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Allocating airport slots: The history of early applied experimental research

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ALLOCATING AIRPORT SLOTS - THE HISTORY OF EARLY
APPLIED EXPERIMENTAL RESEARCH

BY

ANDREJ SVORENČÍK

CHOPE WORKING PAPER NO. 2016-31

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CENTER FOR THE
HISTORY OF POLITICAL ECONOMY
AT DUKE UNIVERSITY

Allocating Airport Slots - The History of Early Applied Experimental Research

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Abstract: The aviation industry changed dramatically in the wake of the Airline Deregulation Act of 1978. My paper looks at an element of this transformation – the policy according to which take off and landing slots were allocated at congested airports including a proposal to change this policy – an issue that affected millions of passengers annually. Caltech economists and experimentalists David Grether, Mark Isaac and Charles Plott were hired by the Civil Aviation Board to study the existing slot scheduling committees that used unanimity voting rule as well as alternative slot allocation mechanisms.

I use their study to trace and depict the emerging practice of applied experimental research as a multilayered endeavor which involves an interplay among theoretical, empirical, and practical considerations (akin to economic modeling) that allows the experimenter to move from the naturally occurring phenomenon to its study in a laboratory only to return back with a policy recommendation. This demonstrates that applied experimental economics research went hand in hand with the emergence and rise of experimental economics in the 1980s.

Keywords: applied economics, experimental economics, airport slot allocation, airline regulation

JEL Codes: B21, B31, C91, D47, L93

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Dedication: This paper is dedicated to the memory of [Martin Filko](#) (1980-2016) a close friend, a fellow traveller, Director of the Institute of Financial Policy, and Chief Economist of Slovakia. He tragically died shortly after the first draft of this paper was completed. Although our last undertaking - coincidentally related to applied economics & policy - caused a long delay in completing this paper, it was worth it.

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By the end of the 1960s, the air transport industry had grown so much that the problem of airport congestion took hold and could not be solved just by increasing capacity (Levine 2009, p. 56). This led the Federal Aviation Administration (hereafter the **FAA**) to impose limits on landing and departure slots on the U.S.'s four busiest airports. For each airport a committee was established to allocate these sought-after slots using unanimity voting. Every airline operating at one of these airports as well as the Civil Aviation Board (hereafter the **CAB**) were members of these committees. But it was really the CAB who was in charge. Since its inception in the 1930s it tightly regulated the industry, determining not only interstate routes and ticket prices but entry to the market as well.

This dramatically changed when the Airline Deregulation Act was passed in 1978. Airlines wishing to fly from popular airports could not be held back by the CAB anymore. What was holding them back at the four airports subject to slot controls -

New York's La Guardia and JFK, Washington's (now Reagan) National and Chicago's O'Hare airports - was the lack of available landing slots especially at peak times. The emergence of new entrant competitors and the rearrangement of route networks by established competitors increased pressure on re-allocating slots 'owned' by legacy airlines as the membership of the slot committees swelled.

In 1979 three Caltech economists – David Grether, Mark Isaac and Charles Plott (hereafter **GIP**) – were hired by the CAB to quickly evaluate the performance and efficacy of the slot committees as well as other methods of allocating slots (Grether, Isaac, and Plott 1979, Grether, Isaac, and Plott 1981, Grether, Isaac, and Plott 1989).¹ They used this policy issue as another testing ground for a novel method in economics - the economic experiment. From early on, pioneers of experimental economics such as Plott were keen to demonstrate the practical value of experimental research. When reflecting on the late 1970s, Plott recalled that:

“Substantial pressure existed to demonstrate that laboratory experimental methodology could be useful. The profession needed examples of the value of the methodology and how the methodology might be used towards the traditional ends of economics (Plott 2001, p. xv).

The GIP study was not the first instance of applied experimental research – economics research that – loosely speaking – is to be used in determining public policy or regulation that draws on experimental evidence. But among the handful of

¹ The 1979 publication is the report submitted to the CAB. Substantially shortened version appeared in the AER in 1981. A decade later the full report was published as a book with a preface summarizing the subsequent development.

early cases it was the most visible one and had the potential to shape, especially had GIP's recommendation to solve an important issue of the day like few other – airport congestion was a problem that affected millions of passengers every year – been implemented.

Applied experimental research presents a new type of applied work in economics that is conducted in a new site (a laboratory) and with a novel method (experiments). Using the airport slot allocation study I trace and depict the emerging practice of applied experimental research as a multilayered, nuanced endeavor which involves an interplay among theoretical, empirical, and practical considerations (akin to economic modeling) that allows the experimenter to move from the naturally occurring phenomenon to its study in a laboratory only to return back with a policy recommendation.²

² To this end a variety of resources is marshaled – archival materials, publications and interviews or email correspondence with key players. These sources are triangulated in a similar fashion as described in the appendix to my dissertation *Distance and Sources in Writing Contemporary History* (Svorenčík, 2015, pp. 243-48).

