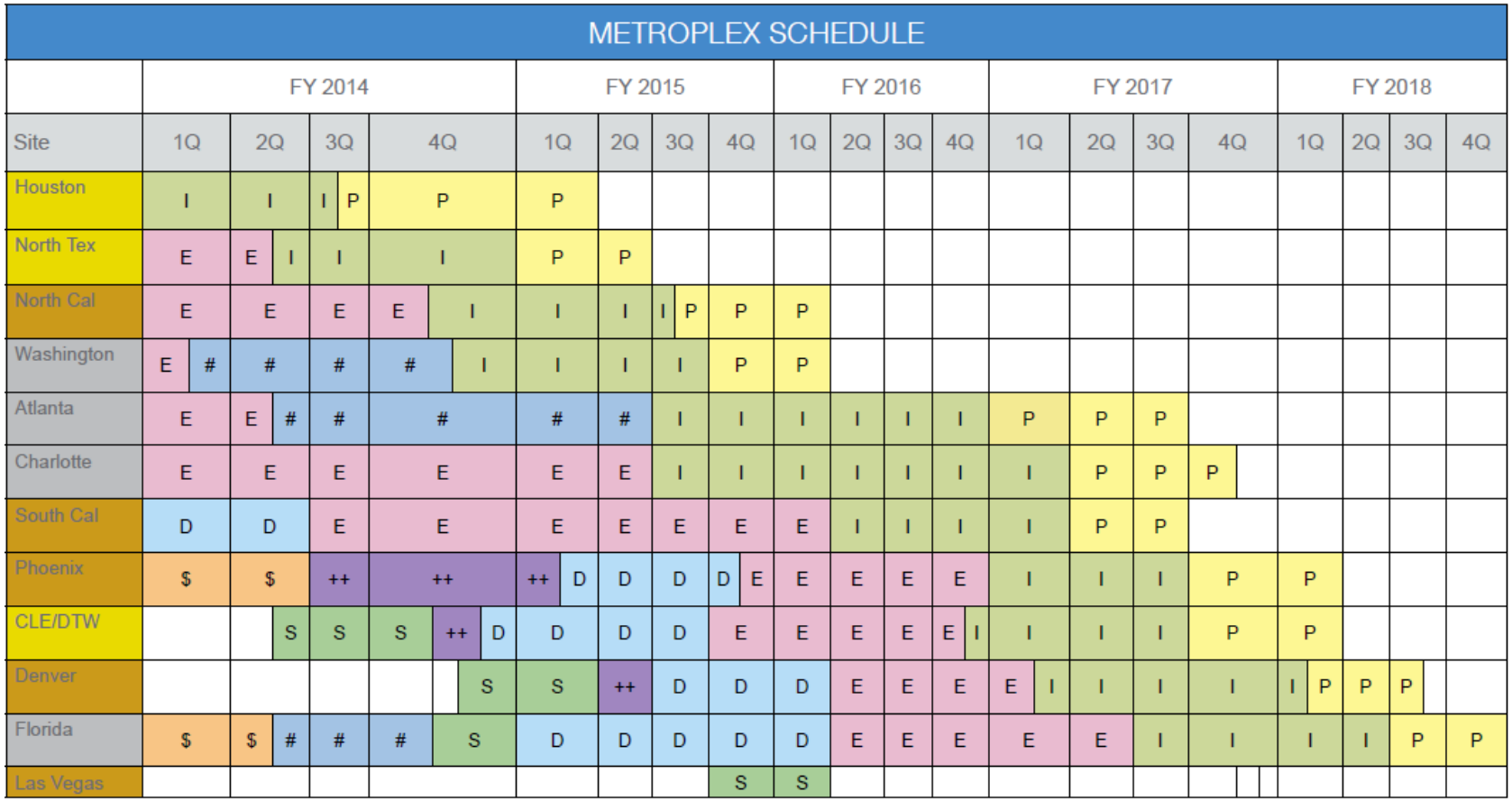
Collect NextGen completion dates from 2009 to 2017

