An auction for takeoff and landing slots would make more efficient use of scarce resources.

A Solution to Airport Delays

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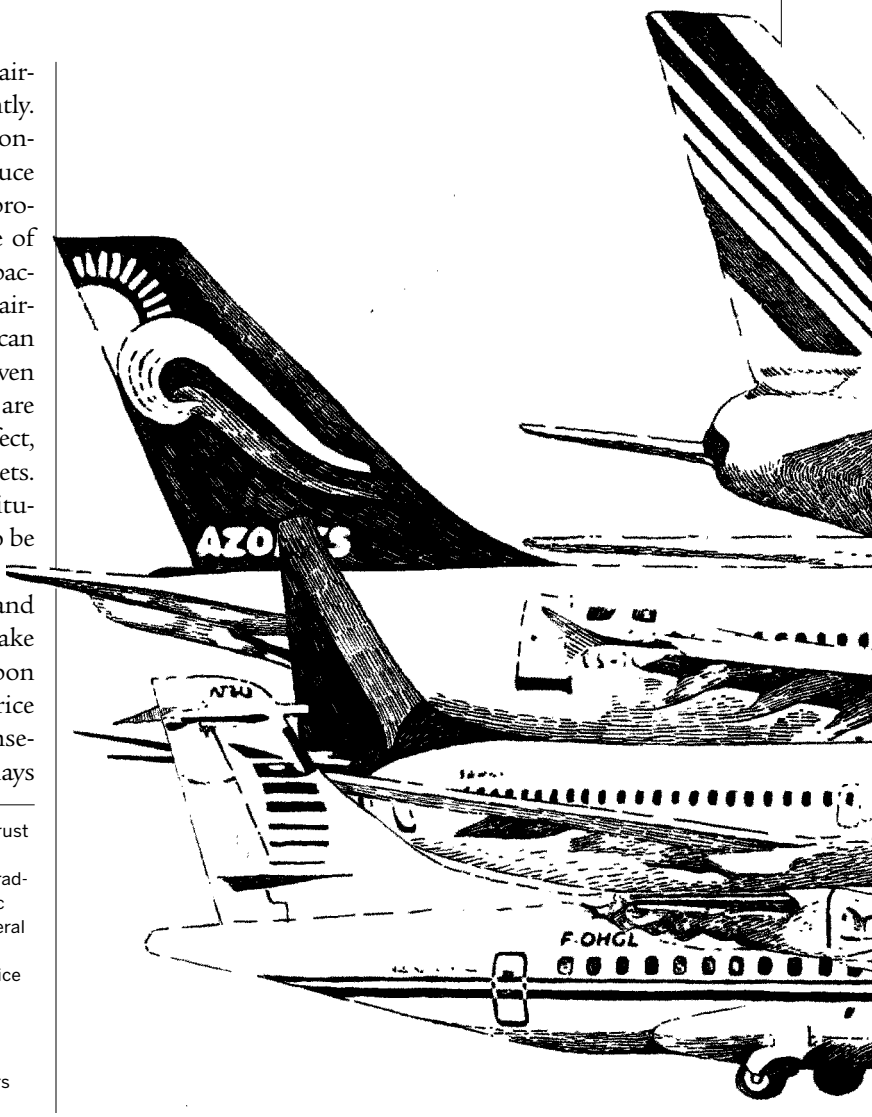
As highlighted in recent news articles, airport delays are increasing significantly. Both the Bush administration and Congress are actively seeking ways to reduce the scope of the problem and better protect the rights of passengers in case of delay. Delays occur because airport capacity (i.e., runways and gates) is a scarce resource and, at key airports, airlines are scheduling more flights than that capacity can support. As a result, more and more flights are delayed, even under normal weather conditions, and considerable costs are imposed on the traveling public. Passengers are paying, in effect, a much higher total price than the dollar price of their tickets.

Solutions for ameliorating an increasingly untenable situation are needed, especially as more airports are forecast to be capacity-constrained in the near future. Airlines' private incentives to schedule flights to serve more destinations and offer passengers more choice in departure times do not take into account the delays that their many flights impose upon other airlines because airlines do not face the proper price incentives to use scarce airport capacity efficiently. Consequently, airlines schedule too many flights, generating delays



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that ripple across the highly integrated airline network and adversely affect all passengers.