The Regulation Policy of the Civil Aeronautics Board

The Civil Aeronautics Act of 1938 transferred federal responsibilities for non-military aviation from the Bureau of Air Commerce to a new, independent agency, the Civil Aeronautics Authority. In 1940, its two parts, the Civil Aeronautics Board and the Civil Aeronautics Administration (CAA), were split into two agencies. The CAA, which became the Federal Aviation Administration in 1966, was responsible for air traffic control, airman and aircraft certification, safety enforcement, and airway development. The CAB was responsible for safety regulation, accident investigation, and most importantly economic regulation of the airlines.³

CAB's duties included route licensing and rate regulation of interstate air travel. For instance all fares of certificated carriers were subject to CAB approval. It exercised control over airlines' entry and exit from particular markets and it vigorously protected airline industry from competition. Fares purported to guarantee airlines a 12 percent return on flights that were 55 percent full (Hershey 2010), but the CAB's lack of ability to control the capacity offered meant that most airlines did not achieve that level of profit, creating constant pressure to raise fares further. Because there were always less-efficient firms struggling to achieve the target level of returns at existing fare levels, the CAB "did not encourage or even allow fare

³ Source: <http://www.faa.gov/about/history/timeline/> [Accessed on June 1, 2016]. Until 1967 the CAB was part of the Department of Commerce. Only then the Department of Transportation (DOT) was established. It combined all federal responsibilities for air and surface transport. See also (Behrman 1980) for a detailed history.

reductions except when all the airlines were prospering and could easily withstand greater price competition” (Behrman 1980, p. 86).⁴

By many critics the CAB was regarded as “the epitome of an agency ‘captured’ by the industry it regulates” (Behrman 1980, p. 75) and “there's no question that that legislation was designed to be protectionist” (Robyn 2011-2012b, p. 178). Since its inception until its deregulation in 1978 no airline received “a category of license which in principle allowed them to be certificated to fly any kind of route” (Robyn 2011-2012b, p. 178). Put differently, no new airline operating on US-interstate level had started between 1938 and 1978 in the U.S. All airlines operating prior to 1938, which lobbied the passage of the 1938 Act, received this type of license. The result of these policies was an oligopolistic market structure with a protectionist regulator that was praised by the operating airlines (Kahn 1971, pp. 210-212).

The 1950s through 1970s are viewed as the heydays of commercial air travel when it was an exclusive experience with passengers typically dressed up for the special occasion. As airlines could not compete with prices due to CAB regulation and were not worried about new entrants to the market, they engaged in service competition. This showed “most notably in adopting the most modern and attractive equipment and in the frequency with which they schedule flights, but also in providing comfort, attractive hostesses, in-flight entertainment, food and drink (Kahn 1971, p. 211).

Until the 1960s slots were allocated on a first-come first-served basis. A “slot” refers to a carrier’s authority to take off or land at an airport.⁵ During the 1960s with the

⁴ I thank Michael Levine for clarifying this point.

advent of jet travel, growing demand for air travel and restricted airport capacity “long queues of airplanes waiting to take off and land became common at major international airports at peak times” (Condorelli 2007, p. 81). In 1968 the Federal Aviation Administration established quotas for scheduled airlines, commuters, and general aviation at four high density airports – J.F. Kennedy & La Guardia in New York, Washington National and O’Hare International in Chicago.⁶ Each of the four airports created a scheduling committee consisting of airlines using the airport (around ten) and CAB representatives. Typically, the airline representative was an expert on the technical aspects of scheduling with the authority to schedule flights. The committee reached decisions about slot allocation in accordance with the restrictions imposed on the number of take offs and landings. As these decisions were to be voluntary, the proposed changes in the committees had to be reached unanimously. For these purposes, airlines were granted immunity from antitrust laws - for a detailed history see (Gleimer 1996, pp. 878-880).

The early 1970s brought about stagflation, an unprecedented occurrence of recession and inflation, which squeezed airline profits and drove several airlines into severe financial problems. Attempting to restore the airlines' financial health, the CAB tightened its anticompetitive policies to an unprecedented level (Behrman 1980, p 76).

⁵ Technically, we should be talking about slot pairs or two slots as any take off slot requires landing slot. Slots are different from landing fees. Their value of a departing slot, for instance for a flight between the SFO-LAX airports that departs at 7am depends on the airline’s landing slot at LAX at 8am. This is a so-called *slot complementarity*.

⁶ For a brief period this high-density rule applied also for the Newark airport.

The Airline Deregulation Act (1978)

Besides the changes in the economic conditions that drew attention to the passenger airline industry in the 1970s, there was also a change both in the external political environment and academic stance towards regulation. The 1960s and 1970s witnessed a growing deregulation movement among economists that fostered the view that economic regulation of prices and entry to the market was a government failure, generating misallocations and inefficiencies (see references in Berman, this conference, pp. 12-3).

Michael E. Levine played a prominent role in the deregulation movement of the airline sector. Already during his graduate studies of law at Yale in mid 1960s, he published an article advocating the deregulation of airline industry based on the superior performance of the California intrastate airline market (Levine 1965). Intrastate service was not regulated by the CAB and Levine observed that prices were approximately half the regulated fares on comparable routes.⁷ A more efficient fleet mix of older and newer aircraft at differential prices were used and intrastate travel grew in the preceding decade six times faster than interstate. His study was picked up and extensively quoted by Alfred Kahn (1917-2010), a leading economist of regulation, in what is hailed as the most important book on regulation of that period (Kahn 1971, pp. 218-20, Button 2015).

⁷ The example Levine used were flights versus flights between Boston and Washington. The motivation for this paper stemmed not just from his lifelong interest in aviation, but also from a practical issue of frequent travelling between the East and West Coast to visit his girlfriend (Robyn 2011-2012b, pp. 175-6).

