# The Effect of Adopting NextGen Air Transportation System on Air Travel Performance: Evidence from High-frequency Air Traffic Data

Jessica Chu[1] Y. Christy Zhou[2]

[1]First Street Foundation

[2]Clemson University

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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 commercial aviation industry accounted for 5.4 percent of US GDP in 2012 (FAA, 2012)
- The appeal: Investing in NextGen may pay for itself

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

- Reduce delay
- Reducing taxi-in and taxi-out time

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

# Motivation

A source of inefficiency of air transportation

- Congestion externality across airlines at an airport (Mayer and Sinai, 2003; Morrison and Winston, 2007)
- A well-designed pigouvian tax such as peak-time pricing adjusted by market power and network effect can target the externality (Daniel, 1995, 2001; Brueckener, 2002)

When infrastructure creates additional binding constraints for airlines' optimal scheduling problem

- Lifting the constraints by implementing modern technologies could improve private and social welfare

# Main Question and Approach

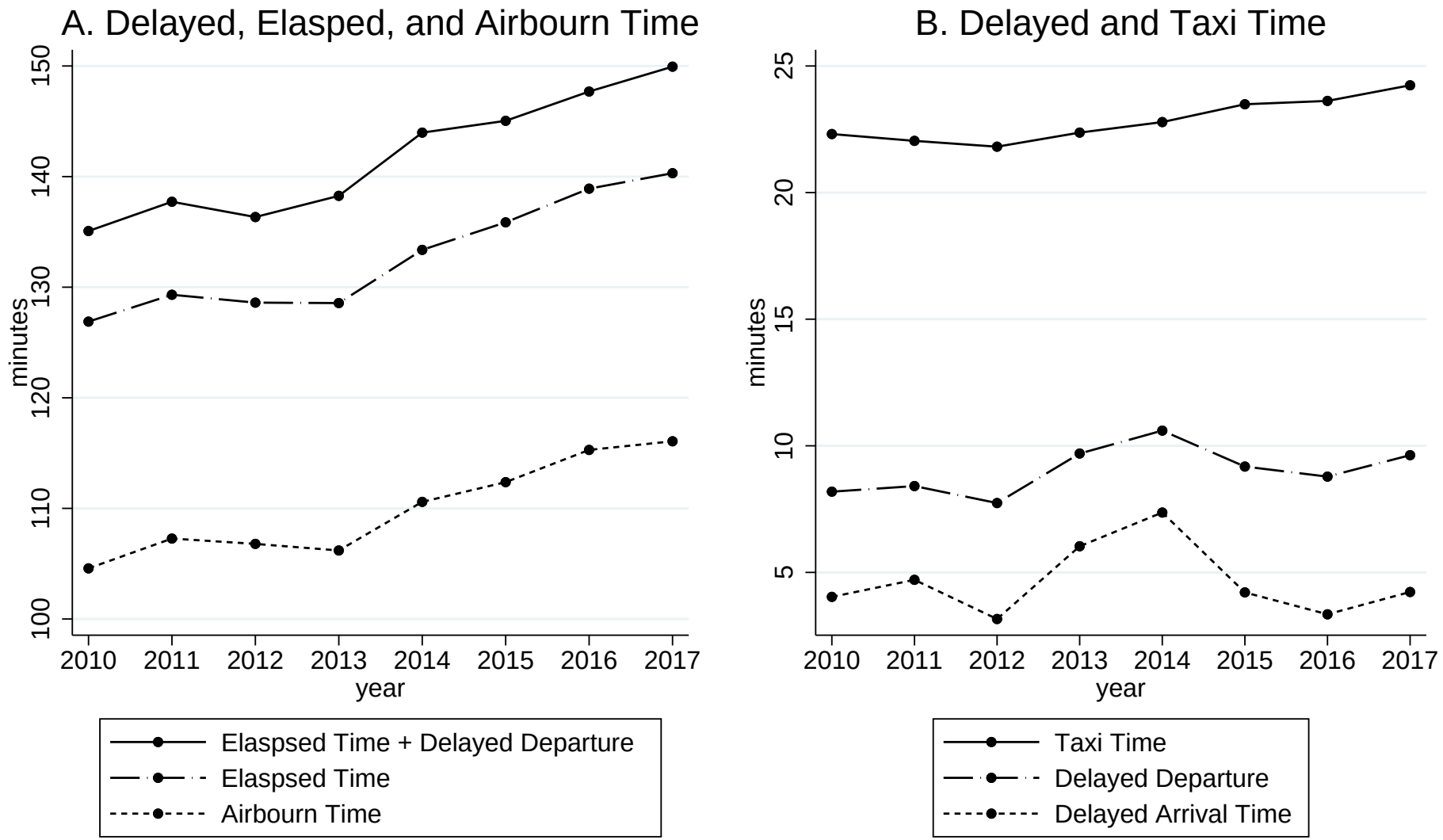
How have adopting NextGen affected **flight travel time**?

- Infer **private benefits** of adopting NextGen for airlines (savings in crew costs and fuel costs via improving flight travel time) and passengers (time saving)
- Study heterogeneous effects of NextGen

Approach

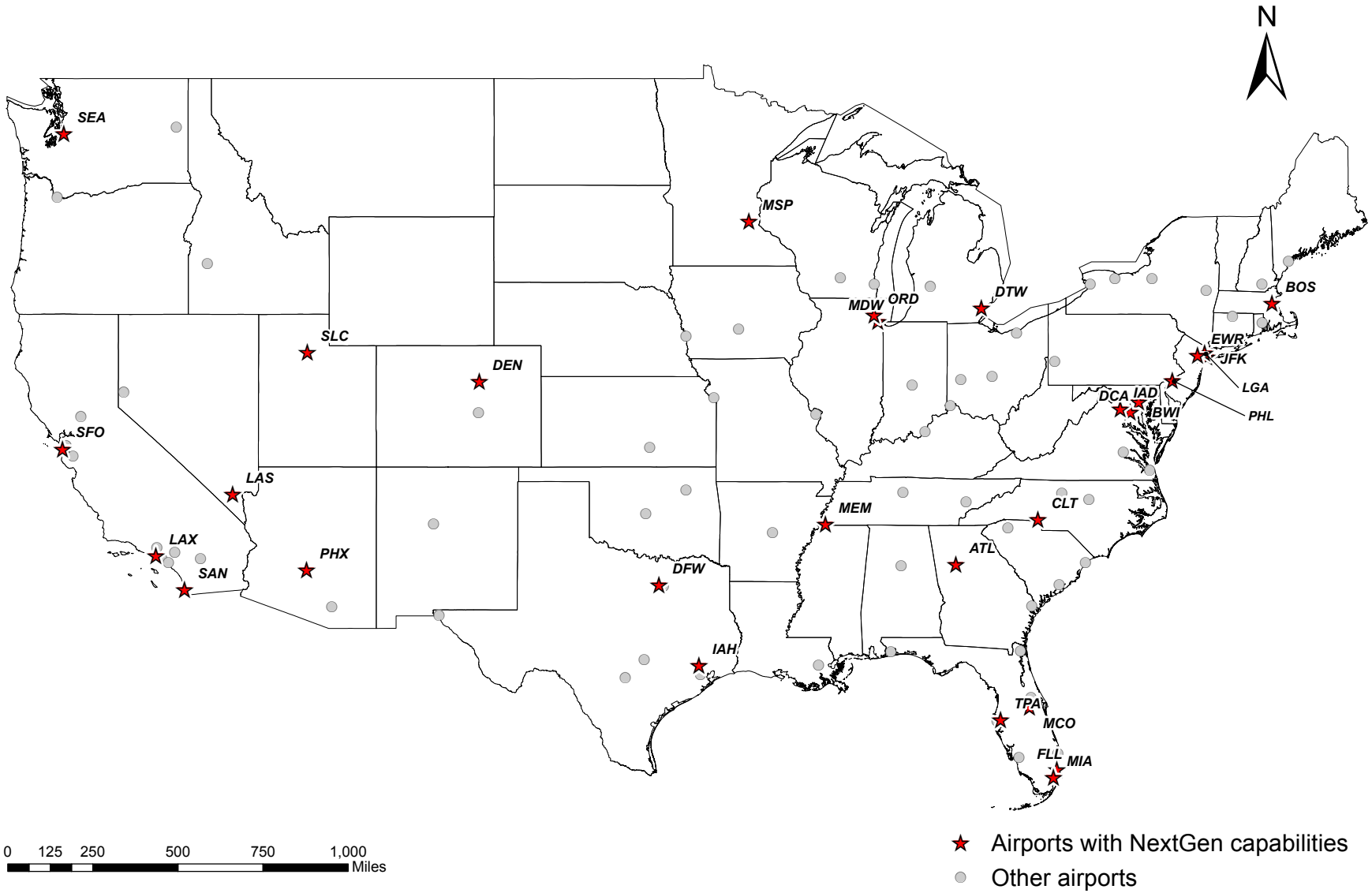
- NextGen has been implemented since 2014
- Use Diff-in-Diff strategy and high-frequency DOT On-Time Performance flight-level data from 2010 to 2017