To address this problem, one approach, implemented by the Federal Aviation Administration at O'Hare Airport in Chicago and, in late 2007, at John F. Kennedy Airport in New York City, is to get the airlines together and have them collectively hammer out a solution. This, however, requires the airlines to make individually costly compromises on a multitude of scheduling decisions. Each airline in the end agrees to abide by a settlement only if the settlement leaves the airline better off than not agreeing, and the system thereby favors incumbents over entrants. Such collective decisionmaking does not necessarily benefit consumers. Indeed, collective decisionmaking by actual and potential rivals raises serious risks to competition.

Other proposed solutions to the airport delay problem seem to have a common theme: eliminate the problem by expanding the airports and improving the air traffic control systems to, in effect, eliminate the capacity scarcity. For example, current popular proposals include the spending of billions of dollars to add runways and expand other physical capacity (such as gates) at airports to accommodate more concurrent flight operations, and to improve air traffic control systems to allow for more intensive usage of existing capacity (by, e.g., shortening the distance between aircraft in airspace). Those methods of dealing with the problem are, as their price tags indicate, costly, providing a prime illustration of the economic axiom, "There is no such thing as a free lunch." Moreover, plans to expand capacity will not — under even the most optimistic projections — ameliorate the problem of delays in anything but the very long term.

We propose a complementary approach, one that uses basic economic and market principles to help allocate existing scarce assets more efficiently. Only by allocating existing assets efficiently can society squeeze the greatest possible value out of its scarce resources. Moreover, failure to do so may well result in capacity expansion plans whose costs do not justify their benefits. In brief, we advocate a market-based approach to the allocation of scarce takeoff and landing rights at airports where the demand for those rights at a zero price exceeds the ability of the airport to handle that many takeoffs and landings during some time period.

MORE AND MORE DELAYS

The rising number of delays has been reported widely in the popular press and it is easily confirmed by viewing delay statistics collected by the Department of Transportation's Bureau of Transport Statistics (BTS). In July 2007, for example, the BTS reports that 30 percent of the flights in the U.S. domestic market arrived late, up from 20 percent in July 2003. Performance at the most capacity-constrained airports is significantly worse: at JFK, for example, 43 percent of the arrivals were late in July 2007, while at LaGuardia, 40 percent were late.

This rise in delays, not surprisingly, correlates with a significant increase in the number of flights across the United States. Currently, no efficient constraint is imposed on the number of flights that can be scheduled at a given time at an airport where scheduled flights would exceed the maximum number the FAA would allow for safety reasons. In fact, at heavily demanded airports, as explained in more detail below, either no mechanism is being used to ration demand or the rationing mechanism has allocated too many landings and takeoffs.

Some of the recent increase in the number of flights is due to rising demand for air travel. But the vast majority is coming from substitution away from large aircraft in favor of more frequent operations of smaller planes, regional jets in particular.