After graduating, Levine briefly worked for the CAB as an attorney (1965-66) where his views were met with skepticism at best. He left within eight months and did further postgraduate work in economics, and eventually got an academic job first at the USC Law School and later in 1972 a joint position at Caltech. One of his USC law colleagues moved to Harvard and this person mentioned him and his contentious airline agenda to Stephen Breyer, a specialist in regulation and future Justice at the Supreme Court. Breyer had been approached by the Democratic Senator Edward Kennedy from Massachusetts to help him find a regulatory issue that would enhance Kennedy's centrist, pro-market profile in a presidential bid that he was contemplating for 1976 or 1980. Soon a meeting with Kennedy was arranged – ironically in an airline lounge at the Boston airport where, in Levine's recollection, they scripted what later became the famous Kennedy congressional hearings (Robyn 2011-2012b, pp. 185-87).⁸ Although the hearings were formally related to CAB's administrative procedures, their extensive press-coverage and dismantling of weak CAB arguments for keeping prices high and regulating the industry put the issue of airline deregulation on the political center stage.⁹ Fearing that Kennedy might take all credit in the upcoming elections, Ford and his Republican

⁸ The extra irony was that the meeting took place at the American Airlines' Admiral Club. The AA CEO was an important fundraiser for Caltech and once Levine published an article in the Caltech alumni magazine advocating deregulation, the CEO complained and threatened to withdraw his support. Caltech ignored his threats (*ibid*, p. 185).

⁹ Oversight of Civil Aeronautics Board Practices and Procedures: Hearings before the Subcomm. on Administrative Practice and Procedure of the Senate Comm. on the Judiciary, 94th Cong., 1st Sess. (1975).

administration pressed “for reform significantly sooner and more vigorously than it otherwise would have” (Behrman 1980, p. 101-2).

In the course of 1975 and 1976 the CAB made a complete about-face from a position of protectionism to fervent supporter of deregulation. Surprisingly, that was not due to a complete replacement of the five CAB Board members. Although a minority was replaced, the transition was a result of intense internal dialogue under the leadership of a new CAB Chairman Robson. He joined the CAB in 1975. A year later he testified on the Ford administration's proposal on aviation regulatory reform. His audience was surprised to learn “that the agency had unanimously agreed that Congress should pass legislation which would substantially reduce the CAB's powers and would thus reduce restraints on competition in the airline industry” (Behrman 1980, p. 104). A year later, in 1977, Robson was replaced by Kahn. He received a mandate to deregulate to the maximum extent possible.

Both Robson and Kahn are credited for overhauling the agency. Kahn was not only an academic authority in the economics of regulation (Kahn 1971), but turned out to be very effective in testifying before Congress and having access to the White House. For his mediagenic skills to sell the idea of economic deregulation to a suspicious public (Robyn 2011-2012a, p. 265) and his involvement in the actual liberalization process, he has been dubbed the Father of Airline Deregulation.

The Act had two main provisions. First, a gradual reduction in CAB regulation, with entry deregulation to be completed by December 31, 1981. Second, price regulation to be ceased two years later. In 1985, the CAB became the first major federal

regulatory agency ever that was abolished. The changes resulted in increased competition, lower fares, declining quality of service and the rise of low-cost carriers like Southwest. On the other hand they also created severe financial problems for the industry, legacy carriers and their unions in particular, leading to bankruptcies and mergers (Hershey 2010).

Assembling Grether, Isaac and Plott to Tackle the Slot Allocation Problem

The CAB had expected that, due to new entrants, once the Airline Deregulation Act comes into effect, slots would become an increasingly scarce resource. New entrants would be granted membership in the scheduling committees and the requirement to reach unanimous agreement could lead to new barriers to entry at those four airports. With time this could become a growing problem. In order to accommodate new entrants, slots would have to be taken from reluctant legacy airlines which were currently using the slots.

Levine was actually the first to study the airport congestion crisis and to propose a market mechanism in the form of peak-load pricing to reduce waiting times (Levine 1969). Kahn had been familiar with Levine's work and therefore invited him to join the CAB as its Director of the Bureau of Pricing and Domestic Aviation in 1978. This was a newly created position that "combined all the senior staff jobs that had not

been filled by previous commitment”.¹⁰ His tasks included airport congestion and the slot scheduling committees at congested airports in the wake of airline deregulation. And Levine knew right away whom to contact to solve this problem. There wasn’t that much structural difference between the scheduling committees and the flying club problem that he studied before joining the CAB together with Charles Plott, his colleague at Caltech.

Having grown up in the vicinity of what is now the JFK airport, Levine, born in 1941, has had a lifelong passion for airplanes and airlines (Robyn 2011-2012b, p. 175).

When he was a faculty member at Caltech in the 1970s he joined a large flying club. At that time the club was contemplating the fleet of airplanes that it would operate and Levine (being a lawyer) was in charge of the agenda – defined as the series of alternative choices on which the group votes – that was to be used at the meeting.

With Arrow’s impossibility theorems looming in the background, Charles Plott, Levine’s colleague at Caltech, convinced Levine “that there was no uniquely best agenda. Instead, there were many good agendas and each could lead to a different outcome. The thing we should do was to decide which of the 'good' agenda would lead to a choice that he [Levine] liked best” (ibid). With Levine’s detailed knowledge of the available options that the club had available and the various preferences of

¹⁰ Email communication with Levine from June 14, 2016. He was later promoted to the position of the General Director for International and Domestic Aviation in 1979 - all of the "line" jobs at the CAB reported directly to Levine. From 1981 until 1982, he was Executive Vice President for Marketing at Continental Airlines, then from 1982 until 1984 Levine was the CEO of New York Air which caused the Scheduling committee deadlock in 1980. In the 1990s he served as the Executive Vice President for Marketing and International at Northwest Airlines.

the over 50 members of the club, Plott designed an agenda that Levine successfully used and got the flying club to select what he wanted.

Plott had by then an excellent track record in axiomatic social choice theory, public choice including voting, and committee decision making (Plott 1973, 1976, Fiorina and Plott 1978) He was also a pioneer of experimental economics; for Plott's path to experimentation see (Svorenčik 2015, chapter 2.2). The central theme of his research supported by the NSF in the mid 1970s was "the relationship between the axioms that were being used to define the desirable consequences of social decision processes and institutions that might be designed to achieve those consequences" (Plott 2001, p. xii).