# Total Air Travel Time, 2010–2017



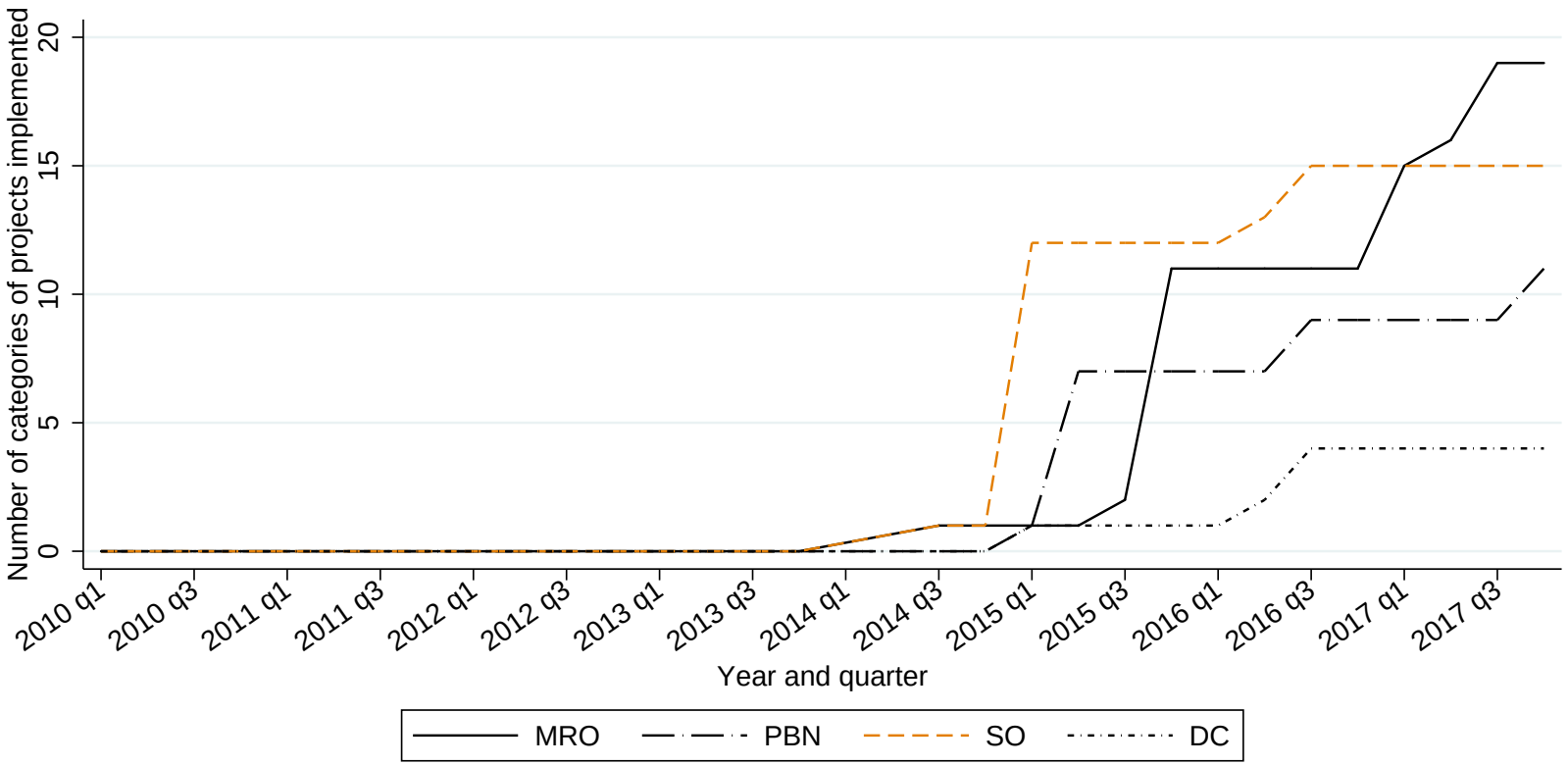

*Sources:* DOT On-Time Performance

# The Map of NextGen Airports

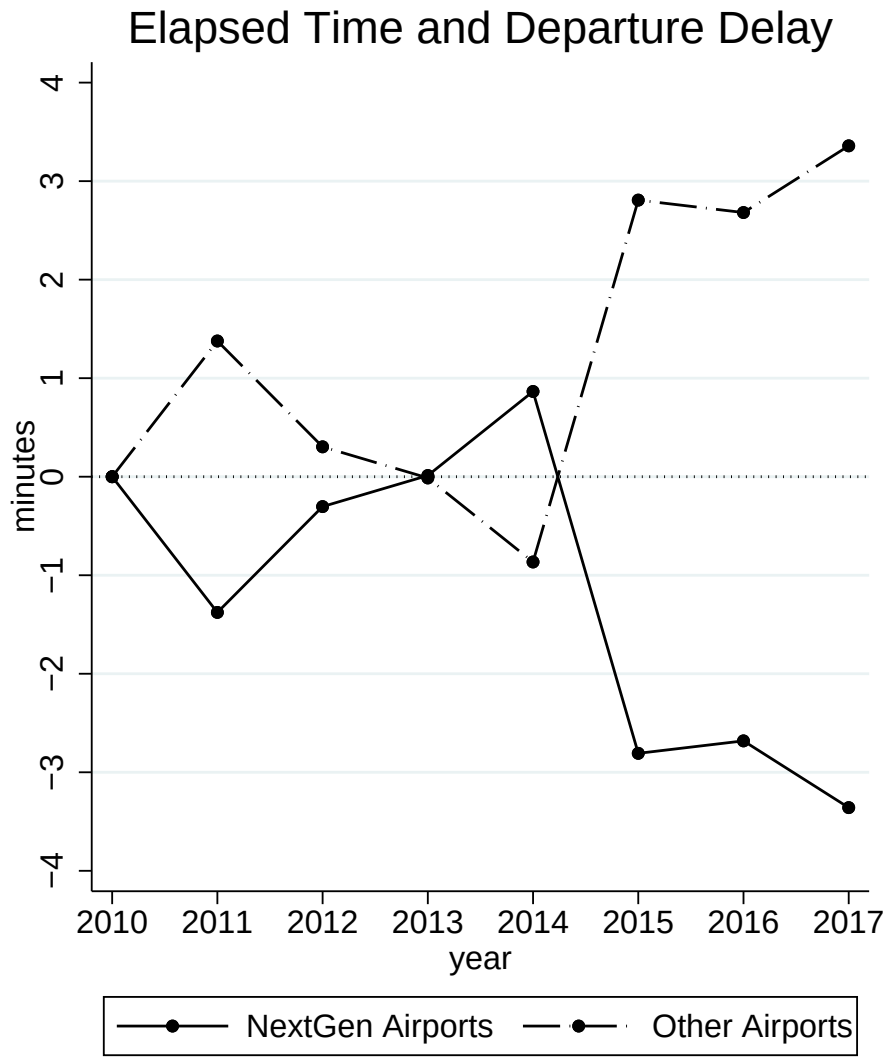


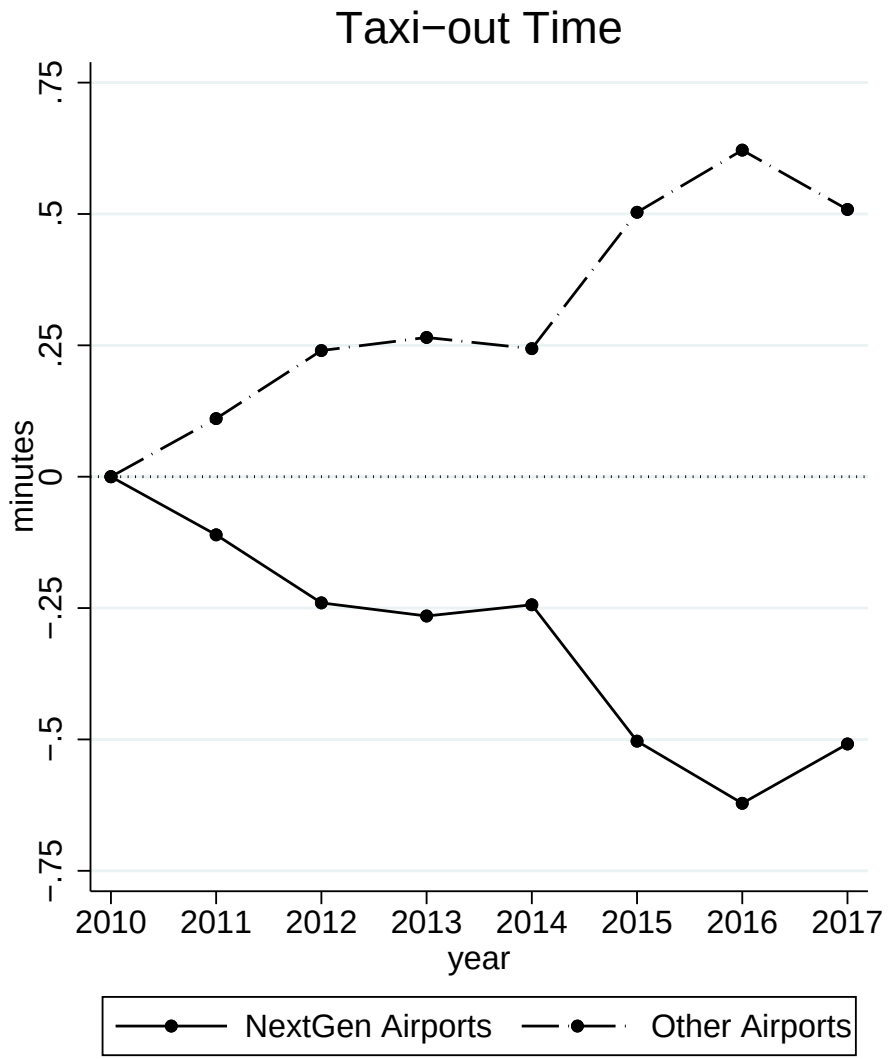
# Four Categories of NextGen Projects

- Multiple-runway operations (MRO), Performance-based navigation (PBN), Surface operation and data sharing (SO), and Data communication (DC)
- We collect *quarterly* completion history of all projects within these four categories at treated airports



