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MARKETABLE LANDING RIGHTS AND ECONOMIC EFFICIENCY

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by

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I. Introduction

For the past 15 years, the Federal Aviation Administration (FAA) has regulated operating rights (slots) at some of the busiest U.S. airports. 1/ In broad outline, this regulation has three main goals: 1) restricting the number of slots during certain hours of the day, 2) allocating slots to the individual airlines, and 3) preventing the carriers receiving slots from selling them to other airlines (except during a brief "experiment"). This general form of regulation began on a relatively small scale in the late 1960's, but expanded greatly in response to the 1981 Professional Air Traffic Controllers (PATCO) strike. 2/

In this paper we focus on the second and third goals of FAA slot regulation during the time period immediately following the PATCO strike. Taking as given the FAA's reduction in the number of slots at peak hours (to match the decrease in air traffic control capacity caused by the strike), we estimate the added losses to consumers because the FAA allocated slots administratively, and did not allow carriers to buy and sell slots. These extra welfare losses take two main forms: 1) a loss due to a misallocation of flights because airlines could not freely substitute high-valued flights for low-valued flights (the misallocation loss) and 2) a loss due to the creation of a barrier to entry allowing incumbent carriers to raise fares above average costs (the entry barrier loss). Our results suggest that a slot market would cause airlines to lower fares and to match actual flights more closely to consumers' preferences. We estimate that the gains to consumers at the time of greatest slot scarcity would have amounted to millions of dollars per year.

Although a slot market was permitted by the FAA during a six-week period in 1982, useful data for our purposes were not generated. The short-lived market was hampered by uncertainty as to the duration of the rights and by the need for FAA approval for all sales. In addition, no price data were collected by the FAA. Because little information on how a freely functioning slot market would operate was provided by the experiment, we develop and use an indirect method of estimating the benefits of a slot market.

This study is divided into seven sections. In the next section, we derive a demand schedule for landing slots from demand and cost functions for air travel. We then estimate our slot demand function from estimates of airline demand and cost functions. Our data are for flights into St. Louis in July, 1981 (i.e. before the PATCO strike). 3/

In section three, we use our estimated slot demand schedule and the FAA's slot supply schedule to estimate the equilibrium price of slots for each constrained hour of the day at St. Louis for the period shortly after the PATCO strike. We also estimate the dollar volume of transactions, on a daily basis, in a market for St. Louis slots. Thus, our estimates are based on the period of greatest slot scarcity, rather than the current slot supply and demand situation.

In the fourth section, we examine how market characteristics such as population, flight frequency and distance affect the demand for slots. Using our sample of St. Louis flights, we address the often expressed contention that flights in dense markets would be able to outbid flights in thin markets if slot sales were allowed.

In section five we examine the misallocation loss resulting from the prohibition of slot sales. Using our estimated demand for slots at St. Louis, we obtain the value of the slots eliminated by the FAA after the PATCO strike from the value of the flights actually cancelled when the FAA allocated the remaining slots administratively to carriers. We then obtain the value of the flights that we predict would have been dropped if slots had been freely transferable. The difference between these two values provides an estimate of the misallocation loss.

In the sixth section we attempt to quantify the deadweight loss that results because the absence of a slot market increases the cost of entry into air transportation markets. Using different assumptions as to the ability of incumbent carriers to elevate fares in city-pair markets involving St. Louis, we obtain different estimates of the entry barrier loss to consumers.

In the final section, we summarize our findings and draw conclusions for air transportation policy.

II. A Derivation of the Demand for Slots

To derive the demand for slots, we adopt the simplifying assumption of strong passenger time preferences, which implies that each air transportation market is defined by a city-pair and a time of the day. In other words, the market between points A and B at time t is separate from that between A and B at time t+1. We further assume that each market can be a pure monopoly, if (perhaps due to regulatory barriers) it contains only one flight, and entry cannot occur. At the opposite extreme, such a market can be perfectly contestable, if (even with only a single flight) there are no entry barriers, and a potential entrant stands ready to offer another flight at the same time, between the same two cities, should the incumbent raise the fare above cost.