With ethical and practical issues of voting group manipulation in mind, after the voting Plott and Levine designed experiments to explore the power of agenda setting under various voting rules. They found that using agenda to sequentially eliminate options can be "a major parameter in determining the group's final choice" and that even the majority-rule equilibrium outcome that Plott observed experimentally earlier (Fiorina and Plott 1978) can be avoided systematically by implementing a properly designed agenda (Levine and Plott 1977, p. 564, Plott and Levine 1978).

Levine, in Plott's and Isaac's recollection, rang up Plott about performing the slot allocation study shortly before the summer 1979 and the deadline – end of summer

– was tight, indicating the urgency of the matter.¹¹ The guiding principle of the CAB commissioned study was to find the most efficient allocation procedure - that is one that assigns slots to airlines that value them the most

After the phone call with Levine, Plott walked down to the graduate students' office and convinced Mark Isaac to spend the summer not just working on his dissertation at the Jet Propulsion Laboratory during the day but also on the airport slot allocation in the evenings. Isaac thus became one of the three authors of the GIP study. He belongs to the first generation of economists trained in experimental method.¹² During his graduate studies at Caltech, Isaac attended Plott's experimental economics class workshop together with Elizabeth Hoffman & Thomas Palfrey, who went on becoming distinguished experimentalists on their own, and James Hong (Svorenčík and Maas 2016).¹³ While his dissertation was in energy economics dealing with information gathering in oil exploration and production, his first publications were primarily of experimental nature. For instance, the first experimental investigation of price controls that grew out of Plott's class got

¹¹ The report was submitted at the end of September 1979.

¹² Isaac's motivation to join the graduate program at Caltech was related to airline deregulation. In his recollection, "in 1971, the Brookings Institution held a conference on "Promoting Competition in Regulated Markets." The book of those proceedings was published in 1975. Chapter 2 was a study of the effects of domestic airline deregulation, by George C. Eads. That book was so quickly well known that I bought it as an undergraduate for a reference for a term paper I was writing. The co-director of the Brookings program which sponsored the conference was Roger G. Noll, a former Brookings Senior Fellow and later a Professor at Caltech (and my dissertation advisor). Seeing that Roger was at Caltech was one the pieces that convinced me to go to Caltech for graduate school." Email communication with Isaac May 23, 2016.

¹³ Isaac interview with the author.

published in the AER (Isaac and Plott 1981).¹⁴ More importantly, by the time Plott was approached by the CAB, Isaac and Plott had recently completed work on a paper that was one of the first to examine the importance of the "default condition" in voting experiments. As the existing slot allocation mechanism was a voting-type process, he was immediately primed to think about the issue of the default conditions, which played an important role in the GIP experiments on the committee processes (Isaac and Plott 1978).

The third member of the GIP team was David Grether. He graduated from Stanford in 1969 specializing in econometrics. However already in his first-year microeconomics sequence he encountered experiments as the visiting teacher who taught the course was Vernon Smith. In 1971, both Plott and Grether joined Caltech and in 1973 Smith arrived for a two-year sojourn in southern California, first at Caltech, then at the USC. Although there were not only students but also many Caltech faculty who members attended Plott and Smith's experimental methods workshop, Grether participated only in a few experiments. His trajectory to experimental research was different from Isaac's. Grether was a regular attendee of the annual conferences in Minneapolis organized by the Minneapolis FED in the mid 1970s, because he was mainly doing time series econometrics. Around 1974 or 1975 he was asked to discuss a paper on rational expectations by Tom Sargent. By that time Grether "had become somewhat disenchanted with this line of work."¹⁵ He decided that rather than simply assuming how people form expectations – as

¹⁴ (Svorenčík 2015, see chapter 5 on the details of refereeing process).

¹⁵ Grether interview with the author.

Sargent did - he would try to see what was known about how people actually formed expectations. Therefore he perused available literature from psychology and came across, for instance, Kahneman and Tversky's research. At the conference instead of commenting on Sargent's paper, Grether discussed psychologists' findings about expectation formation. On the one hand some people in the audience told Grether that "they thought [he] won the conference." On the other hand, he was never invited back.¹⁶ That eventually led to his experimental research on Bayes rule (Grether 1978, 1980). At the same time he engaged with Plott to investigate experimentally the preference reversal phenomenon observed earlier by psychologists which led to their most cited and perhaps best-known article (Grether and Plott 1979, for a discussion see Svorenčík, 2016).

It was not just the pioneering spirit of promoting a new method in economics and desire to show its practical qualities that drew GIP to the airport slot allocation problem. It was also Caltech's ethos that is conducive to applied research.

Interconnection between basic and applied research are abundant. Probably the best-known example is the Jet Propulsion Laboratory, a federally funded research center that is managed by Caltech for NASA. When the Division of Humanities and Social Sciences was established a half a century ago in 1966 and the Social Science doctoral program commenced in 1972 the vision was clear: "a program in social science that is interdisciplinary but scientific, theoretical but directed toward solution of current socioeconomic problems" (1976, p. 2). The Division has brought

¹⁶ Ibid.

interdisciplinary faculty together who, according to Plott, shared " their mutual interest in policy analysis and their appreciation for the importance of basic theory and measurement" (1976, p. 5).¹⁷ Many faculty were involved with Caltech's Environmental Quality Laboratory, a center for research on large-scale systems problems of natural resources and environmental quality such as water and air quality, energy and resources policy.

Observing the Scheduling Committees

GIP's analysis rested on three modes of observing. First, they availed themselves of the historical allocations made by the scheduling committees. Second, they observed actual scheduling committee meetings in situ. Third, they conducted experiments with a set of alternative allocation procedures to find out how they fare in comparison to the unanimity vote.