# Suggestive Evidence of Diff-in-Diff



# Data

Daily flight-level data from DOT On-Time Performance

- Scheduled and actual departure and arrival, duration of elapsed time, airborne time, taxi-in, and taxi-out
- Tail number (allow us to track aircraft model), previous operation and delays and other flight-level information

Other data

- Hourly weather data at the monitor near each airport from NOAA
- Daily terminal air travel tower information such as overflights from FAA
- Aircraft make and model from DOT Form-B43(link using tail number)
- Market level data from DOT DB1B
- Airline monthly fuel consumption and costs from DOT Form-F41 Schedule-P52
- Simulated mapping from taxi-in and taxi-out time to fuel consumption, emissions, and noises from FAA's Aviation Environmental Design Tool (AEDT)

# A Diff-in-Diff Design

For flight $i$ travels from airport $o$ and $d$ operated by airline $j$ on date $t$ and time $m$

$$travel_{ijodtm} = \beta_1 NextGen_{ot} + \beta_2 NextGen_{dt} + \alpha_{od} + \alpha_j + \alpha_o \times y + \alpha_d \times y + \phi_{tm} + u_{ijodtm}$$

- *travel*: eight dep. vars: minutes of (1) elapsed time plus departure delay, (2) elapsed time, (3) airborne time, (4) taxi-time, (5) taxi-out time, (6) taxi-in time, (7) departure delay, and (8) arrival delay
- $NextGen_{ot}$: the number of categories of projects (MRO, PBN, SO, and/or DC) completed at airport $o$ at a given quarter
- $\alpha_{od}$: route fixed effects
- $\alpha_j$: airline fixed effects
- $\alpha_o \times y$: departure airport fixed effects interacted with a linear year trend
- $\phi_{tm}$: separate fixed effects of year-by-month, day-of-month, day-of-week, and hour-of-day

# Identifying Assumptions

$$travel_{ijodtm} = \beta_1 NextGen_{ot} + \beta_2 NextGen_{dt} + \alpha_{od} + \alpha_j + \alpha_o \times y + \alpha_d \times y + \phi_{tm} + u_{ijodtm}$$

- The treated airports are not randomly assigned
- Assume conditional on controls, treatment on *a given quarter* is as good as random
- The following factors work in favor for the identification:
- Uncertainty and variation of the duration of the previous stages: such as "study stage" and "implementation stage"
- Uncertainty and variation of the time it takes for airline companies to respond to NextGen by rescheduling flights to the Computer Reservation System (CRS)

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

| | |
|---|---|
| **Flight A1:** JetBlue Flight 1446<br>CLT–BOS, Non-stop, Embraer E-190<br>Departed at 6pm, April 19, 2015 | Flight B1: Another flight<br>LAX–BOS, Non-stop, Embraer E-190<br>Departed at 6pm, April 19, 2015 |
| Flight A0:<br>Departed at 6pm, April 19, 2012 | Flight B0:<br>Departed at 6pm, April 19, 2012 |

- 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

# Effect of NextGen on Air Travel Time

Table 2: **The effect of NextGen on air travel time**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Dep var.: air travel time (minutes) | elapsed time + departure delay | elapsed time | airborne time | taxi time | taxi-out time | taxi-in time | departure delay | arrival delay |
| Panel A. Effect of Total Number of Categories of Projects (MRO, PBN, SO, and DC) Implemented | | | | | | | | |
| NextGen Origin | -1.267*** | -0.195** | -0.030 | -0.165*** | -0.141*** | -0.024 | -1.072*** | -1.598*** |
| | (0.154) | (0.078) | (0.058) | (0.044) | (0.037) | (0.024) | (0.124) | (0.156) |
| NextGen Dest. | -1.166*** | -0.119 | 0.046 | -0.165*** | -0.171*** | 0.006 | -1.047*** | -1.000*** |
| | (0.149) | (0.078) | (0.061) | (0.048) | (0.038) | (0.028) | (0.114) | (0.151) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |

# Effect of NextGen from 2014 to 2017 on Air Travel Time

- Consider a scenario if airports in 2017 had not been treated, i.e., as if the airports were in the beginning of 2014
- Compare the actual travel performance in 2017 vs. the counterfactual level

Table 3: **The effect of NextGen from 2014 to 2017 on air travel time**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Unit (minutes) | elapsed time + departure delay | elapsed time | airborne time | taxi time | taxi-out time | taxi-in time | departure delay | arrival delay |
| Actual | 149.04 | 139.30 | 115.78 | 23.51 | 16.32 | 7.18 | 9.6 | 4.13 |
| Change | 2.54 | 0.33 | -0.02 | 0.35 | 0.33 | 0.02 | 2.22 | 2.72 |
| Change (percent) | 1.71% | 0.24% | -0.01% | 1.47% | 2.00% | 0.26% | 23.17% | 65.94% |
| Counterfactual | 151.42 | 139.62 | 115.77 | 23.85 3 | 16.65 | 7.20 | 11.80 | 6.85 |
| Number of obs. | | | | | | | 4,736,642 | |

*Notes*: The first row reports the actual travel time in 2017. This table reports the counterfactual travel time and delay if the treated airports in 2017 had been untreated, i.e., as if the airports were in the beginning of 2014. We use baseline in Table 2. In Appendix Table A.6 we use estimates in Table 2 Panel B and estimates in Table 8.

# Evaluate Private Benefit

Follow FAA (2016) "Economic Values for FAA Investment and Regulatory Decision, A Guide"

- Crew cost: $1,039.58 per hour per flight
- Fuel and oil: $2,443.23 per hour per flight (will talk about how to improve this calculation)
- Maintenance: $793.39 per hour per flight
- Passenger time (business and casual combined) at $48.71 per hour per person
- The number of passengers from DOT DB1B dataset

# NextGen from 2014 to 2017: Private Benefit per Flight

Table 4: **The benefit of reducing delay of NextGen in 2017**

Panel A. Itemized Benefit Per Flight

| | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| Panel A.1 Variable Airline Cost Per Flight (2017 USD) | | | | | | | | |
| Crew cost | 44.15 | 5.70 | -0.29 | 5.99 | 5.66 | 0.33 | 38.45 | 47.15 |
| Fuel and oil | – | – | -0.29 | 14.08 | 13.31 | 0.77 | – | – |
| Maintenance | – | – | – | 4.57 | 4.32 | 0.25 | – | – |
| Panel A.2 Passenger Cost Per Flight (2017 USD) | | | | | | | | |
| Time saving | 128.10 | 16.53 | -0.842 | 17.37 | 16.42 | 0.95 | 111.50 | 136.80 |
| Num. of obs. | | | | | | | 4,736,642 | |

- FAA parameter we use: Fuel and oil: $2,443.23 per hour per flight
- We could use gallon of fuel and oil per hour per flight recommended by FAA (2016), and evaluate at 2017 jet fuel price from EIA
- The number is 30% smaller than the above table

# NextGen from 2014 to 2017: Private Benefit

Panel B. Benefit of NextGen via Reducing Delay and Air Travel Time in 2017

| | Cost saving per flight (2017 USD) | Cost saving in 2017 (million 2017 USD) | (percentage) |
|---|---|---|---|
| Crew cost | 70.72 | 258.58 | 21.4 % |
| Fuel and oil | 41.20 | 150.64 | 12.5 % |
| Maintenance | 13.71 | 50.13 | 4.15 % |
| Passenger | 205.14 | 750.04 | 62.02 % |
| Total private benefits | 330.77 | 1209.40 | |

Next (details at the end of the talk):

- Refine private benefits: fuel and oil consumption
- Add social benefit: emissions (SO2, NOx, CO2, etc.) and noises
- Use FAA AEDT, DOT B52, and DOT Form-F41 Schedule-52 data