Under these assumptions, an airline's willingness to pay for a slot depends solely on the revenues from the flight that would use the slot and on the other costs of operating that flight. We can therefore derive a slot demand function from the underlying flight demand and cost functions. After specifying those functions, we use them to derive the willingness to pay for a flight that is free from the threat of entry. Expressing this willingness to pay as a function of exogenous variables (e.g. income and distance), we then show that it is equal to the willingness to pay for a flight that faces the threat of instantaneous entry. In other words, airline willingness to pay for a slot is the same whether the flight that would use the slot is in a monopoly market or a contestable market.

Airline Demand

The first step in estimating airline willingness to pay for a slot is specifying flight demand and cost functions. Unfortunately, the lack of adequate flight specific data prevents the estimation of a flight demand function. There is, however, an extensive literature on city-pair demand functions under regulation (e.g. Abrahams (1981), DeVaney (1974), Ippolito (1981), Olson and Trapani (1981 and 1982), and Verleger (1972)). 4/ For our purposes, Ippolito's demand function is most suitable.

5/ It is written as follows:

(1) $Q = A \exp(bF^2)\ N^{g1}\ L^{g2}$

where: Q = number of passengers in the market
$A = \exp(a0)\ D^{a1}\ X^{a2}\ Y^{a3}\ \exp(a4\ Z)$
F = the fare
N = the number of flights in the market
L = the market load factor
D = market distance
X = the product of the populations of the two cities
Y = the simple average of the per capita populations of the two cities
Z = a vector of dummy variables (see Table 1)
g1, g2, a0, a1, a2, a3, and a4 are constants.

To convert this city-pair market demand function into a flight demand function, we assume that passengers are highly sensitive to arrival time, i.e. that they fly on the most convenient flight available, regardless of fare differences between flights. 6/ This assumption gives each flight a constant fraction of the potential passengers between the two cities 7/ and allows us to express the flight demand curve as follows:

(2) $q = s\ Q = a \exp(bF^2)\ N^{g1}L^{g2}$

where: q = number of passengers on the flight
s = the flight's share of city-pair demand 8/
$a = s\ A$.
and all other variables are defined as in equation (1).

Table 1 presents Ippolito's estimates of the coefficients of the city-pair market demand function, equation (1).

Table 1.

Coefficient Estimates for the Demand for Air Travel in a City-Pair Market ‡

Variable	Coefficient	t-value
constant (a0)	-26.04	3.14
N (g1) *	.75	3.03
L (g2) *	-.854	1.68
F^2 (b)	-.000105	2.56
D (a1)	.733	2.35
X (a2)	.336	2.71
Y (a3)	2.35	5.05
dummy variables (a4):		
0-100 miles	-2.09	4.17
100-200 miles	-.258	.99
Las Vegas	1.94	6.22
Florida	.258	.80
California	.334	1.36

‡ Two modifications were made before these estimates were used with the values of the exogenous variables in order to estimate 1981 daily flight demand. First, a is multiplied by 10 and divided by 365 to adjust for Ippolito's use of a ten per cent sample of annual passenger traffic; next, b is deflated by $(1.62)^2$ and Y is deflated b 1.62 in order to account for the 62 percent increase in prices from 1976 (the period on which the estimates were based and 1981 (the period for which the slot demand is estimated).

* Since Ippolito assumed that flight frequency, N, and load factor, L, are endogenous, he used fitted values of these variables and estimated the demand equation by two-stage least squares.

Source: Ippolito (1981, p. 13)

Airline Costs

In choosing a specification for a flight cost function, the question of economies of scale arises. Prior studies of airline costs (e.g. Douglas and Miller (1974), Eads, Nerlove and Raduchel (1969), Pulsifer *et al.* (1975), and White (1979)) found no economies of scale with respect to airline size. However, we know of no studies of economies of scale at the city-pair level. 9/ Thus we do not know to what extent dense markets are served at a lower average cost than thin markets.

Bailey and Panzar (1981) suggest economies of scale in aircraft size as an argument to support economies of scale at the city-pair level. 10/ Thus, if larger aircraft are used in dense markets and costs per passenger are lower for larger aircraft, dense markets may have lower costs. Comparisons of costs per seat-mile of different sizes of aircraft reveal lower costs for larger planes (e.g. Douglas and Miller (1974, p. 11)). While these cost comparisons exaggerate the cost advantage of larger aircraft by ignoring other factors that affect costs, 11/ the advantage clearly exists. 12/ The real issue, however, is not whether economies of scale with respect to aircraft size (and hence city-pair market size) exist, but whether they are important in the relevant range.