While Isaac was mostly involved in designing and running experiments, Grether spent a few days in Denver attending an airline scheduling committee. The meeting dealt with the Washington National Airport and took place on July 23-25, 1979 (Grether, Isaac, and Plott 1979, transcript of the meeting in Appendix C). For Grether, it was "a fascinating experience" to see how the committee operated in action. A topic that preoccupied the committee was what happens if they do not

¹⁷ There were plans to establish a Center for Applied and Theoretical Research in the Social Aspects of Public Needs in the early 1970s.

reach an agreement, i.e. there is a default. That option was not specified by the CAB rules and it had never happened before but became more likely when market entry was permitted.

“I remember sitting there and listening to the talk, and each airline had a representative. And much of the conversation was about what would happen if we didn’t have an agreement. A representative of one of the airlines would say: “Senator so and so who flies into this airport will insist that he can go from X to this airport.” So clearly, they were saying you cannot take that slot away from us, because [if we block the committee,] the government won’t let you do that [take those slots].”¹⁸

Using the transcript of this and two other meetings as well as historical records of changes agreed by the scheduling committees, they found that committees with unanimity voting were prone to several faults and were “found inadequate in almost all dimensions of economic efficiency” (Grether, Isaac, and Plott 1979, Chapter O, pp. 1-2)). Efficient carriers could not expand and inefficient ones were not encouraged to leave. Each carrier had the capacity to block the growth and operations of its competitors. Typically considerations at the meeting ran along the lines of past allocation agreed at the previous session, actual usage of allocated slots and submission of requests that typically exceeded the limits imposed by the FAA. One of the practical shortcomings of these committees was the absence of a use-or-lose

¹⁸ Grether Interview with the author. The transcript of the meeting reveals such instances (Grether, Isaac, and Plott 1979, Appendix C, p. 7, p. 11).

rule “which would have freed up so called “pocket slots” which carriers held but did not need to support their operations” (Gleimer 1996, p. 882).

While the committee allocations lacked the flexibility to respond to changing economic conditions (e.g. the oil crisis), they were sensitive to the whims of regulatory political climate. As each airport committee convened independently and at separate times, coordination of slot allocation across airports (i.e. slot complementarity – see Footnote 6) was an issue. “Discussions of city-pairs, scheduled fares, profitability, and other general aspects of airline competition [we]re explicitly prohibited” at the scheduling meetings (Grether, Isaac, and Plott 1981, p. 167). The committees were not designed to “generate funds for airport expansion” needed to improve capacity and there was no link between profitability of an airlines competing for the same slots. Tacit collusion was also a particular risk. The airline industry had prior experience in cooperative behavior such as joint fares and interline agreements under the cloak of anti-trust protection due to be heavy regulation (Grether, Isaac, and Plott 1981, p. 170).

The Role of Experiments in Airport Slot Study

There were two specific reasons why GIP employed experiments to study slot allocation in their study besides the general fact that they had experience with the experimental method and were at the forefront of advancing it. First, the lack of a clearly stated default rule for the case when no agreement is reached led GIP to

consider several potential courses of action: first come, first served that was used in non-restricted airports; FAA administered and determined allocation; grandfathered slots; lotteries; auctions; and markets (Grether, Isaac, and Plott 1979, Chapter IV, pp. 8-10). While they were able to describe economic disadvantages of these alternatives based on reasoning with basic economic principles and verbal models, their only empirical evidence came from the transcripts and was insufficient to select which alternative would work the best. Second, they were tasked to compare the current institutional set-up with alternative allocation mechanisms. In this task, there was no empirical evidence available that they could rely on.

Experiments provided GIP with a way of generating data needed to find the most suitable allocation mechanism. The idea that experimental data could inform theory not to mention policy was radically novel. One of the driving forces of the rise of experimental economics was a redefined, equal relationship between theory and data that experimental economists promoted (Svorenčík 2015, pp. 34-39). Data that is properly controlled as for instance collected in laboratory experiments could not be the only source of blame if theory did not perform well. Experiments allowed GIP to “gain experiences with the tendencies of such committees by studying committees which make decisions in a controlled environment” (Grether, Isaac, and Plott 1979, Chapter V, p. 1). The advantage of experimental data was that it was rigorous in the sense of being produced under the control of the experimenter as well as that it was replicable.

GIP split the alternative institutional arrangements for slot allocation into two sequential steps. The first provided a primary allocation of slots at each airport. The second allowed for adjustments in the primary allocation due to changing economic circumstances, mistakes, unfulfilled expectations, etc.

The alternatives for the primary allocation that GIP considered included committees (either with *unanimity* or majority vote); auctions (either *sealed-bid one-price auction*, *sealed-bid discriminatory auction*, oral English or oral Dutch auction); *grandfathering* of slots, entitlements,¹⁹ slot lottery, and adjustable landing fees. Possible secondary processes included bilateral trade, committee vote, *organized market*, administered reallocation or no secondary allocation (i.e. doing nothing) (Grether, Isaac, and Plott 1979, Chapter III, pp. 1-3).

Not all alternatives were examined experimentally by GIP as they ruled out many options – all except those in italics in the paragraph above. The reasons were varied. Majority vote as a primary market was ruled out due to poor performance in previous experiments. Oral auctions were viewed as too costly compared to the other two auction formats. Landing fees were excluded due to past poor implementation. Lotteries would invite entry of inefficient airlines wishing to collect rents in the after-market. Bilateral vote as an after-market would invite collusion and committees were not entirely suitable for coordinating.