- FAA first completed upgrade three airports in 2014 Q3 on Multiple Runway Operations
- 30 major US airports: E.g., Boston Logan BOS
- Also collected projects starting dates

FAA air service performance data

- **Daily flight-level data**: Scheduled and actual gate-out time, take-off time, landing time, and gate-in time at a precise minute level, and other flight-level information such as weather conditions, origin and destination airports, plane model, *etc.*
- **Hourly airport-level data** including air traffic and delay (every 15 minutes)

NextGen Schedule: E.g., Performances-Based Navigation



Milestone Leads Organizational Symbol	Functional Description
AJV-1	Airspace Services
AJV-121	Airspace Optimization Group
AJV-E	Mission Support, Eastern Service Center
AJV-C	Mission Support, Central Service Center
AJV-W	Mission Support, Western Service Center
AJV-114	Environmental Analysis
AJW-3	Aviation Systems Standards – Flight Checks

S	Study
D	Design
E	Evaluation
I	Implementation
P	Post Implementation
$	Budget Impact
#	ERAM Resource Impact
++	Facility Resource Issue

Other Data

Airline Industry Commitments:

- Airline industry mostly upgrade the "Performance-Based Navigation (PBN)" on their hubs
- FAA collect Airline Industry commitment timestamps as well
- E.g., "2017 Q4, American to Provide Data on their Utility and Usability for Charlotte Metroplex Procedures for PBN"
- E.g., "2017 Q1, JetBlue to Provide Data on their Utility and Usability Data for BOS"

Other Industries

- Other industries' commitment could be picked up by Time FEs.
- E.g., Aircraft manufacturers commitment usually affect the whole National Airspace System (NAS)

Fuel Consumption and GHG Emissions

Need high-frequency flight-level actual fuel consumption data. FAA started to collect fuel use since FAA Modernization and Reform Act of 2012. Not publicly available yet

Our plan: Simulate predicted and counterfactual **fuel consumption** and **greenhouse gas (GHG) emissions** using the Advanced Emission Model (AEM)

- An engineering formula/model by EuroControl
- The airline industry and government agencies (FAA and GAO) use simulated fuel consumption as well

Data input:

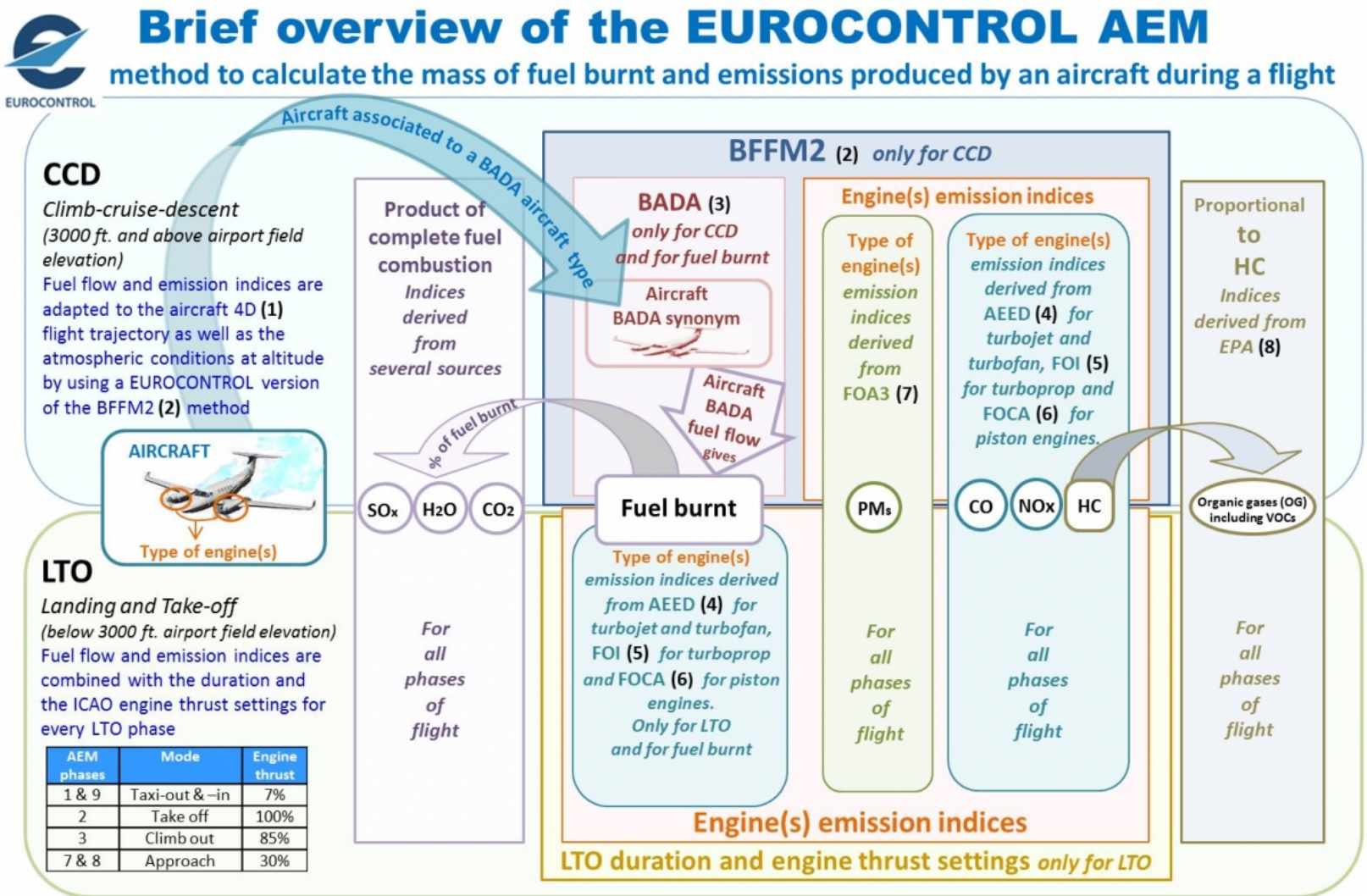
- Estimated air travel time saving
- E.g., Taxi-out (Runway waiting before wheel-off), taxi-in, air time, *etc.*
- Aircraft type and other flight-level observables from our data

Calibrate to air carrier-monthly fuel consumption by DOT

Benefits of Flight Time Saving and Fuel Saving

- Air Time Saving
  - Airline savings: Use business value of time from FAA Guideline
  - Passenger: Use value of time from DOT (2016) "Departmental Guidance on Valuation of Travel Time in Economic Analysis"
- Fuel saving: Use fuel price following FAA Guideline
- Social benefits from GHG emissions: At a variety of SSC

Simulate Fuel Use and GHG Emissions



(1)	A 4D trajectory is specified by latitude, longitude, flight level and time	(5)	Swedish Defence Research Agency
(2)	Boeing Fuel Flow Method 2	(6)	Federal Office of Civil Aviation (Swiss Confederation)
(3)	Base of Aircraft DAta, EUROCONTROL aircraft performance model	(7)	"First Order Approximation method", ICAO - Doc 9889 - Airport Air Quality
(4)	ICAO Doc 9646 Aircraft Engine Emissions Databank	(8)	EPA (U.S. Environmental Protection Agency)

Discussions

Limitation:

- Unobservable: Air time further break down into (climb, cruise, descent)
- Exclude international flights

Other factors:

- Airport may respond to upgrade by adding capacities (number of flights operated by hour block), which in turn might reduce time savings
- Potential network effects from treated airports
- Not including air manufacturing's long-run response in technology adoption