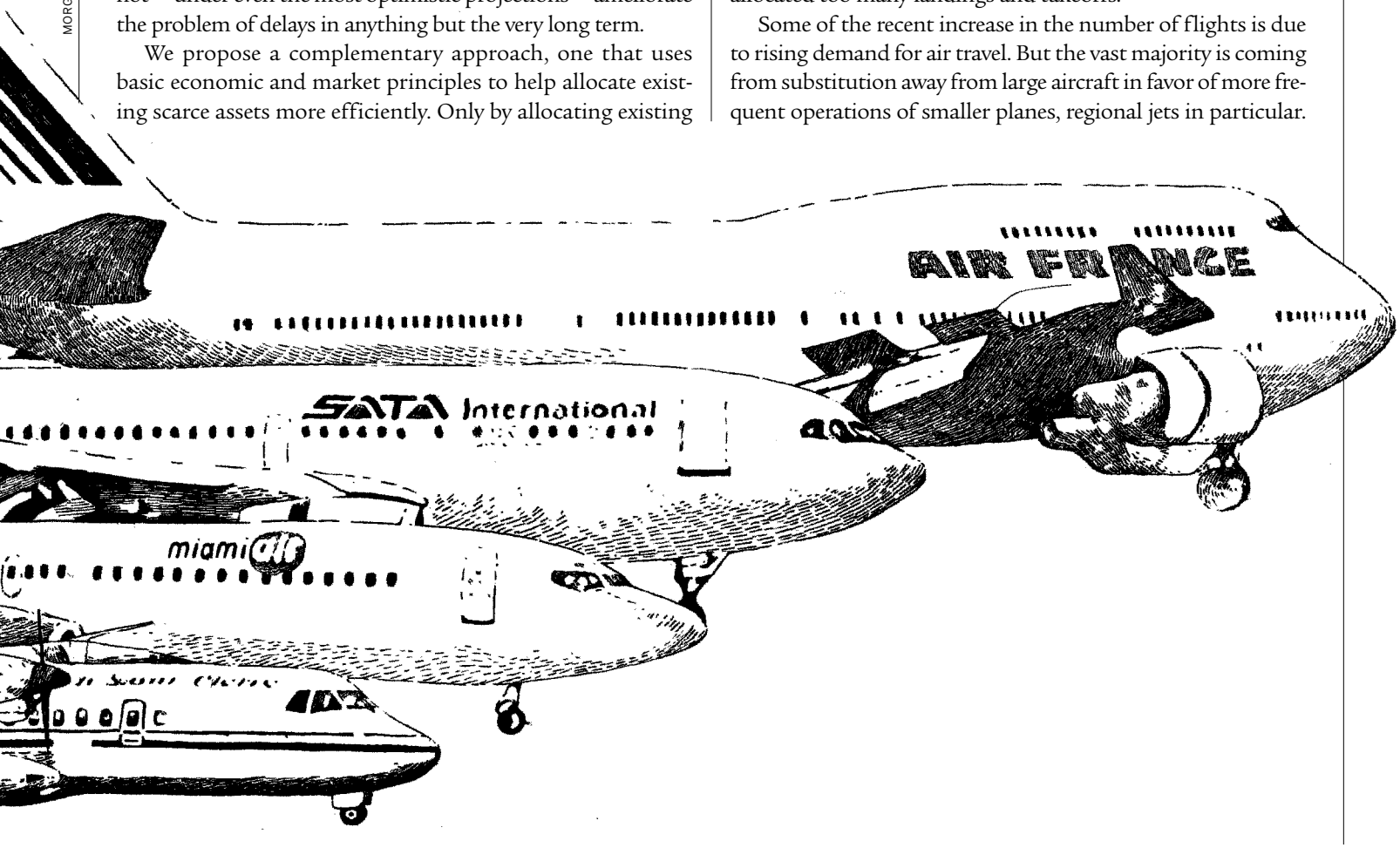

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Figure 1 illustrates this point, showing that the number of departures has skyrocketed by 35 percent in recent years while the total number of seats has risen by less than 6 percent. This implies that the number of seats per aircraft has declined dramatically. At some airports, and especially at those airports reporting the most delays, this effect is quite pronounced. At LaGuardia, for example, the average number of seats per aircraft was 143 in the first quarter of 1998, but that fell to 94 as of the first quarter of 2007. At O'Hare, the average number of seats fell from 124 to 98 over the same period.

The shift to more frequent flights using regional jets can benefit passengers, as it gives them more opportunities to find flights close to their preferred flying time and more options should a flight be cancelled. The airlines have also used bankruptcy proceedings to renegotiate pilot contracts, which had traditionally limited the use of smaller aircraft. The additional, smaller aircraft require the same access to the same scarce airport facilities and air traffic network as do larger aircraft. Hence, as more flights are scheduled into a capacity-constrained air traffic system, delays rise. Problems are exacerbated whenever bad weather occurs, as delays at almost any airport in the United States cause ripple effects throughout the integrated airline network.

UNDERESTIMATES As troubling as the statistics on delay are, they likely understate the extent of the problem. Because the BTS defines a late arrival as one landing 15 minutes past its scheduled arrival time, airlines can reduce reported delays simply by inflating the scheduled time of the flight. And, indeed, evidence shows that airlines have done exactly that.