# Heterogenous Effects

- Effect by weather condition
- Effect by prior delay
- Effect by hub status

# Effect by Weather

Table 5: **Conditional Effect of NextGen on Air Travel Time by Weather Condition**

| Dep var.: air travel time (minutes) | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| | | | | A. Baseline | | | | |
| NextGen Origin | -1.267*** | -0.195** | -0.030 | -0.165*** | -0.141*** | -0.024 | -1.072*** | -1.598*** |
| | (0.154) | (0.078) | (0.058) | (0.044) | (0.037) | (0.024) | (0.124) | (0.156) |
| NextGen Dest. | -1.166*** | -0.119 | 0.046 | -0.165*** | -0.171*** | 0.006 | -1.047*** | -1.000*** |
| | (0.149) | (0.078) | (0.061) | (0.048) | (0.038) | (0.028) | (0.114) | (0.151) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| | | | | B.1 Sky Ceiling $<$ 1,500 Feet (Origin) | | | | |
| NextGen Origin | -1.779*** | -0.363*** | -0.141* | -0.223*** | -0.182*** | -0.041 | -1.416*** | -2.010*** |
| | (0.274) | (0.115) | (0.085) | (0.070) | (0.063) | (0.031) | (0.235) | (0.269) |
| NextGen Dest. | -0.898*** | -0.094 | -0.045 | -0.049 | -0.113* | 0.065* | -0.804*** | -0.679** |
| | (0.285) | (0.128) | (0.098) | (0.077) | (0.066) | (0.038) | (0.239) | (0.276) |
| Number of obs. | 2,255,847 | 2,255,847 | 2,255,847 | 2,255,847 | 2,255,847 | 2,255,847 | 2,255,847 | 2,255,847 |
| R-squared | 0.75 | 0.97 | 0.99 | 0.21 | 0.20 | 0.22 | 0.06 | 0.07 |
| | | | | B.2 Sky Ceiling $<$ 1,500 Feet (Destination) | | | | |
| NextGen Origin | -0.758** | 0.037 | 0.090 | -0.053 | -0.050 | -0.003 | -0.795*** | -1.053*** |
| | (0.305) | (0.122) | (0.088) | (0.076) | (0.067) | (0.037) | (0.250) | (0.296) |
| NextGen Dest. | -1.206*** | 0.155 | 0.163* | -0.008 | -0.073 | 0.065* | -1.361*** | -0.987*** |
| | (0.291) | (0.120) | (0.090) | (0.071) | (0.058) | (0.038) | (0.246) | (0.279) |
| Number of obs. | 2,121,711 | 2,121,711 | 2,121,711 | 2,121,711 | 2,121,711 | 2,121,711 | 2,121,711 | 2,121,711 |
| R-squared | 0.73 | 0.96 | 0.98 | 0.21 | 0.18 | 0.23 | 0.08 | 0.09 |

# Effect by Prior Delay

Table 6: **Conditional Effect of NextGen on Air Travel Time by Prior Delay**

| Dep var.: air travel time (minutes) | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| | | | | A. Baseline | | | | |
| NextGen Origin | -1.267*** | -0.195** | -0.030 | -0.165*** | -0.141*** | -0.024 | -1.072*** | -1.598*** |
| | (0.154) | (0.078) | (0.058) | (0.044) | (0.037) | (0.024) | (0.124) | (0.156) |
| NextGen Dest. | -1.166*** | -0.119 | 0.046 | -0.165*** | -0.171*** | 0.006 | -1.047*** | -1.000*** |
| | (0.149) | (0.078) | (0.061) | (0.048) | (0.038) | (0.028) | (0.114) | (0.151) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| | | | | B.1 Prior Delay > 15 minutes | | | | |
| NextGen Origin | -2.563*** | -0.452*** | -0.173*** | -0.279*** | -0.274*** | -0.005 | -2.111*** | -2.726*** |
| | (0.298) | (0.093) | (0.067) | (0.061) | (0.052) | (0.029) | (0.279) | (0.293) |
| NextGen Dest. | -1.789*** | -0.289*** | -0.076 | -0.213*** | -0.175*** | -0.037 | -1.500*** | -1.640*** |
| | (0.286) | (0.100) | (0.076) | (0.067) | (0.053) | (0.036) | (0.269) | (0.280) |
| Number of obs. | 3,045,782 | 3,045,782 | 3,045,782 | 3,045,782 | 3,045,782 | 3,045,782 | 3,045,782 | 3,045,782 |
| R-squared | 0.62 | 0.96 | 0.98 | 0.21 | 0.21 | 0.21 | 0.07 | 0.07 |
| | | | | B.2 Prior Delay > 30 minutes | | | | |
| NextGen Origin | -3.012*** | -0.630*** | -0.236*** | -0.394*** | -0.388*** | -0.006 | -2.382*** | -3.084*** |
| | (0.371) | (0.105) | (0.075) | (0.071) | (0.060) | (0.033) | (0.352) | (0.362) |
| NextGen Dest. | -2.013*** | -0.379*** | -0.081 | -0.299*** | -0.221*** | -0.077* | -1.633*** | -1.783*** |
| | (0.363) | (0.114) | (0.085) | (0.077) | (0.061) | (0.042) | (0.342) | (0.355) |
| Number of obs. | 1,770,528 | 1,770,528 | 1,770,528 | 1,770,528 | 1,770,528 | 1,770,528 | 1,770,528 | 1,770,528 |
| R-squared | 0.58 | 0.96 | 0.98 | 0.20 | 0.21 | 0.20 | 0.08 | 0.08 |

# Effect by Prior Delay

Table 6: **Conditional Effect of NextGen on Air Travel Time by Prior Delay**

| Dep var.: air travel time (minutes) | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| | | | | B.3 Prior Delay > 60 minutes | | | | |
| NextGen Origin | -3.340*** | -0.757*** | -0.278*** | -0.479*** | -0.464*** | -0.015 | -2.583*** | -3.322*** |
| | (0.436) | (0.117) | (0.081) | (0.078) | (0.066) | (0.037) | (0.414) | (0.427) |
| NextGen Dest. | -2.241*** | -0.359*** | -0.056 | -0.302*** | -0.206*** | -0.096** | -1.882*** | -1.964*** |
| | (0.434) | (0.126) | (0.091) | (0.087) | (0.067) | (0.047) | (0.412) | (0.428) |
| Number of obs. | 1,188,996 | 1,188,996 | 1,188,996 | 1,188,996 | 1,188,996 | 1,188,996 | 1,188,996 | 1,188,996 |
| R-squared | 0.55 | 0.95 | 0.98 | 0.19 | 0.20 | 0.20 | 0.10 | 0.10 |
| | | | | B.4 Prior Delay > 90 minutes | | | | |
| NextGen Origin | -4.456*** | -0.717*** | -0.306*** | -0.411*** | -0.414*** | 0.003 | -3.739*** | -4.342*** |
| | (0.644) | (0.142) | (0.096) | (0.099) | (0.085) | (0.046) | (0.631) | (0.640) |
| NextGen Dest. | -2.323*** | -0.263 | -0.038 | -0.226* | -0.186** | -0.040 | -2.060*** | -2.038*** |
| | (0.690) | (0.161) | (0.110) | (0.116) | (0.088) | (0.065) | (0.673) | (0.683) |
| Number of obs. | 480,384 | 480,384 | 480,384 | 480,384 | 480,384 | 480,384 | 480,384 | 480,384 |
| R-squared | 0.52 | 0.95 | 0.98 | 0.19 | 0.20 | 0.20 | 0.16 | 0.16 |
| | | | | B.5 Prior Delay > 120 minutes | | | | |
| NextGen Origin | -4.505*** | -0.523*** | -0.198* | -0.325*** | -0.319*** | -0.007 | -3.981*** | -4.471*** |
| | (0.871) | (0.161) | (0.109) | (0.111) | (0.099) | (0.053) | (0.856) | (0.870) |
| NextGen Dest. | -2.781*** | -0.181 | -0.027 | -0.154 | -0.107 | -0.047 | -2.600*** | -2.508*** |
| | (0.942) | (0.183) | (0.127) | (0.130) | (0.102) | (0.074) | (0.929) | (0.936) |
| Number of obs. | 285,103 | 285,103 | 285,103 | 285,103 | 285,103 | 285,103 | 285,103 | 285,103 |
| R-squared | 0.51 | 0.95 | 0.98 | 0.19 | 0.20 | 0.20 | 0.21 | 0.20 |

# Effect by Hub Status at Origin Airport

Table 7: **Conditional Effect of NextGen on Air Travel Time by Hub Airlines**

| Dep var.: air travel time (minutes) | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| **A. Baseline** | | | | | | | | |
| NextGen Origin | -1.267*** | -0.195** | -0.030 | -0.165*** | -0.141*** | -0.024 | -1.072*** | -1.598*** |
| | (0.154) | (0.078) | (0.058) | (0.044) | (0.037) | (0.024) | (0.124) | (0.156) |
| NextGen Dest. | -1.166*** | -0.119 | 0.046 | -0.165*** | -0.171*** | 0.006 | -1.047*** | -1.000*** |
| | (0.149) | (0.078) | (0.061) | (0.048) | (0.038) | (0.028) | (0.114) | (0.151) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| **B.1 Hub Airport and Hub Airline (Origin)** | | | | | | | | |
| NextGen Origin | -1.332*** | -0.368** | -0.065 | -0.304*** | -0.199*** | -0.104** | -0.964*** | -2.094*** |
| | (0.315) | (0.147) | (0.110) | (0.083) | (0.073) | (0.047) | (0.243) | (0.311) |
| NextGen Dest. | -0.812** | 0.030 | 0.028 | 0.001 | -0.026 | 0.028 | -0.842*** | -0.641* |
| | (0.339) | (0.190) | (0.150) | (0.111) | (0.083) | (0.069) | (0.245) | (0.328) |
| Number of obs. | 6,539,157 | 6,539,157 | 6,539,157 | 6,539,157 | 6,539,157 | 6,539,157 | 6,539,157 | 6,539,157 |
| R-squared | 0.87 | 0.97 | 0.99 | 0.21 | 0.17 | 0.23 | 0.04 | 0.04 |
| **B.2 Hub Airport and Non-hub Airline (Origin)** | | | | | | | | |
| NextGen Origin | -2.292*** | -0.049 | 0.271*** | -0.320*** | -0.348*** | 0.029 | -2.243*** | -2.651*** |
| | (0.220) | (0.109) | (0.084) | (0.072) | (0.058) | (0.039) | (0.176) | (0.223) |
| NextGen Dest. | -0.823** | -0.342** | -0.077 | -0.265*** | -0.362*** | 0.098* | -0.481* | -0.704** |
| | (0.335) | (0.161) | (0.125) | (0.101) | (0.076) | (0.057) | (0.264) | (0.344) |
| Number of obs. | 6,998,051 | 6,998,051 | 6,998,051 | 6,998,051 | 6,998,051 | 6,998,051 | 6,998,051 | 6,998,051 |
| R-squared | 0.78 | 0.97 | 0.99 | 0.18 | 0.16 | 0.24 | 0.04 | 0.04 |