Such economies appear not to be important in our sample, because all the aircraft used are relatively large (more than 76 seats), and most are similar in size. 13/ Accordingly, we assume that long run cost 14/ is independent of density in the relevant range. This simplifies our analysis by allowing us to treat average cost as exogenous. We note the effect of this assumption when our results are sensitive to it.

While we assume that long run average cost is (locally) independent of traffic, we allow cost to vary with distance. We estimate the relationship between these two variables by regressing average per-passenger cost, c, against the natural logarithm of distance, lnD, for our sample of the 59 city-pair markets involving St. Louis. 15/

Average per-passenger cost was computed for each city-pair market as follows. The average seat-mile cost for each flight in the sample was multiplied by the distance of the market to give the average seat cost for the flight. 16/ The average seat cost for each city pair was then computed as the weighted average of the average seat costs for the flights in the city-pair, with each flight's share of seats as the weight. 17/ Average seat cost was translated into average passenger cost by assuming a load factor of 60 and by doubling to reflect the assumption that flight-specific costs are one half of total costs. 18/

The estimated average passenger cost function is

$$(3)\quad c = 22.633(\ln D)$$

standard error of estimate = 2.2885
$R^2 = .87$

Willingness to Pay Absent the Threat of Entry

Our assumption that passengers are highly sensitive to arrival time implies that each flight has a constant share, s, of the city-pair demand. Facing a flight demand curve as in equation (2), and assuming that entry is impossible (say because of CAB-type restrictions), the airline providing the flight would earn profits from it equal to

(4) $\pi = (F - c)\ q.$

Absent the threat of entry, the airline would set the fare at the level that maximizes profit function (4). This level is found by differentiating (4) with respect to the decision variable of each flight, fare, which gives the first order condition of profit maximization as

$$(5)\quad F(F - c) = -\frac{1}{2b}\ .$$

Solving this quadratic equation for its positive root, the profit maximizing fare is

$$(6)\quad F' = \frac{c + (c^2 - 2/b)^{1/2}}{2}\ .$$

Equation (6) is substituted into the flight demand function, equation (2), in order to find the profit maximizing quantity, q', for each flight. The profit maximizing fare and quantity are substituted into equation (4) to find the profit that each flight would earn, absent the threat of entry, π'. Since the right to land is essential to conducting a flight, an airline would be willing to pay up to the flight's profits for a slot. Thus, the profit function gives the willingness to pay for each flight as a function of the exogenous variables that determine the flight's actual profit, 19/

(7) $\pi' = (F' - c)\ q'.$

<u>Willingness to Pay with the Threat of Instantaneous Entry</u>

The assumption that airlines can charge monopoly fares in the long run is generally unrealistic. Since deregulation, barriers to entry are minimal, and pricing at the monopoly level will in most instances encourage entry and rapidly eliminate profits. Most markets are closer to the opposite end of the pricing spectrum, the perfectly contestable market in which entry is free and exit is costless. 20/ In this section we demonstrate that the maximum price a flight would be willing to pay for a slot is the same when the flight is in a perfectly contestable market as it is when entry barriers are insurmountable and monopoly fares are charged.

If slots were marketable, an airline offering a flight in a perfectly contestable market could not raise its fare above the average cost of providing air service, including the price of the slot used by the flight, even if there were only one flight in the market. 21/ If a fare higher than average cost were charged, another airline could buy a slot and offer a flight between the same two cities, at the same time, charging a lower fare and still earning a profit. Because of the lower fare, passengers would fly on the new entrant rather than on the incumbent carrier. Because such entry could occur instantaneously, the mere threat of it would limit each flight's fare level to that which just covers costs.