In Table 1, we list the average scheduled travel time of a common aircraft type in June 1998 and June 2007 for service on routes with the worst on-time performances in the first seven months of 2007. All but one of the routes we investigated saw travel times increase while on-time performance fell. On one of the worst performing routes, O'Hare to Newark, average scheduled travel time on a Boeing 737 aircraft rose by 21 minutes while delayed arrivals rose by 12 percent. While it is hard to estimate the exact extent to which padding the schedules affects reported delays, the direction of the effect is clear: if scheduled travel times had not changed over time, airlines would have reported more delays.

The actual cost of delay consists of the opportunity cost of the time that delayed travelers spend on planes, in airports, and in hotels. To get a glimpse of how large those costs likely are, we use a conservative estimate of the total number of hours "lost" by passengers because of delays, which we derive from Department of Transportation delay and ticket data. We multiply that number by an estimate of the value of an hour of a traveler's time, derived from per capita incomes of the relevant cities. For the first quarter of 2007, we estimated the cost of delays at $239 million. That is equivalent to the cost of one million one-way flights between Reagan National Airport and Seattle. This estimate is conservative and a likely underestimate in that it only counts delay at the destination airport of a passenger's itinerary and it omits the delay costs incurred by connecting passengers who miss their connections at intermediate airports and spend hours (or days) waiting to continue their trip.

Perhaps even more troubling than the current cost of delays is that over the next 20 years the number of airports where demand exceeds capacity is expected to grow. FAA forecasts of demand for airport capacity show that even with all planned airport improvements, a growing number of airports will find demand for departures and arrivals in excess of capacity. While the forecasts show only four airports as being short of capacity in 2007 (LaGuardia, O'Hare, JFK, and Newark), by 2015 between six and 18 airports will have insufficient capacity to meet demand — depending on the completion of planned improvements. The situation worsens by 2025, when between 14 and 27 of the busiest airports in the country are forecast to be short on capacity.

FAILED FIXES

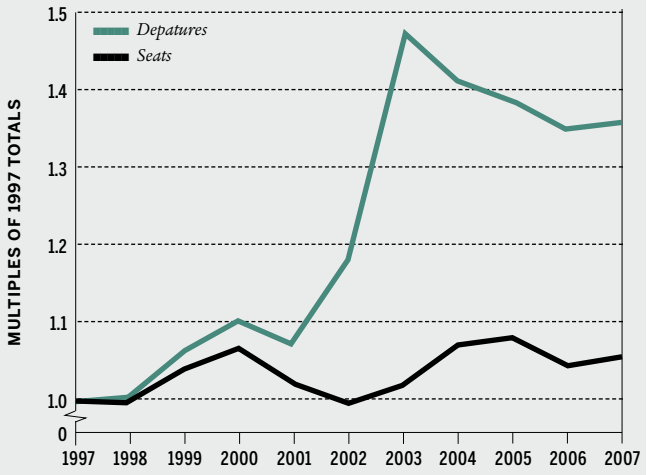
Historically, the FAA has restricted landing and takeoff rights at four major airports: LaGuardia, JFK, O'Hare, and Reagan National. In 2006, those airports accounted for about 64 million arriving passengers and 20 percent of flight departures and arrivals across the United States. The High Density Rule, adopted by the FAA in 1969, imposed slot constraints at the four airports. A slot gave an airline the right to either take-off or land at the airport in a specified time period, and airlines could only access the airport with a slot. The slot allocations were awarded at no charge by the FAA and largely went to incumbent airlines based on their levels of service at the time.

Whether or not the initial allocation of slots in 1969 was efficient, more than 15 years went by before a mechanism was put in place by which airlines could reallocate slots through sale or temporary lease. Then, in 1985, the FAA allowed for the development of a secondary market for sales and leases to promote entry and competition. In theory, a secondary market should have allowed slots to flow to airlines that valued them most highly, thereby resulting in a more efficient allocation of airport

Figure 1

Smaller Planes, Busier Skies

Growth of flights and seats, 1997–2007



SOURCE: *BTS*

capacity. Yet after an initial burst of trading, the FAA found that it was rare for more than a few slots to be available in the secondary market at any given time. While the small number of transactions is not itself proof that the secondary market failed, it is doubtful the result was an optimal use of airport capacity.