# Effect by Hub Status at Origin Airport

Table 7: **Conditional Effect of NextGen on Air Travel Time by Hub Airlines**

| Dep var.: air travel time (minutes) | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| | | | | A. Baseline | | | | |
| NextGen Origin | -1.267*** | -0.195** | -0.030 | -0.165*** | -0.141*** | -0.024 | -1.072*** | -1.598*** |
| | (0.154) | (0.078) | (0.058) | (0.044) | (0.037) | (0.024) | (0.124) | (0.156) |
| NextGen Dest. | -1.166*** | -0.119 | 0.046 | -0.165*** | -0.171*** | 0.006 | -1.047*** | -1.000*** |
| | (0.149) | (0.078) | (0.061) | (0.048) | (0.038) | (0.028) | (0.114) | (0.151) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| | | | | B.3 Hub Airport and Hub Airline (Destination) | | | | |
| NextGen Origin | -0.405 | -0.210 | -0.111 | -0.099 | -0.117 | 0.018 | -0.195 | -0.807** |
| | (0.343) | (0.177) | (0.137) | (0.103) | (0.086) | (0.061) | (0.274) | (0.337) |
| NextGen Dest. | -2.493*** | -0.626*** | -0.438*** | -0.188* | -0.236*** | 0.048 | -1.867*** | -2.347*** |
| | (0.277) | (0.139) | (0.103) | (0.100) | (0.070) | (0.063) | (0.209) | (0.274) |
| Number of obs. | 6,522,845 | 6,522,845 | 6,522,845 | 6,522,845 | 6,522,845 | 6,522,845 | 6,522,845 | 6,522,845 |
| R-squared | 0.82 | 0.97 | 0.99 | 0.20 | 0.18 | 0.15 | 0.03 | 0.03 |
| | | | | B.4 Hub Airport and Non-hub Airline (Destination) | | | | |
| NextGen Origin | -1.023*** | -0.248 | -0.070 | -0.178* | -0.205*** | 0.027 | -0.774*** | -1.312*** |
| | (0.362) | (0.160) | (0.118) | (0.099) | (0.079) | (0.054) | (0.287) | (0.369) |
| NextGen Dest. | -2.362*** | -0.262** | -0.092 | -0.170** | -0.158*** | -0.012 | -2.100*** | -1.851*** |
| | (0.228) | (0.113) | (0.086) | (0.073) | (0.056) | (0.042) | (0.181) | (0.231) |
| Number of obs. | 6,986,915 | 6,986,915 | 6,986,915 | 6,986,915 | 6,986,915 | 6,986,915 | 6,986,915 | 6,986,915 |
| R-squared | 0.78 | 0.97 | 0.99 | 0.19 | 0.20 | 0.16 | 0.04 | 0.04 |

# Alternative Specifications

- Richer fixed effects:
  - Route # Airline # Day-of-week # Hour-of-day (667,400 cells, 36 obs per cell)
  - Route # Airline # Aircraft model (38,700 cells, 226 obs per cell)
- Additional interaction with linear trend
  - Airline # linear trend
  - Hub status # linear trend
- Alternative measure of treatment
  - Number of projects completed
  - If each category of NextGen has a project completed
  - Number of projects completed for each category
- Alternative sample
  - Do not drop 2013 (5 million obs.)
  - Add flights not matched in form B-43 (8 million obs.)

# Next Step and Approach

- Refine private benefits: fuel and oil consumption
- Add social benefit: emissions (SO2, NOx, CO2, etc.) and noises
- 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.

Approach: Simulate predicted and counterfactual **fuel consumption, pollution emissions, greenhouse gas (GHG) emissions, and noises** using the the Aviation Environmental Design Tool (AEDT) simulator

- An engineering formula/model built upon EuroControl's Base of Aircraft Data (BADA) and Aviation Emission Model (AEM)
- Simulated mapping from **taxi-in and taxi-out time** to the above outcomes at the level of **airport and aircraft**
- Link to our main data using tail number and aircraft model (DOT Form-B43)
  - Current testing: 90% of models in Form-B43 can be found in AEDT
- Calibrate to airline monthly fuel consumption in DOT Form-F41 Schedule-P52

# AEDT Simulated Data

Emissions | Speciated Organic Gases

Choose Columns

| Event ID | Equipment Type | Departure Airport | Arrival Airport | Mode | Fuel (g) | Distance (km) | Duration | CO (g) | HC (g) | TOG (g) | VOC (g) | NMHC (g) | NOx (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100000 | H500D | ATL | | Above 10000 | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100001 | H500D | ATL | | Above 10000 | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100000 | H500D | ATL | | Climb Below 1000 | 5182.80 | 30.52 | 00:10:24.22 | 5714.51 | 89.32 | 87.51 | 74.56 | 77.93 | 17.3 |
| 100001 | H500D | ATL | | Climb Below 1000 | 5182.80 | 30.52 | 00:10:24.22 | 5714.51 | 89.32 | 87.51 | 74.56 | 77.93 | 17.3 |
| 100000 | H500D | ATL | | Climb Below 10000 | 5182.80 | 30.52 | 00:10:24.22 | 5714.51 | 89.32 | 87.51 | 74.56 | 77.93 | 17.3 |
| 100001 | H500D | ATL | | Climb Below 10000 | 5182.80 | 30.52 | 00:10:24.22 | 5714.51 | 89.32 | 87.51 | 74.56 | 77.93 | 17.3 |
| 100000 | H500D | ATL | | Climb Below Mixing Height | 5182.80 | 30.52 | 00:10:24.22 | 5714.51 | 89.32 | 87.51 | 74.56 | 77.93 | 17.3 |
| 100001 | H500D | ATL | | Climb Below Mixing Height | 5182.80 | 30.52 | 00:10:24.22 | 5714.51 | 89.32 | 87.51 | 74.56 | 77.93 | 17.3 |
| 100000 | H500D | ATL | | Climb Ground | 504.00 | 0.00 | 00:01:00.00 | 548.77 | 8.63 | 8.45 | 7.20 | 7.53 | 1.7 |
| 100001 | H500D | ATL | | Climb Ground | 504.00 | 0.00 | 00:01:00.00 | 548.77 | 8.63 | 8.45 | 7.20 | 7.53 | 1.7 |
| 100000 | H500D | ATL | | Climb Taxi | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100001 | H500D | ATL | | Climb Taxi | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100000 | H500D | ATL | | Descend Below 1000 | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100001 | H500D | ATL | | Descend Below 1000 | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100000 | H500D | ATL | | Descend Below 10000 | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100001 | H500D | ATL | | Descend Below 10000 | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100000 | H500D | ATL | | Descend Below Mixing Height | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100001 | H500D | ATL | | Descend Below Mixing Height | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100000 | H500D | ATL | | Descend Ground | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100001 | H500D | ATL | | Descend Ground | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100000 | H500D | ATL | | Descend Taxi | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| 100001 | H500D | ATL | | Descend Taxi | 0.00 | 0.00 | 00:00:00.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |

24 of 24 item(s) shown. 4 item(s) selected.