¹⁹ Entitlements would “involve a title to a “slot” which could be sold, traded, or simply not used as the preference of the owner dictates” (Grether, Isaac, and Plott 1979, pp. III 1).

In their experiments, GIP used two experimental economics techniques. The first was the induced value theory of inducing preferences over outcomes by providing corresponding monetary payoffs. It was originally developed by Vernon Smith in the context of oral double auctions, later generalized to other market settings and expanded to the world of public goods (e.g. committees) by Plott in the early 1970 (Smith 1976, 1982, Fiorina and Plott 1978).

The second technique was the efficiency measure developed in the mid 1970s by Plott and Smith. It was ideal for the task at hand as it allows for comparison of various institutions (Plott and Smith 1978, Hong and Plott 1981). Within any controlled economic environment such as an experiment with a particular institution in place there exists a maximum which participants can possibly collectively earn. This is the sum of the maximal consumers' and producers' surpluses. "Whenever this maximum is attained," then the environment or the institution is operating at 100% efficiency. The efficiency of a process is then defined as the ration of the actual earnings achieved in the experiment to the maximum possible earnings (Grether, Isaac, and Plott 1979, Chapter II, p. 6). The efficiency measure defined this way abstracts from interpersonal comparisons of utility.

Moving the World of Committees Inside the Lab

GIP conducted two types of experiments. First, they assessed committee decision-making using unanimous vote with various default rules. Second, they examined the performance of the proposed alternative allocation mechanisms. The latter experiments are discussed in the following section.

In regards to the first type of experiments, GIP ran 23 controlled environment committee experiments with 9 or 14 participants. The number of participants reflected the size of the actual slot allocation committees. The committees made two decisions by a unanimous vote.

The set of 23 experiments can be divided into two groups depending on whether the two decisions were independent or not. In those experiments, where the decisions were tied, “the participants made a ‘system’ decision; that is, they divided among themselves 28 ‘cards’ (10 ‘blue’, 9 ‘pink’, and 9 ‘green’) and 32 ‘flags’ (10 ‘blue’, 11 ‘pink’, and 22 ‘green’). The decisions in the first (card) and second (flag) meetings were interdependent in that a participant's payoffs in the flag meeting depended on the total number of cards received in the first meeting.” In the remaining committee experiments, two independent decisions were made: in each of two meetings the participants divided up 32 cards (10 ‘blue’, 11 ‘pink’, 11 ‘green’). These meetings were independent in that the payoffs in each meeting were determined solely by the number of cards received in that meeting” (Grether, Isaac, and Plott 1979, Appendix F, p. 1).

Three default rules were considered. The initial allocation rule mimicked grandfathering. If participants failed to agree within allotted time period, they would be paid based on their initial endowment of cards and/or flags. In case of no agreement, the pure randomness rule would distribute cards and/or flags randomly using a bingo cage. The mixed default rule “used the initial allocation as a starting point, with a random process used to take slots away from the persons with large initial allocations to be used to give "entrants" (or persons with zero initial allocation) a small number of slots (Grether, Isaac, and Plott 1979, Appendix F, p. 2).

A card was analogous to a slot and the color of the card was analogous to the time of day. Cards and flags represented different airports. In designing parameters of the committee experiments certain features of the Chicago O'Hare airport were used as a guide for the card meeting. Features of the Washington National airport were used for the flag meeting. However, GIP are silent in their report which features were taken. The initial allocation of cards to committee members was analogous to the historical allocation of slots among carriers. GIP were not explicit about which airline matches to the distribution. However airline representatives reading the report might have easily identified themselves in the experimental initial allocations. The declining marginal values to committee members were analogous to diminishing returns to operations for carriers at a given airport. The procedures followed by the experimental committees were almost exactly those that had evolved for the scheduling committees (Grether, Isaac, and Plott 1979, chapter V, p. 4). The reason for all these efforts to resemble the target environment of the airline

industry in the experimental setting was that “you could show the expectations about what would happen in default and what drove those results”.²⁰

However, they did not take airline executives or CAB administrators to the lab. GIP’s experiments were conducted during four nights using students from Caltech and the nearby Pasadena City College – all with experience with experiments. Using students as test subjects has been a standard procedure in experimental economics from the beginning. Not only they are cheaper (i.e. their opportunity costs can be controlled within a smaller research budget), but models, theories or intuitions tested in the experiments typically do not specify the applicable subject pool domain. Only if objections against using students are raised, subjects with different backgrounds are sought. The GIP experiments did not encounter such criticism.

In an earlier applied experimental economics study about the regulation of dry bulk barge industry on inland waterways, Plott with his co-author and graduate student James Hong followed in a similar but not identical fashion (Hong and Plott 1981). Similarly to Hong and Plott, GIP attempted to incorporate a number of significant economic features’ of the scheduling committees (bulk freight industry) into an experiment designed to test the efficiency of different allocation (pricing) rules. But while in the case of Hong and Plott the authors provided detailed reasons of the scaling process of how the actual industry was scaled down and converted to laboratory dimensions and converted back – described in much detail by (Maas

²⁰ Grether interview with the author.

2012), GIP did not provide such detail about the scaling process. For instance when referring to the alternative market based allocation system, they summarized that:

“In many respects O'Hare and National peak hours were used as a model. Size distributions of participants, demand elasticities are all similar up to scale factors. An attempt to stay completely consistent, however, was aborted because of both lack of information about profit details and the necessary expense of any attempt to stay completely consistent” (Grether, Isaac, and Plott 1979, chapter VII, pp. 1-2).

For them it was not crucial to be able to convince the CAB that they studied the actual scheduling committees. It was sufficient that their controlled committees bore only some resemblance with their target world. Far more importantly, their reasoning was based on the general principles or theories of how any committee operated and how these principles played out given various default institutional rules.