In part because of the perceived failures of the secondary market, the FAA in the early 1990s received statutory authority to grant exemptions from the slot rules to new entrant airlines. When additional slots were periodically made available, the FAA would hand them out at its discretion, usually through an application process that predictably fostered intensive and costly lobbying efforts by parties working to convince the FAA to choose them.

A lack of clear property rights could have contributed to the apparent problems with the secondary market. Under FAA regulations, slots are operating authorizations, not property rights, and the FAA retains the right to repossess them at any time. This uncertainty can impose substantial transaction costs because parties to a slot transaction may have to specify a variety of contingencies to the transaction. The uncertainty may also reduce the economic value of a slot (a problem not helped by the thin trading volume). The structure of the slot system may also have led incumbents and potential entrants systematically to value slots differently, preventing what would otherwise be efficient transactions. In particular, because the FAA gives away new slots for free from time to time to airlines with few or no slots, those airlines' valuation of existing slots would include the possibility of getting some from the FAA in the future for free. In fact, in 2000 the FAA gave away for free 24 new slots at Reagan National to airlines with no or few slots at the airport. Similarly, before JetBlue began operations, it was granted 75 slots for free at JFK to facilitate its startup. The same policy that prioritizes new entrants or those with few slots when new slots are made available makes it very unlikely that the FAA will allocate new ones to incumbent airlines. In addition, if the chance of receiving new slots is perceived as being dependent on whether the incumbent has "given up" slots in the past by selling or leasing them, this too would impede the efficient operation of the secondary market. If incumbents are able to acquire additional slots only in the secondary market, their valuations of slots may be higher than those of new entrants.

Table 1

Padding Schedules

Average scheduled travel time (minutes)

Origin – Destination	June 1998	June 2007	Change in travel time	Increase of flights delayed
Detroit–Newark	103	108	5	9%
Charlotte–Newark	112	110	–2	22%
O'Hare–Newark	125	146	21	12%
Detroit–LaGuardia	114	117	3	2%
Denver–LaGuardia	212	222	10	17%
Dallas–Newark	205	227	22	19%
Boston–Philadelphia	80	86	6	17%
Cincinnati–Newark	125	131	6	16%
Raleigh, NC–Newark	95	106	11	20%
Dallas–LaGuardia	200	211	11	20%
Minneapolis – Newark	154	169	15	1%

SOURCES: *OAG and BTS delay statistics*

AIR-21 In 2000, in an attempt to promote entry and competition, Congress passed the Wendell H. Ford Aviation Investment and Reform Act of the 21st Century (AIR-21). AIR-21 relaxed, and ultimately eliminated (at least temporarily), slot constraints at three of the airports: LaGuardia, JFK, and O'Hare. As shown in Table 2, in all three cases airlines quickly responded to the new rules by expanding the number of flights they offered regardless of total airport capacity.

Not surprisingly, delay problems significantly worsened. In 2000, after exemptions to the slot rules were allowed at LaGuardia, the number of scheduled arrivals rose by 34 percent and on-time performance fell by 28 percent. At O'Hare, from February 2002 (shortly before slots were lifted) to February 2004, scheduled arrivals rose 37 percent while on-time performance dropped 16 percent. At JFK, after the slot system expired in 2007, scheduled arrivals rose 58 percent and on-time performance fell 13 percent.

At all three airports, the FAA intervened to ration demand by forcing airlines to reduce their number of flights. At LaGuardia, the FAA chose to freeze entry and roll back service across airlines. At O'Hare and JFK, the FAA organized "conferences" to secure voluntary cutbacks from all airlines operating at the airports. As a result, despite the official expiration of slot controls by Congress, the FAA is again administratively controlling airport access to LaGuardia, JFK, and O'Hare.

A MORE EFFICIENT SOLUTION

In most markets, resources used to produce a good have prices that act as a rationing mechanism. Use of a resource is less profitable to firms as its price rises, all else equal, and when resources are scarce and firms compete for the right to use them, their prices begin to be bid up. Price rises until those valuing the resource the least drop out, and eventually the market clears when the quantity demanded is equal to the quantity supplied. In this way, scarce resources are allocated by the price mechanism to their highest valued uses.