# A follow-up work: "Network Propagation and Air Traffic Policies" w/ Jessica Chu and Tom Lam

- Goal: Document network propagation on delays and infer effectiveness of second-best policies
- Congestion externality and market inefficiency: arises as hub airlines do not internalize congestion imposed on non-hub airlines at a hub airport (Mayer and Sinai, 2003, Morrison and Winston, 2007)
- The external cost could get propagated via network under what we usually think as internalized cost. E.g., (i) flights connection within a window of time, (ii) sharing the runway/ATC operation resources within a window of time, (iii) sharing aircraft (i.e., operation N and N+1), (iv) sharing gates
- Heterogeneity (and highly skewness) of social cost of congestion depending on (i) where the minutes of delay locate in the distribution, and (ii) the relative importance of a flight in propagating delays. The heterogeneity may inform us how well second-best policies can approximate the first-best
- Approach: (i) estimate the centrality of propagation network (done in sample data) and (ii) construct social cost of delay by adjusting costs of delay using centrality measures

# Thank you!

# Summary Statistics

Table 1: **Summary statistics of air travel time 2010–2017**

| Variable | Mean | SD. | Min. | Max. |
|---|---|---|---|---|
| Panel A. Air Travel Performance and FAA Treatment | | | | |
| Actual elapsed route time + departure delay (minutes) | 142.7 | 82.5 | -20 | 2,594 |
| Actual elapsed route time (minutes) | 133.7 | 73.2 | 20 | 784 |
| Actual airborne time (minutes) | 110.9 | 71.1 | 6 | 723 |
| Actual taxi time (minutes) | 22.8 | 10.5 | 2 | 481 |
| Actual taxi-out time (minutes) | 15.7 | 9.0 | 0 | 278 |
| Actual taxi-in time (minutes) | 7.1 | 5.2 | 2 | 414 |
| Departure delay (minutes) | 9.0 | 36.2 | -45 | 2,402 |
| Arrival delay (minutes) | 4.7 | 38.6 | -115 | 2,444 |
| 1 = Travel from or to an NextGen airport | 0.92 | 0.27 | 0 | 1 |
| Categories of NextGen projects completed | 0.34 | 0.70 | 0 | 3 |

# Panel Information

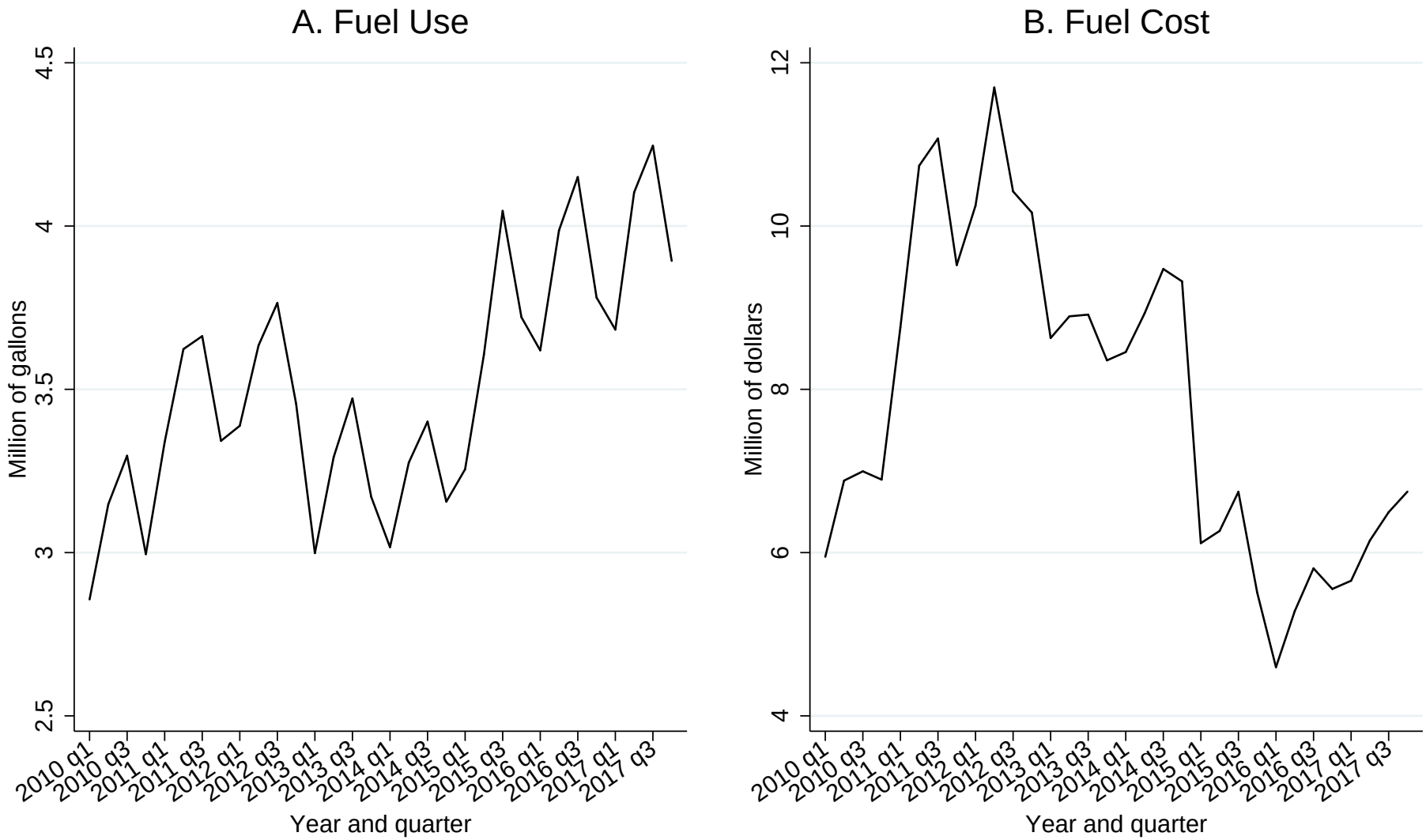
| Panel B. Panel Information | |
|---|---|
| Number of airports | 275 |
| Number of airports with FAA projects | 39 |
| Number of airlines | 19 |
| Number of routes | 5,819 |
| Number of routes by airline | 14,194 |
| Number of routes by airline by hour-of-day by day-of-week | 667,389 |
| Number of routes by airline by aircraft model | 38,681 |
| Number of aircraft models | 44 |
| Number of aircraft model trims | 262 |
| Number of aircraft | 6,957 |
| Number of observations | 25,037,569 |

# List of Airports (selected)

Table A.1: **List of NextGen Airports**

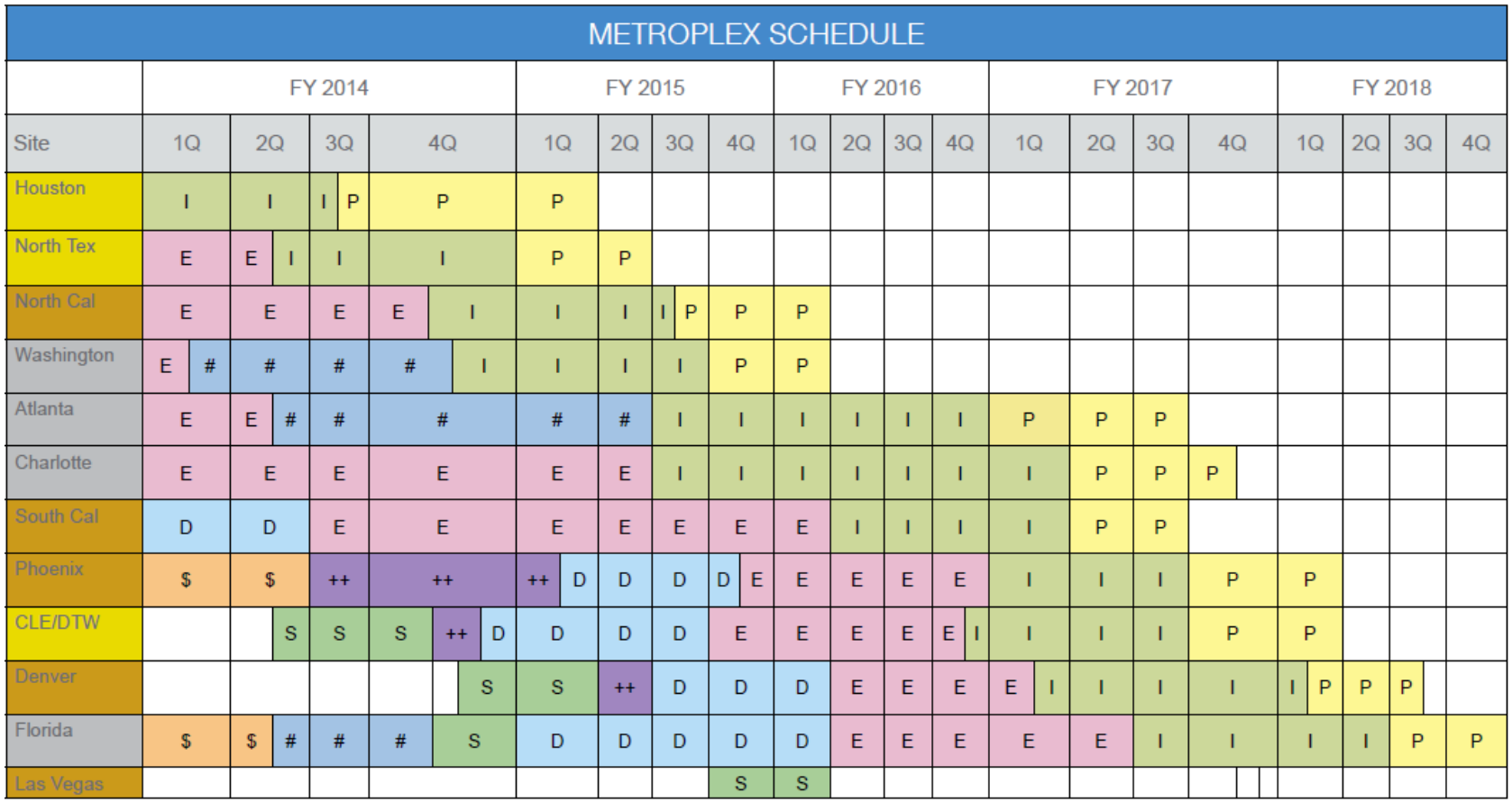
| Airport Code | City | State | Hub airport | First year of NextGen | Percentage of flights departing from the airport |
|---|---|---|---|---|---|
| ANC | Anchorage | AK | 1 | 2016 | 0.29 |
| ATL | Atlanta | GA | 1 | 2014 | 6.53 |
| AUS | Austin | TX | 0 | 2017 | 0.77 |
| BOS | Boston | MA | 0 | 2015 | 1.89 |
| CLE | Cleveland | OH | 0 | 2015 | 0.72 |
| CLT | Charlotte | NC | 1 | 2015 | 2.09 |
| CVG | Cincinnati | OH | 1 | 2014 | 0.42 |
| DAL | Dallas | TX | 1 | 2015 | 0.92 |
| DEN | Denver | CO | 1 | 2015 | 3.86 |
| DFW | Dallas/Fort Worth | TX | 1 | 2016 | 4.13 |
| DTW | Detroit | MI | 1 | 2015 | 2.00 |
| EWR | Newark | NJ | 1 | 2015 | 1.90 |
| HOU | Houston | TX | 0 | 2014 | 0.93 |
| IAD | Washington | DC | 1 | 2017 | 0.98 |
| IAH | Houston | TX | 1 | 2014 | 2.77 |
| IND | Indianapolis | IN | 0 | 2016 | 0.50 |
| JFK | New York | NY | 1 | 2015 | 1.64 |
| LAS | Las Vegas | NV | 1 | 2016 | 2.47 |
| LAX | Los Angeles | CA | 1 | 2016 | 3.64 |
| LGA | New York | NY | 0 | 2015 | 1.64 |