While each flight in a contestable market would earn zero profits if slots were marketable, the airline providing the flight might still be willing to pay for a slot. The price that the airline would be willing to pay for the slot is determined by the fare that its passengers would be willing to pay for the flight. The airline's willingness to pay would be the difference between the flight's revenues and costs, excluding the price of the slot, when the fare is set so as to maximize this difference. This fare level is given by the tangency of the average cost function (including the slot price, P) and the demand function. 22/ At this point of tangency, fare equals average cost,

$$(8)\quad F = \frac{P}{q} + c = AC,$$

and the partial derivative of the inverse demand function with respect to quantity equals the partial derivative of average costs with respect to quantity

$$(9)\quad \frac{\partial F}{\partial q} = \frac{1}{2bFq} = -\frac{P}{q^2} = \frac{\partial AC}{\partial q}.$$

Solving equation (8) for q and substituting the result into equation (9) yields equation (5). Hence, the monopoly fare is equal to the fare that an airline would charge for a flight in a contestable market, if the carrier paid the maximum slot price that is consistent with zero profits. At that fare, the flight would have the same number of passengers as it would if it were in a monopoly market. Since, at the point of tangency, the contestable-market flight has the same fare, F', and the same quantity, q', as the monopoly-market flight, equation (8) can be solved to obtain

$$(10)\quad P = (F' - c)\, q',$$

which is identical to the monopoly willingness to pay as shown in equation (7). 23/ In sum, regardless of which of the two extreme assumptions is used--absolute barriers to entry or no barriers to entry--an airline's maximum willingness to pay for a slot can be expressed as the same function of variables and coefficients from the flight demand and cost functions.

Results

Using Ippolito's estimated demand function (see equation (1) and Table (1)), our estimated cost function (see equation (3)), and our derived willingness-to-pay expression (see either equation (7) or equation (10)), we estimated airline willingness to pay for a slot as a function of the city-pair characteristics of the flight to be provided. For our sample of flights to St. Louis, the mean values of these characteristics are presented in Table 2. 24/ Assuming no threat of entry, we estimate that the average profit maximizing fare (F') in the sample would be $202, and, at that fare, the average flight would have 22 passengers. We also estimate that the airline providing the average flight would be willing to pay $1,275 per day for a slot.

Table 2.

Means of City-Pair Market Characteristics
for Flights into St. Louis

Variable	Mean Value	
Flight Frequency (N)	8	
Load Factor (L)	54	
Distance (D)	561	
Population (X) *	2,318,886	
Per Capita Income (Y) #	7,847	
Dummy Variables:		
0-100 miles		.107
100-200 miles		.053
Las Vegas		.014
Florida		.047
California		.047

* This figure is the population of the origin city. The figure used in the estimation is the product of the origin city population and the population of the St. Louis SMSA, which is 2,356,460.

\# This figure is the per capita income of the origin city. The figure used in the estimation is the simple average of the origin city and St. Louis, which has a per capita income of $7,517.

Of course these are not necessarily the equilibrium values of fare, quantity of passengers, and slot price. If there is any threat of entry (which there surely is for airline markets), fares will be much closer to costs (including both operating costs, c, and the per passenger scarcity value of slots, P/q), and consequently flights will have more passengers and lower profits. For a flight in a perfectly contestable market, the fare would equal average cost including the scarcity value of slots, although (as we have shown) airline willingness to pay for slots would be the same as in the monopoly case. In addition, the equilibrium slot price would not be $1,275, which is the estimated willingness to pay of the average flight in our sample.

III. The Equilibrium Price of a Slot

The actual slot price during each hour of the day will depend on the demand for slots and the supply of slots during that hour. The demand for slots at St. Louis, during any hour of the day, can be obtained by ranking airlines' willingness to pay for each flight in descending order. The supply of slots during each hour is determined by the FAA. Given those two functions, the price will lie between the value of the lowest-valued flight that buys a slot and the value of the highest-valued flight that does not buy a slot.

Estimated slot prices for restricted hours at St. Louis are presented in Table 3. Each estimate is the value of the most valuable flight that would have been dropped at the indicated hour, if a slot market had been allowed. This value is a lower bound of the market price for slots (on a daily basis). As can be seen in Table 3, estimated restricted-hour slot prices range from

$389 per day, for the 12 noon hour, to $1,621 per day, for the 5 pm. hour. Because slot availability for hours not shown exceeds slot demand, the equilibrium price is zero.

Using our St. Louis slot price estimates, the dollar volume of transactions in the slot market can also be estimated on a daily basis. Multiplying the slot price during each hour by the number of slots bought during that hour, we find that the total volume would be $89,304 per day. Since, under our contestablility assumption, there is an average of 6,978 passengers during restricted hours at St. Louis, these payments for slots would represent an average of $13 per peak period passenger. This does not, of course, mean that slot marketing would raise the average fare by $13. Fares reflect slot scarcity whether or not slots are marketable.