In the airline industry though, the rationing mechanisms, if they exist at all, are executed through scheduling conferences or arbitrary service suspensions. Those measures are unlikely to promote efficient airport usage or competition. Across the nation, airports impose a weight-based fee on landings (there is no fee on takeoffs) to pay for the maintenance and operation of the airfield. To the extent that heavier aircraft impose more costs on the runway and taxiways, a weight-based fee is a sensible means of covering those

costs. It, however, is not a substitute for a mechanism designed to reduce delays.

Market-based methods of allocating scarce airport resources could rely on either a quantity-setting mechanism or a price-setting mechanism. Under a quantity-setting mechanism such as slot auctions, regulators would fix the total amount of output by creating slots while the prices for landings and takeoffs would be determined through a competitive bidding process. Under a price-setting mechanism, such as variable access fees at airports, regulators would set prices for landings and takeoffs that induce the "appropriate" level of output at the airport. While in principle both approaches yield the same outcome, in instances where there is uncertainty in demand or supply, the two mechanisms differ (see Weitzman 1974).

Table 2

Busiest Airports

Number of scheduled arrivals and on-time performance

	Arrivals			On-Time %		
	With Slots	Post-Slots	Change	With Slots	Post-Slots	Change
LaGuardia	10,477	14,063	34%	75%	47%	−28%
O'Hare	25,944	35,597	37%	83%	67%	−16%
JFK	8,037	12,680	58%	78%	65%	−13%

SOURCE: *BTS airline on-time performance data and T-100*

In the airline industry, engineering and technological factors such as airport design and air traffic control requirements largely determine the output an airport can safely support, given weather conditions. Because the FAA must first determine the number of slots that can be used consistent with safety considerations, we propose the use of slot auctions rather than access pricing to allocate them, although either method can in principle be used to ration demand more efficiently than is being done today (For this article, we assume that this determination is clear cut, but it should also be a subject for further study).

MARKET-BASED SYSTEM Our preferred method to allocate scarce airport capacity is to auction slots for landings and takeoffs by time of day and to convey upon their purchasers well-defined property rights. Unlike access pricing, which may require the airport authority to continuously adjust prices, slot auctions require only that the airport authority set at the outset the total number of takeoffs and landings the airport can accommodate in each time period under normal weather conditions. This approach plays to the strengths of airport authorities and the FAA, who have far greater expertise in determining an airport's capacity than they do at setting prices.

The slots should then be auctioned off through a market-based bidding process where each airline decides how much it would be willing to pay for each slot. The prices obtained for slots would reflect the degree of scarcity of capacity. The price could be close to zero at times of the day when capacity is great relative to demand. Price will be highest during periods when demand is at its greatest. Property rights would be awarded to the highest bidders, as long as acquisitions do not anti-competitively enhance market power. Prohibiting airlines from scheduling flights at times when they do not have the right to use one of the auctioned slots would efficiently address the problem of airport delay. Moreover, this market-based auction would allocate the scarce slots to their highest-valued uses.

If controlling the supply of slots over time or having large numbers of slots periodically available for new entrants is important, some percentage of slots could be set to expire periodically at known dates. Upon expiration, ownership of the slots would revert to the FAA (or airport authority) and the slots could, if desired, be re-auctioned. Auctions could be held annually, allowing a certain proportion of the slots, say 10 percent or 20 percent, to go up for auction each year. Analysis would be needed to determine the appropriate duration that a property right to a slot entitles the owner to enjoy.

Slot holders should also be permitted to sell or lease slots in a secondary market. As service patterns and market conditions change, particular airlines may want to move some of their operations at slot-constrained airports to different times, and the right to sell or lease would facilitate those types of efficient adjustments. Having well-defined property rights should encourage the development of a robust secondary market for slots, helping to ensure that slots are allocated to their highest-valued uses. At some airports, to facilitate entry and expansion, property rights to slots may have to come with access rights to other constrained physical facilities such as gates and counter space. Some airports may need to reacquire control of those assets.