# Total Fuel Use and Fuel Cost, 2010–2017




*Sources:* DOT Schedule Form-F41 Schedule P-52

# Variation and Uncertainty of Implementation Period




| 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 |

# Summary Statistics of Conditions Associated with Air Travel Performance

Table A.2: **Summary statistics of other conditions associated with air travel performance 2010–2017**

| Variable | Mean | SD. | Min. | Max. |
|---|---|---|---|---|
| Panel A. Conditions associated with air travel delay | | | | |
| Number of operations per aircraft | 5.0 | 2.1 | 1 | 17 |
| 1 = Prior flight is delayed | 0.36 | 0.48 | 0 | 1 |
| Prior delay (minutes) | 15.5 | 37.5 | 0 | 2,028 |
| Flights traveled from or to a hub airport | 0.84 | 0.37 | 0 | 1 |
| Origin visibility (km) | 14.9 | 3.1 | 0 | 160,000 |
| Origin sky ceiling (km) | 12.7 | 9.7 | 0 | 22,000 |
| Destination visibility (km) | 15.0 | 3.1 | 0 | 160,000 |
| Destination sky ceiling (km) | 12.6 | 9.6 | 0 | 22,000 |
| Number of observations | | | | 25,037,569 |

# Alternative Measure of Treatment Variable

Table 8: **Alternative Measure for the Treatment Variables**

| Dep var.: air travel time (minutes) | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| | | | | A. Baseline | | | | |
| NextGen Origin | -1.267*** | -0.195** | -0.030 | -0.165*** | -0.141*** | -0.024 | -1.072*** | -1.598*** |
| | (0.154) | (0.078) | (0.058) | (0.044) | (0.037) | (0.024) | (0.124) | (0.156) |
| NextGen Dest. | -1.166*** | -0.119 | 0.046 | -0.165*** | -0.171*** | 0.006 | -1.047*** | -1.000*** |
| | (0.149) | (0.078) | (0.061) | (0.048) | (0.038) | (0.028) | (0.114) | (0.151) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| | | | | B. Number of Projects Completed | | | | |
| NextGen Origin | -0.946*** | -0.171*** | -0.127*** | -0.044 | -0.024 | -0.020 | -0.775*** | -1.077*** |
| | (0.118) | (0.060) | (0.048) | (0.033) | (0.027) | (0.019) | (0.098) | (0.122) |
| NextGen Dest. | -0.421*** | 0.145** | 0.182*** | -0.037 | -0.112*** | 0.076*** | -0.566*** | -0.539*** |
| | (0.111) | (0.063) | (0.045) | (0.038) | (0.028) | (0.021) | (0.084) | (0.121) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| | | | | C.1 Only Include NextGen at Origin | | | | |
| NextGen Origin | -1.159*** | -0.184** | -0.035 | -0.150*** | -0.125*** | -0.025 | -0.975*** | -1.505*** |
| | (0.155) | (0.077) | (0.058) | (0.044) | (0.037) | (0.024) | (0.126) | (0.158) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| | | | | C.2 Only Include NextGen at Destination | | | | |
| NextGen Dest. | -1.049*** | -0.101 | 0.049 | -0.150*** | -0.158*** | 0.008 | -0.948*** | -0.852*** |
| | (0.150) | (0.078) | (0.061) | (0.048) | (0.037) | (0.028) | (0.116) | (0.154) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |

# Effect of Specific Category of NextGen Project

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Dep var.: air travel time (minutes) | elapsed time + departure delay | elapsed time | airborne time | taxi time | taxi-out time | taxi-in time | departure delay | arrival delay |
| Panel B. Effect of Specific Category of Projects | | | | | | | | |
| NextGen Origin MRO = 1 | 0.047 | 0.256** | 0.184* | 0.071 | 0.128** | -0.057 | -0.208 | 0.064 |
| | (0.208) | (0.122) | (0.098) | (0.076) | (0.065) | (0.038) | (0.153) | (0.206) |
| NextGen Origin PBN = 1 | -2.119*** | -1.409*** | -0.784*** | -0.625*** | -0.683*** | 0.058 | -0.710** | -1.843*** |
| | (0.438) | (0.209) | (0.188) | (0.130) | (0.123) | (0.074) | (0.343) | (0.452) |
| NextGen Origin SO = 1 | -3.460*** | -0.781*** | -0.453*** | -0.328*** | -0.371*** | 0.042 | -2.679*** | -4.645*** |
| | (0.402) | (0.201) | (0.164) | (0.108) | (0.092) | (0.053) | (0.331) | (0.443) |
| NextGen Origin DC = 1 | -1.555*** | 0.043 | 0.370*** | -0.327*** | -0.266*** | -0.061 | -1.598*** | -2.063*** |
| | (0.313) | (0.143) | (0.114) | (0.085) | (0.067) | (0.051) | (0.248) | (0.301) |
| NextGen Dest. MRO = 1 | 0.337 | 0.470*** | 0.112 | 0.358*** | -0.047 | 0.405*** | -0.133 | -0.091 |
| | (0.236) | (0.132) | (0.106) | (0.076) | (0.057) | (0.044) | (0.167) | (0.231) |
| NextGen Dest. PBN = 1 | -1.336** | -0.235 | 0.129 | -0.364** | -0.062 | -0.302*** | -1.101*** | -1.035** |
| | (0.570) | (0.273) | (0.199) | (0.149) | (0.116) | (0.081) | (0.390) | (0.508) |
| NextGen Dest. SO = 1 | -3.758*** | -0.905*** | -0.114 | -0.791*** | -0.394*** | -0.397*** | -2.853*** | -2.516*** |
| | (0.450) | (0.221) | (0.174) | (0.121) | (0.096) | (0.065) | (0.331) | (0.457) |
| NextGen Dest. DC = 1 | -1.933*** | -0.775*** | -0.063 | -0.711*** | -0.313*** | -0.399*** | -1.158*** | -1.563*** |
| | (0.282) | (0.146) | (0.109) | (0.097) | (0.072) | (0.058) | (0.219) | (0.276) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |

# Effect of Specific Category of NextGen Project (cont)

D. Effect of the Number of Projects for Each NextGen Category

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NextGen Origin Num. of MRO | -0.046 | 0.274*** | 0.119 | 0.155*** | 0.178*** | -0.022 | -0.320** | -0.115 |
| | (0.155) | (0.084) | (0.073) | (0.051) | (0.045) | (0.027) | (0.126) | (0.169) |
| NextGen Origin Num. of PBN | -1.920*** | -1.348*** | -0.771*** | -0.577*** | -0.643*** | 0.066 | -0.572* | -1.633*** |
| | (0.442) | (0.213) | (0.187) | (0.131) | (0.121) | (0.073) | (0.344) | (0.453) |
| NextGen Origin Num. of SO | -2.851*** | -1.200*** | -0.924*** | -0.276*** | -0.289*** | 0.013 | -1.651*** | -3.114*** |
| | (0.370) | (0.212) | (0.169) | (0.101) | (0.078) | (0.061) | (0.291) | (0.379) |
| NextGen Origin Num. of DC | -1.628*** | -0.046 | 0.318*** | -0.363*** | -0.311*** | -0.052 | -1.583*** | -2.136*** |
| | (0.309) | (0.143) | (0.116) | (0.086) | (0.069) | (0.049) | (0.249) | (0.300) |
| NextGen Dest. Num. of MRO | 0.678*** | 0.621*** | 0.333*** | 0.288*** | -0.124*** | 0.412*** | 0.056 | -0.324* |
| | (0.186) | (0.100) | (0.074) | (0.059) | (0.044) | (0.031) | (0.132) | (0.187) |
| NextGen Dest. Num. of PBN | -1.115** | -0.154 | 0.142 | -0.296** | -0.032 | -0.264*** | -0.961** | -0.824 |
| | (0.567) | (0.267) | (0.196) | (0.148) | (0.117) | (0.077) | (0.390) | (0.521) |
| NextGen Dest. Num. of SO | -2.451*** | -0.598*** | -0.103 | -0.495*** | 0.000 | -0.495*** | -1.853*** | -0.464 |
| | (0.382) | (0.187) | (0.157) | (0.102) | (0.079) | (0.054) | (0.301) | (0.396) |
| NextGen Dest. Num. of DC | -2.133*** | -0.911*** | -0.130 | -0.781*** | -0.284*** | -0.497*** | -1.222*** | -1.511*** |
| | (0.283) | (0.147) | (0.112) | (0.097) | (0.072) | (0.057) | (0.220) | (0.277) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |

# Richer Fixed Effects

Table 9: **Richer Fixed Effects and Alternative Identifying Assumptions**

| Dep var.: air travel time (minutes) | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| | | | | A. Baseline | | | | |
| NextGen Origin | -1.267*** | -0.195** | -0.030 | -0.165*** | -0.141*** | -0.024 | -1.072*** | -1.598*** |
| | (0.154) | (0.078) | (0.058) | (0.044) | (0.037) | (0.024) | (0.124) | (0.156) |
| NextGen Dest. | -1.166*** | -0.119 | 0.046 | -0.165*** | -0.171*** | 0.006 | -1.047*** | -1.000*** |
| | (0.149) | (0.078) | (0.061) | (0.048) | (0.038) | (0.028) | (0.114) | (0.151) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| | | | | B.1 Richer Fixed Effects: Route by Carrier by Day-of-week by Hour-of-day | | | | |
| NextGen Origin | -1.223*** | -0.232*** | -0.055 | -0.177*** | -0.138*** | -0.039 | -0.992*** | -1.585*** |
| | (0.163) | (0.080) | (0.061) | (0.046) | (0.039) | (0.024) | (0.132) | (0.164) |
| NextGen Dest. | -1.183*** | -0.108 | 0.036 | -0.145*** | -0.145*** | 0.001 | -1.075*** | -1.012*** |
| | (0.156) | (0.082) | (0.065) | (0.051) | (0.038) | (0.031) | (0.119) | (0.159) |
| Number of obs. | 24,997,532 | 24,997,532 | 24,997,532 | 24,997,532 | 24,997,532 | 24,997,532 | 24,997,532 | 24,997,532 |
| R-squared | 0.81 | 0.97 | 0.99 | 0.30 | 0.28 | 0.30 | 0.08 | 0.08 |
| | | | | B.2 Richer Fixed Effects: Route by Carrier by Aircraft Model Trim | | | | |
| NextGen Origin | -1.258*** | -0.135* | 0.011 | -0.147*** | -0.141*** | -0.006 | -1.123*** | -1.547*** |
| | (0.160) | (0.080) | (0.059) | (0.045) | (0.037) | (0.024) | (0.132) | (0.162) |
| NextGen Dest. | -1.237*** | -0.103 | 0.040 | -0.143*** | -0.174*** | 0.031 | -1.134*** | -1.035*** |
| | (0.156) | (0.082) | (0.063) | (0.050) | (0.038) | (0.029) | (0.122) | (0.157) |
| Number of obs. | 25,034,463 | 25,034,463 | 25,034,463 | 25,034,463 | 25,034,463 | 25,034,463 | 25,034,463 | 25,034,463 |
| r2 | 0.80 | 0.97 | 0.99 | 0.24 | 0.23 | 0.24 | 0.04 | 0.04 |

# Richer Fixed Effects

Table 9: **Richer Fixed Effects and Alternative Identifying Assumptions**

| Dep var.: air travel time (minutes) | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| | | | | A. Baseline | | | | |
| NextGen Origin | -1.267*** | -0.195** | -0.030 | -0.165*** | -0.141*** | -0.024 | -1.072*** | -1.598*** |
| | (0.154) | (0.078) | (0.058) | (0.044) | (0.037) | (0.024) | (0.124) | (0.156) |
| NextGen Dest. | -1.166*** | -0.119 | 0.046 | -0.165*** | -0.171*** | 0.006 | -1.047*** | -1.000*** |
| | (0.149) | (0.078) | (0.061) | (0.048) | (0.038) | (0.028) | (0.114) | (0.151) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| | | | | C.1 Further Relax Parallel Trend Assumption: Add Airline Fixed Effects by Linear Trend | | | | |
| NextGen Origin | -1.138*** | -0.166** | -0.019 | -0.147*** | -0.144*** | -0.003 | -0.972*** | -1.498*** |
| | (0.154) | (0.076) | (0.057) | (0.043) | (0.037) | (0.024) | (0.122) | (0.154) |
| NextGen Dest. | -1.037*** | -0.089 | 0.058 | -0.147*** | -0.174*** | 0.027 | -0.947*** | -0.900*** |
| | (0.148) | (0.077) | (0.059) | (0.048) | (0.038) | (0.028) | (0.113) | (0.149) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| | | | | C.2 Further Relax Parallel Trend Assumption: Add Airline Hub Status by Linear Trend | | | | |
| NextGen Origin | -1.287*** | -0.186** | -0.028 | -0.158*** | -0.133*** | -0.025 | -1.101*** | -1.625*** |
| | (0.153) | (0.078) | (0.058) | (0.044) | (0.038) | (0.024) | (0.123) | (0.155) |
| NextGen Dest. | -1.200*** | -0.117 | 0.046 | -0.162*** | -0.174*** | 0.012 | -1.084*** | -1.034*** |
| | (0.149) | (0.078) | (0.061) | (0.047) | (0.037) | (0.028) | (0.114) | (0.150) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |

# Alternative Sample: Add Flights not Matched in B-43 Form

Table A.5: **Effect of NextGen: Alternative Sample**

| Dep var.: air travel time (minutes) | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| | | | | A. Baseline | | | | |
| NextGen Origin | -1.267*** | -0.195** | -0.030 | -0.165*** | -0.141*** | -0.024 | -1.072*** | -1.598*** |
| | (0.154) | (0.078) | (0.058) | (0.044) | (0.037) | (0.024) | (0.124) | (0.156) |
| NextGen Dest. | -1.166*** | -0.119 | 0.046 | -0.165*** | -0.171*** | 0.006 | -1.047*** | -1.000*** |
| | (0.149) | (0.078) | (0.061) | (0.048) | (0.038) | (0.028) | (0.114) | (0.151) |
| Number of obs. | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 | 25,037,569 |
| R-squared | 0.80 | 0.97 | 0.99 | 0.22 | 0.21 | 0.22 | 0.04 | 0.04 |
| | | | | B. Alternative Sample with Aircraft Not Matched in B43 | | | | |
| NextGen Origin | -0.987*** | -0.060 | 0.048 | -0.108*** | -0.089*** | -0.019 | -0.927*** | -1.327*** |
| | (0.133) | (0.067) | (0.050) | (0.039) | (0.033) | (0.021) | (0.105) | (0.135) |
| NextGen Dest. | -1.055*** | -0.164** | -0.013 | -0.151*** | -0.134*** | -0.017 | -0.891*** | -0.859*** |
| | (0.128) | (0.068) | (0.054) | (0.042) | (0.033) | (0.026) | (0.098) | (0.131) |
| Number of obs. | 33,447,478 | 33,447,478 | 33,447,478 | 33,447,478 | 33,447,478 | 33,447,478 | 33,447,478 | 33,447,478 |
| R-squared | 0.79 | 0.97 | 0.99 | 0.24 | 0.22 | 0.22 | 0.04 | 0.04 |

# Alternative Counterfactual

Table A.6: **The effect of NextGen from 2014 to 2017 on air travel time using alternative estimates**

| | (1) elapsed time + departure delay | (2) elapsed time | (3) airborne time | (4) taxi time | (5) taxi-out time | (6) taxi-in time | (7) departure delay | (8) arrival delay |
|---|---|---|---|---|---|---|---|---|
| Actual (minutes) | 149.04 | 139.30 | 115.78 | 23.51 | 16.32 | 7.18 | 9.6 | 4.13 |
| | | | | Panel A. Baseline (Repeat Table 3) | | | | |
| Change (minutes) | 2.54 | 0.33 | -0.02 | 035 | 0.33 | 0.02 | 2.22 | 2.72 |
| Change (percent) | 1.71% | 0.24% | -0.01% | 1.47% | 2.00% | 0.26% | 23.17% | 65.94% |
| | | | | Panel B. Use Estimates from Table 2 Panel B | | | | |
| Change (minutes) | 2.71 | 0.43 | -0.04 | 0.39 | 0.36 | 0.03 | 2.30 | 2.84 |
| Change (percent) | 1.82% | 0.31% | -0.04% | 1.64% | 2.18% | 0.41% | 23.89% | 68.90 % |
| Number of obs. | | | | | | | 4,736,642 | |

*Notes*: The first row reports the actual travel time in 2017. This table reports the counterfactual travel time and delay if the treated airports in 2017 had been untreated, i.e., as if the airports were in the beginning of 2014. We use baseline in Table 2. In Appendix Table we use estimates in Table 2 Panel B and estimates in Table 8.