2017 NBER Research Proposal: Economics of Energy Use in Transportation

Topic:	Fuel Use in Aviation
Proposed Project:	The Effect of Adopting NextGen Air Transportation System on Air Travel Time and Jet Fuel Consumption: Evidence from High-frequency Air Traffic Data
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Industry Advisor:	Kathleen Yan, MITRE Corporation
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Project description:

The U.S. government and airline industries have spent billions of dollars to improve air transportation efficiency. In 2004 the U.S. Congress passed the Integrated National Plan for the Next Generation Air Transportation System (NextGen), which grew out of the Vision 100 -- Century of Aviation Reauthorization Act.[2] According to the United States Federal Aviation Administration (FAA), "NextGen is the FAA-led modernization of our nation's air transportation system. Its goal is to increase safety, efficiency, capacity, predictability, and resiliency of American aviation…Airlines, general aviation operators, pilots, and air traffic controllers gain better information and tools that help passengers and cargo arrive at their destinations more quickly, while aircrafts consume less fuel and produce fuel emissions."[3] The FAA received 7.4 billion dollars from Congress to facilitate the NextGen programs from 2004 to 2014 and has projected 20.6 billion USD in total spending to NextGen programs through 2030 (GAO, 2017a).

Policymakers and the airline industry support the program because investing in NextGen can pay for itself by helping to address the increased demand for air transportation. It will do this by reducing the frequency and length of delays that are costly to airline and consumers, reducing cruising time by allowing planes to fly closer and to take straighter routes, reducing waiting time on runways, and reducing fuel consumption via the above channels.[4] In addition to private benefits, policymakers support NextGen because it has the potential to reduce greenhouse gas emissions (GHG) from air transportation.[5] In 2015, the transportation sector contributed 27 percent of total

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[2] The CAR Act (P.L. 108-176) was signed by President G.W. Bush. Congress authorized and created the Joint Planning and Development Office (JPDO) to coordinate NextGen programs with the FAA.

[3] https://www.faa.gov/nextgen/what_is_nextgen/

[4] It also has other benefits such as providing safer flights and improving national security. For example, the Vision 100 – The CAR Act was signed after the events of September 11, 2001.

[5] NextGen has other public benefits in addition to climate benefits such as national security benefits, but those are beyond the scope of this project.

CO2 emissions in the US, among which jet fuel consumption alone contributes 9 percent (EPA, 2017). The existing studies are either engineering studies focused on simulating predicted costs and benefits based on a range of parameters chosen outside of the system (e.g., JPDO 2011), or accounting exercises without isolating confounding factors.[6] Despite the importance of NextGen in private and public welfare, as well as the magnitude of investments made in NextGen from the U.S. government, there is a lack of empirical studies that investigate the causal effects of NextGen on air travel time, which has important implications for air travel time savings, fuel consumption savings, and climate cobenefits.

I am applying for NBER funding on Economics of Energy Use in Transportation to support the research to fill this gap at the crucial time in the midterm of NextGen programs. This project aims to quantify the treatment effect of adopting NextGen on four key outcome variables: air travel time, airport capacities, fuel consumption, and greenhouse gas emissions. The first measure has implications for private consumer benefits from time savings and private producer surplus from avoided forgone profits from canceled flights. The second, measured by the number of flights that take off per time block, has implications for private consumer and producer benefits, which may result from increasing the number of flights possible in the market. The third measure has direct implications on private benefits from fuel savings. The fourth has implications for public benefits. This project aims to make two contributions. First, this project contributes to the literature that studies the effect of technology adoption on energy efficiency by examining the effect of NextGen on jet fuel consumption via reducing air travel time. Second, this project contributes to the literature that investigates the benefits of infrastructure investment in the case of air transportation system upgrades.

I begin by investigating the effect of NextGen on air travel time. This project employs a difference-in-difference (DID) approach to evaluate the causal effect of NextGen adoption for the treated flights.[7] I exploit the rich information available for air travel from the FAA's high-frequency airline service performance data. I use the following data from this set: observations of daily flight information, including both scheduled and actual gate-out time, take-off time, landing time, and gate-in time at a precise minute level; other daily flight-specific information such as weather conditions; and flight airline and number, which allows me to control for flight-specific factors. To further control for airport-time specific effects, this project links the daily flight data with the high-frequency airport metrics data which report air traffic every 15 minutes. These data include information such as the number of flights, and percent of on-time departures and arrivals, as well as other statistics, every 15 minutes every day at an airport.

To distinguish treated and untreated flights, this project utilizes airport- and date-specific NextGen adoption data from the FAA. For example, the Atlanta International Airport (ATL) implemented wake recategorization on July 2014, which allows aircrafts to safely takeoff and land closer to each other, increasing capacity and flight efficiency.[8] At an airport given a random date from 2004 to 2016, only a subset of airports has adopted NextGen (I later describe the NextGen timeline). This study uses flights going to and from untreated airports as the control group.[9] I list the types of

[6] For example, one accounting case study found that since the adoption of NextGen at the Minneapolis International Airport (MSP) in 2015, airlines saved 9.5 million dollars in fuel expenditures by 2017.
[7] To further complement the DID analysis, this project proposes to conduct an event study analysis on how the effect of NextGen persists over time for the treated flights.
[8] Explanation of wake recategorization from FAA: https://www.faa.gov/tv/?mediaId=1689
[9] The adoption of a particular NextGen at an airport given a random date is as good as random.