NO EXEMPTIONS An important component of our proposal is that general aviation users, such as corporate jets, be required to bid for access rights in competition with all others who wish to use them. Under the current system, a number of slots are reserved for general aviation aircraft. This number varies across airports, but it is at times relatively high compared to the total capacity available. At Reagan National, for example, 20 percent of slots are reserved for general aviation even though very few unscheduled flights can meet the security restrictions imposed when such flights were again permitted after October 2005. At LaGuardia, just over 7 percent of slots are reserved for general aviation.

While such special interest carve-outs greatly benefit some, they impose potentially substantial costs by interfering with the market's ability to allocate the scarce and valuable assets to those who value them most. To the extent that these entities value scarce airport capacity highly, they can demonstrate that by outbidding others for the right to use it. If they are unwilling to do so, the scarce assets should go instead to larger commercial aircraft carrying greater numbers of travelers. If individual general aviation users value slots highly but are unlikely to purchase them because of the unscheduled nature of their service, new businesses might arise and, for example,

purchase slots and lease them out on a temporary basis to high-value general aviation. Such owner-brokers might occasionally lease them also to scheduled airliners that have a temporary need for increased frequencies.

Likewise, there should be no exemptions for foreign carriers. Ideally, foreign carriers should be required to bid and pay for slots on a par with, and under the same terms as, U.S. carriers. Exemptions would be highly inefficient. Indeed, first note that they would have to apply to international flights by not only foreign carriers but also U.S. carriers to avoid putting U.S. airlines at a competitive disadvantage. Then consider that, at some airports, international flight departures account for a large fraction of total flight departures. For instance, in the first six months of 2007 about 30 percent of scheduled passenger flight departures at JFK Airport, and 25 percent of departures at Newark Airport, were to destinations outside of the United States. Exempting those flights from a slots auction would generate not only inefficiencies in the optimal use of scarce capacity at the airports but would also, given the highly integrated nature of airline networks, create inefficiencies across other airports in the system.

However, the FAA and the Department of State seem to have historically interpreted U.S. obligations under international bilateral aviation agreements as exempting foreign carriers from having to pay for congestion-relief measures. We believe the United States should endeavor to close this loophole in allocating our scarce resources. But should special treatment be unfortunately unavoidable, modifications to the slot auctions could be implemented that preserve some efficiency, though they would benefit international carriers. International flights could be grandfathered some historical slots by, for example, issuing those airlines vouchers that could be redeemed for the price of their current slots at the auctions or, otherwise, sold to other airlines. This scheme preserves the ability of international carriers to keep their current slots, but creates incentives for them to do so only if it is efficient (see Evan Kwerel 2004). Should airlines then wish to add international flights, they would have to bid along with everyone else for new slots. Alternatively, slots could be auctioned with a guarantee that international flights would not pay more than they currently do under weight-based landing fees that could then be eliminated or reduced. This could be handled by capping slot prices at the landing fees paid by international flights, or by issuing a voucher (that could be sold) to operators of those flights to pay for the difference between current landing fees and slot prices.

BAD WEATHER The creation of priority rights through slots auctions may be used to further improve the efficiency of our current system. Weather issues at almost any airport in the system frequently force airlines to delay or cancel flights, as the FAA temporarily limits operations to respond to weather conditions. When those conditions arise, not all slot holders will be able to exercise the right conveyed by the slot, and the reduced capacity will have to be rationed. A question then arises as to how to allocate that capacity among slot holders most efficiently.

One approach would be for the property rights of each slot to include a cancellation priority in the event of weather-related cancellations. This could be accomplished by ordering the slots in each time period, each with a different priority. As weather conditions require cancellations, slots would be cancelled in order of their priority. Airlines could thus choose to pay a premium to acquire slots that are less likely to be cancelled, and they would be able to advertise this high priority service to customers who value a lower probability of delay. Such tickets likely would command a premium. Moreover, during the delay period, the secondary market for slots would allow the airlines to transact slots for that day efficiently. In particular, an airline with a valuable departure could "buy up" to a higher priority position, while an airline with a priority slot but a less valuable flight on that day could sell its priority position (though it could obviously not do so if it had sold its flight as a "high priority" one).