GIP concluded from the committee experiments that the final outcome was strongly dependent on the default rule. Allocations also tended to favor the status quo and/or to lean in the direction of equity rather than efficiency. The unanimity voting placed downward pressure on the carriers with the largest number of slots at a given airport. And it prevented the growth of large and medium sized firms even if the economics suggested growth (Grether, Isaac, and Plott 1979, chapter V, pp. 22-23).

Market Based Slot Allocation Experiments

The second type of experiments that GIP performed studied various alternative slot allocation mechanisms. For primary markets sealed-bid one-price and discriminatory auctions and grandfathering were investigated. The difference between one-price auction and discriminatory auction is the prices that winning bidders pay. In one-price auction all winners pay the same price equal to the lowest accepted bid. In the discriminatory auction every winning bidder pays the price equal to her bid. Oral double auction was used as secondary market.

As in committee experiments, cards (blue, pink, and green) were analogous to slots and flags (blue, pink, and green) represented different airports. Demand for them was induced by application of induced value theory. “[S]ize distributions of participants, demand elasticities [we]re all similar up to scale factors” to peak hour at the Chicago O’Hare and Washington National airports (Grether, Isaac, and Plott 1979, Chapter VII, p. 1).

Results from market based experiments were very close to the theoretical prediction. The market itself was almost always 100 percent efficient even after parameter changes. The price was always exactly the competitive equilibrium price (Grether, Isaac, and Plott 1979, Chapter VI, p. 4).

The following table compares the two types of experiments in terms of efficiency.

Comparison of two allocation procedures with identical economic parameters				
	Unanimity Committees *		Market Process **	
	Exp. 23	Exp. 24	No. 2	No. 1
Efficiency	82.4%	84.9%	99.5%	98.2%
Number of Persons on Wrong Flag Chart	8	8	2	2

* These two committees operated with a rule in which default meant that payments were based on the initial allocation. In experiment 23, the initial allocation was Pareto optimal with respect to “sliding”; that is, no two persons could exchange slots in their initial allocation and both be better off. In experiment 24, Pareto optimality did not hold for the initial allocation.

** This process consisted of six competitive auctions (one for cards and flags of each color) followed by six secondary markets.

Table 1: Part of Table 16 from (Grether, Isaac, and Plott 1979, Chapter VII, p. 6).

As can be seen from the row efficiency, markets allocated slots almost perfectly.

Initial allocation of slots became irrelevant as “those who should expand did so and those who should contract got smaller” (Grether, Isaac, and Plott 1979, Chapter VII, p. 5). Hence the final allocations reflected economic efficiency. Committee allocations were inefficient which was almost entirely driven by the consequences of the default rule. Large and medium-sized ‘airlines’ experienced no expansion and entrants received only a minimal number of slots which “was consistent with all other experience and theories about how such committees operate” (ibid).

Moving the Lab into the World

GIP's proposal envisioned an independent primary market for slots at each airport that would be organized as a sealed-bid competitive auction at regular intervals. If, for instance, five slots were available, then the highest five bids would be accepted and the price paid by each of the winning bidders would be the value of the lowest, fifth accepted bid.²¹ A computerized after-market in the form of computerized oral double auction with the revenues earmarked for airport expansion would follow. The after-market would allow airlines to purchase freely and sell primary market slots to each other, thereby addressing the primary market's lack of provision for slot complementarities. Explaining GIP's proposal "an airline that acquired slots at Washington National which did not flight-match the slots acquired at O'Hare could either buy additional O'Hare slots or sell its excess Washington slots in the after market" (Rassenti, Smith, and Bulfin 1982, p. 403). In order to prevent the danger that service to small communities from restricted airports will be closed because other routes would be more profitable, GIP proposed special provisions for small communities. Also airlines would be sanctioned, if they fail to fully utilize their slots.

²¹ GIP recognized the loss of incentive compatibility of their auction format, that is if a bidder wants to acquire multiple units of the same slot, then the GIP format invites the bidder to strategically underbid their true value. However, they did not, as Rassenti et al pointed out, explain why they prefer it to Vickrey's original proposal for multiple unit auctions (Rassenti, Smith, and Bulfin 1982, p. 406).

How did this policy recommendation exactly follow from the evidence GIP collected? It certainly was not entirely implied by the experimental evidence that they collected in favor of a market based primary market. Rather, the plethora of options that was available at the onset of GIP's study was sequentially reduced through the application of a mixture of empirical evidence that ranged from the analysis of committee meetings and their transcripts, data on historical allocations, insights from economic theory and informal modeling to evidence from previous experiments. Only then were experiments performed. Even their design was informed by all these considerations and was adjusted, back and forth in the course of their inquiry.

This depicts GIP's practice of applied experimental research as akin to economic modeling in its mutual interplay of all various empirical, theoretical and also practical considerations such as limited experimental budget, available technology and time constraints (Morgan, 2012). This depiction of applied experimental research is far more complex than the simple description proposed at the beginning of this paper – economics research that – loosely speaking – is to be used in determining public policy or regulation that draws on experimental evidence. Rather conducting applied experimental research is a complicated endeavor that is driven by the interplay of all these considerations in order to successfully move the world into the lab and then move the lab back into the world (see Maas, 2012, for another example).

An important element of GIP's study is the issue: what guarantees that the experimental results readily translate outside the setting where they were obtained. This problem is nowadays typically referred to as external validity. The concept originated in psychology and was not used in experimental economics until the second half of the 1980s (Heukelom 2011). Until then experimental economists argued that to be able to draw policy inferences from laboratory experiments requires that the experiments satisfy the condition of "parallelism" (Plott 1987, Smith 1980). That is, the experimental design must capture the structure of the incentives in the institution being investigated and the subjects must be provided with sufficient information for informed decision-making. GIP asserted that they satisfied the parallelism condition by selecting properly scaled down parameters in their experiments that reflected the conditions of target airports.