NextGen projects implemented, the first implementation quarter for each type of NextGen upgrade, and the number of airports first implemented in that quarter in Table 1.

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)

Since the legislation was passed in 2004, the FAA has conducted an initial analysis of implementing NextGen. The first implementation originated in 2014. Since then, the FAA has implemented four major categories of NextGen technologies. To estimate the effect of these four upgrades, I will break the panel into different time blocks to analyze their effect separately. Doing so allows me to identify the time savings from each category separately. Using a literature benchmark of the value of time for consumers, my estimate will provide a lower bound of private consumer benefits from air travel time savings. Also, imputing from the forgone profits from canceled flights, my estimates will provide a lower bound of airline benefits from air travel time savings. Using the same methodology in combination with the airport and time-specific data, this project will then quantify the effect of NextGen on airport capacities measured by the number of flights that take off per hour block.

One challenge is that a DID estimate may be subjected to confounding factors which are unobservable to econometricians and are also correlated with NextGen upgrades. For example, an airport may initiate incentive programs and training programs to improve operators' efficiency at the same time an airport is under a NextGen upgrades. The rich high-frequency panel data allow me to mitigate this concern by controlling for varies types of fixed effects. However, doing so may cause overfitting problems and produce inaccurate counterfactuals. The accuracy of the causal estimate relies on constructing an accurate counterfactual to capture the hypothetical changes in air travel time for the flights flying from or to the treated airports if NextGen had not been in place. To flexibly and correctly predict the counterfactual air travel time out-of-sample without running the risk of overfitting, this project leverages the recent development of machine learning (ML) techniques in the context of causal inference (e.g., Athey and Imbens 2015; Athey 2017). The

methodology of this project is based on Burlig et al. (2017), in which the authors extend the literature of ML in causal inference using selection-on-unobservable designs.

The second challenge of this project is to interpret the impact of reduced air travel times on fuel consumption savings and emission reductions. In an ideal world, this project would directly estimate fuel consumption savings and emission reductions caused by NextGen in the same way as estimating air travel time savings resulting from NextGen. However, the FAA only provides high-frequency data on air travel and have yet to require that airports and airlines report refueling and emissions. Their current reports on fuel consumption savings have been based on imputations.[10] As more data become available in the future, I can directly estimate the causal effect of NextGen on fuel consumption and emissions for future projects.[11] Because of this limitation, in the current phase, I propose using the Advanced Emission Model (AEM) model provided by EuroControl to simulate "simulated actual" as well as "simulated counterfactual" fuel consumption and greenhouse gas emissions using actual air travel time and predicted air travel time.[12] The flight data include not only gate-to-gate time for each flight but also detailed compositions of the overall gate-to-gate duration, including taxi-out time (from gate to take-off), cruising time (from take-off to landing), and taxi-in time (from landing to gate) as well as rich information of relevant variables that are crucial for fuel consumption. This project investigates the causal effects of different categories of NextGen upgrades on various types of air travel time saved for the treated flights. This result has important implications for fuel consumption and emissions since the average fuel consumption rate varies by phases of flight.

This project will be carried out by Christy Zhou at Clemson University, in collaboration with an industry advisor from MITRE corporation who provides valuable inputs, and a graduate student at University at Maryland and at Clemson University who provide research support. I welcome other researchers to join in the process of this project. Regarding the timeline, I will allocate January through April 2018 to link the daily flight data, the 15-min-block airport data, and NextGen timeline data together, and produce suggestive evidence from the conventional DID and preliminary results. I will allocate time from May to October 2018 to produce the main baseline results and counterfactuals. I will allocate November 2018 to early 2019 to prepare the working paper for circulation. Obtaining funding support from NBER would accelerate the progress of this project with additional research support.

I expect this research to contribute to both the lively cost-benefit debate surrounding the Next Generation Air Transportation System, which is an important part of US public expenditures and to the public debate on regulations targeting fuel consumption and emissions from aviation.

This project is important to lay the ground work that is necessary for future research on economics of fuel use in aviation which I am passionate to follow up. For example, adopting NextGen would create additional network effect from treated airports, which is an important channel to study in the future. Also, FAA's implementation of NextGen at major airports would incentivize airlines

[10] See this link. Quote" Accordingly, as reported, this metric is not a direct measure of operational fuel efficiency and should not be used as a proxy for system fuel efficiency on its own."

[11] The FAA Modernization and Reform Act of 2012 has reauthorized the FAA to request and report fuel consumption data and the author has reached out to the FAA to obtain the data.

[12] AEM is a widely used engineering model. It simulates fuel consumption and emissions based upon actual and counterfactual air travel time predicted in the model I describe in different phases of flights, and based upon a range of other variable inputs which are available in the FAA data.

to alter their operations in the long run. This project is valuable for its potential to extend to future research on market responses to the NextGen.

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Disclosure Statement

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The following statement applies to Zhou. Zhou declares that she has no relevant or material financial interests that relate to the research described in this paper. She has not received any other financial support for the particular research described in this paper. The results produced in this project do not represent views of Clemson University, nor views of other organizations and institutions that Zhou consult in the research process.

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