It is difficult to justify subsidizing airlines by granting them rights to use valuable public assets whose sale could generate considerable revenue.

REVENUE Significantly as well, under our proposal the slot auctions would generate revenues for the FAA and airport authorities. Indeed, it is difficult to justify subsidizing airlines by granting them, for free, rights to use valuable public assets whose sale at auction could generate considerable revenue.

The revenue should first be used to replace weight-based landing fees and passenger facility charges at the airports. Should there be excess revenues, those revenues could be set aside in an account under the control of the Department of Transportation, with the funds to be allocated for capacity expansion projects that pass a cost/benefit test. The Transportation Department could use the slots prices as a measure of the value of adding additional capacity at an airport or in a metropolitan area. Rising slot prices are a sign of increasing scarcity and the Transportation Department could use the prices as an input into cost/benefit analysis for when, where, and whether costly capacity-enhancing investments are worth the benefits they would provide.

Another possible use for the revenues generated by slot auc-

tions would be to help fund expansion projects designed to improve capacity utilization of air space, such as the NextGen satellite navigation system the FAA is constructing. Lastly, to the extent that the revenues still exceed the funds needed for investment in capacity (including airport expansion and improvements in air traffic controls), the excess revenues could be returned to air travelers through a subsidy on fares during non-congested times, though this option would create some distortions. Alternatively, the excess revenues could be transferred to the federal government to be used for other projects or to replace distortionary taxes, though this solution may be politically complicated to implement efficiently. Such a lump-sum transfer would not introduce distortions in the efficient allocation of slots.

Auctioning the use of scarce public resources is hardly a novel concept. It has been used with success by other regulatory agencies, such as the Federal Communication Commission and the U.S. Forest Service. In fact, taken as whole, our proposal would not only help achieve efficient usage of airport resources and reduce delays, but it would also provide signals and generate revenues for efficient capacity expansion.

CONCLUSION

With the clamor rising over airport delays, it is time to implement an effective, market-based solution that promotes efficient usage of airport capacity and reduces delays. In this article, we have proposed implementing a market-based auction system with well-defined property rights to slots for airport capacity. Our proposal would ensure that airlines effectively take into account airports' scarce resources when scheduling their flights, thereby reducing delays. The proposal would also help ensure that these public resources are allocated to their highest-valued uses. This approach strives to balance administrative costs with economic efficiency, as it facilitates efficient flight schedule adjustments and entry at capacity-constrained airports. Lastly, and importantly, the revenues generated by this approach could be utilized to fund capacity expansions when the benefits of the expansions outweigh the costs, as might be indicated, for instance, by the prices airlines bid for airport slots.

While slot auctions, clearly defined property rights, secondary markets, capacity additions, and an end to special interest carve-outs can go a long way toward enhancing the efficiency of our air traffic system, they alone would not prevent airlines with an already large share of rights at particular airports from enhancing or maintaining their market power by, for example, purchasing too many of these scarce rights. Here, antitrust authorities would need to remain watchful; not to prevent large carriers from growing efficiently, but to ensure that anti-competitive acquisitions in these markets would be prevented.

Lastly, the proposal developed in this article should further be applied to the allocation of operating authorizations for international service to countries with which the United States does not have an Open Skies Treaty. Those authorizations, which come up on occasion, are currently awarded at the discretion of the FAA, again for free. As a result, during the regulatory proceedings to award the authorizations, airlines spend significant sums of money lobbying the FAA intensely to secure the highly valued rights, as evidenced by the recent proceeding for authorizations to China. Here as well, a simple market-based auction should be used to not only determine which airline has the highest valued use for the authorization, but also to ensure that the FAA, and not lobbyists, collects the revenues from the allocation process.

The use of market-based solutions to problems of airport capacity allocation and airport delays is long overdue. Implementation of proposals along the lines of those laid out in this article would contribute greatly to achieving this objective.

A fuller discussion of many issues raised in this paper and of the references cited at the end of this paper can be found in the Economic Analysis Group Discussion Paper Series EAG 07-14, "Proposal for a Market-Based Solution to Airport Delays." R

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