Aftermath of the Slot Allocation Study Economics

GIP submitted their study in September 1979 and presented an academic version at the 1980 AEA meetings as part of Models for Antitrust session. A decade later, GIP concluded that the report was taken seriously by the airlines because the CAB supported its recommendation for changing slot allocation rules. Also there was no opposition against the use of experiments in this study (Grether, Isaac, and Plott 1989, pp. xxii-xiii).

At first, it looked that the GIP results about inefficiency were vindicated. In 1980, the FAA had to intervene when the Washington National scheduling committee was deadlocked for months, as it could not resolve a request by New York Air, a new entrant to the market, for a significant number of slots to launch a competitive Washington-New York service. In the end the FAA took slots from legacy carriers, thereby effectively uprooting any future unanimous agreements in slot scheduling committees.

Given the centrality of airline deregulation in U.S. economic policy at the turn of the 1970s, if the GIP proposal to auction slots were implemented, it would have been a major success for Plott and experimental economics. However in August 1981, during high travel season, the Professional Air Traffic Controllers Organization (PATCO) strike took place. In a defining moment of Reagan's presidency, over eleven thousand air traffic controllers were fired. The FAA contingency plan required temporary reduction of flights and the idea to auction slots was shelved. As the number of airports with slot limits expanded from 4 to 22, airlines had to reduce their flights across the board and a barter process to swap slots was developed. This temporary measure turned into policy by 1986.²² Scheduling committees thus ceased to exist and were replaced by a single organization for all airports involved. According to the new rules, slots were assigned to airlines on the basis of historical precedence, i.e. were grandfathered, with a use-it-or-lose-it rule and allowing

²² For twists and turns, see (Grether, Isaac, and Plott 1989, pp. xii-xiv).

secondary trading.²³ The Congress did not adopt slot auctions, but in the following years, proposals to auction slots appeared regularly, but only in the 2010s did an actual auction take place.²⁴

This was not the first setback for Plott and his applied experimental research proposals. The study on regulation of the dry bulk barge industry on inland waterways for the Department of Transportation was first stopped by the DOT. It appeared in print only in 1981, seven years after it was completed (Hong and Plott 1981, Maas 2012). The agenda control study of the flying club faced substantial publication hurdles and had to be published as two separate papers one in a law journal, the other in economics (Levine and Plott 1977, Plott and Levine 1978). Subsequent applied work in the 1980s such as the anti-trust case against the producers of lead-based antiknock compounds or the regulation of pricing of natural gas transmission were far more successful in changing institutions.²⁵ The latter work showed for instance that that the tâtonnement process proposed for use

²³ For detailed rules see (Kilian 2008, p. 255). For instance the 'use-it-or-lose-it' rule required that the airline used a slot 80% of time.

²⁴ In 2008 the Bush administration proposed auctioning landing slots at all three NYC airport. That proposal was withdrawn in 2009. In late 2011 bidding for slots at New York LaGuardia and Washington National Airport started. The basis for auction proposals was not the format suggested by GIP, but multiple unit or combinatorial auctions for paired take off and landing slots as developed by the experimental economist Stephen Rassenti in his Ph.D. thesis written under supervision of Robert Bulfin, an operations researcher, and another pioneer of experimental economics Vernon Smith (Rassenti, Smith, and Bulfin 1982). Combinatorial auctions have become very popular with wide applications such as FCC spectrum auctions (Plott 1997, Guala 2005).

²⁵ I thank Spencer Banzhaf for highlighting this point.

in the natural gas pipelines would not work and it changed the direction of the proposed regulation (Plott 1988).

Conclusions

The aviation industry changed dramatically in the wake of the Airline Deregulation Act of 1978. My paper looks at a small element of this transformation – the policy according to which take off and landing slots were allocated at congested airports including a proposal to change this policy – an issue that affected millions of passengers annually. Caltech economists and experimentalists David Grether, Mark Isaac and Charles Plott were hired by the Civil Aviation Board to study the existing slot scheduling committees that used unanimity voting rule as well as alternative slot allocation mechanisms. Their study demonstrated to the CAB and airlines that such committees were inefficient and their outcomes were highly dependent on a default allocation rule should a committee fail to reach an agreement. Also GIP were the first to propose a market solution of the slot congestion problem.

The highly unusual aspect of this applied economics research at that time was the usage of economic experiments as a valid source for generating relevant, controlled data. In the course of this paper I tried to show that applied experimental economics research is not just about using experiments in the same way as applied economics research is not just about being empirical in nature. Rather the work GIP depicts the

practice of applied experimental research as a complicated and nuanced endeavor, which combines experimental intervention and design with elements of theory, modeling, non-experimental evidence and observation of the target phenomenon. Precisely this colligation allows the experimenter to move from the naturally occurring phenomenon to its study in a laboratory only to return back with a policy recommendation.

Experiments opened up new venues for economists to offer their expertise. They expanded the boundaries of policy space in economics. And last but not least they demonstrated the practical value of their novel research method – economic experiments. Early experimentalists such as Plott and Smith placed equal emphasis on applied work and theory testing – though this dichotomy does not exhaust all types of experimental economics research. It were the 1970s that marked the beginning of uninterrupted engagement of economists with the experimental method and the GIP work was part of this process allowing experimental economics to take off in the following 1980s (Svorenčík 2015, Svorenčík and Maas 2016, Svorenčík 2016). Applied experimental economics research thus went hand in hand with the emergence and rise of experimental economics.

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