Table 3.

Estimated Equilibrium Slot Prices
for Restricted Hours at St. Louis
(in dollars per day)

Time (CDT)	Slot Price
8:00 am.	412
11:00 am.	918
12:00 noon	389
1:00 pm.	854
3:00 pm.	997
5:00 pm.	1,621
6:00 pm.	816

IV. City-Pair Market Characteristics and Slot Demand

In this section, we examine the effects of city-pair market characteristics on airline willingness to pay for slots. Using market characteristic data and our slot demand function, we draw inferences concerning the types of city-pair markets that are most likely to obtain slots in a market. Air transportation policy makers have asserted that, if slot marketing were permitted, flights in dense city-pair markets (i.e. markets with many passengers) would outbid flights in thin markets (i.e. markets with few passengers). 25/ This allegation is difficult to analyze rigorously because many factors determine market density. To sort out some of these factors, we examine separately the effects of four individual market characteristics that influence market density--population (X), per capita income (Y), flight frequency (N), and distance (D)--under the assumption that all other characteristics are constant.

Population and Per Capita Income

The effect of the population (per capita income) of the origin city (recall that St. Louis is the destination city) is examined by differentiating the willingness to pay function, equation (7), by population (per capita income)

$$(11) \quad \frac{\partial \pi'}{\partial X} = (F' - c) \frac{\partial q'}{\partial X} .$$

Since demand is increasing with population (and with per capita income), a larger (or richer) city would indeed be willing to pay more for its marginal slot than would a smaller (or poorer) city, all else being equal. 26/

Flight Frequency

Larger cities usually have more flights than smaller cities. In fact, flight frequency is an endogenous variable for a city-pair market and is therefore determined by, *inter alia*, city size. By holding frequency constant when we examine the effect of city size on willingness to pay, we ignore the fact that larger cities have more flights and thus the marginal flight in a city-pair market with a large city is not the same as the marginal flight in a market with a smaller city. We now consider that effect. To see how flight frequency affects willingness to pay, assuming all else is constant, we differentiate equation (7) by the number of flights in the city-pair market to find

$$(12) \quad \frac{\partial \pi'}{\partial N} = (F' - c)\,\frac{\partial q'}{\partial N} .$$

Since the demand for each flight decreases with the total number of flights in the city-pair market, 27/ the presence of more flights implies that the marginal flight has a lower willingness to pay for a slot than the marginal flight in a city-pair market that has few flights. This is a fairly intuitive result since the value of the marginal flight in terms of improved service quality is smaller for a city-pair market that already has numerous flights and hence a high level of service quality. 28/

Distance

The effect of distance on slot demand is somewhat more complicated than the effect of population, income, or flight frequency. The derivative of (7) with respect to distance is

$$(13)\quad \frac{\partial \pi'}{\partial D} = \left(\frac{\partial F'}{\partial c} - 1\right)\frac{\partial c}{\partial D}\, q' + (F'-c)\left(\frac{\partial q'}{\partial F'}\,\frac{\partial F'}{\partial c}\,\frac{\partial c}{\partial D} + \frac{\partial q'}{\partial D}\right) .$$

The first term of equation (13) represents the change in profits caused by the change in per passenger profits (fare minus costs) due to the cost increase resulting from an increase in distance. The second term represents the change in profits that results from a change in the number of passengers due both to the change in fare and the change in distance.

Since a monopolist cannot pass on all of an increase in variable costs to consumers, the first term is negative. This is true, *a fortiori* when we consider that a monopolist's ability to pass on any increase in variable costs depends inversely on the (absolute value of) the elasticity of demand which itself increases with distance. 29/ For our sample of flights into St. Louis, the first term has an average value of -$0.21. The sign of the second term depends on whether the change in passengers in response to the change in distance 30/ is matched by the change in passengers in response to the change in fare induced by the change in distance. On average for the sample there are 0.03 more passengers for each mile increase in distance, while there are 0.01 fewer passengers owing to the fare increase resulting from that increase in distance. The second term is therefore $1.28, indicating that the entire expression is positive. Thus, while, *a priori*, the effect of distance on willingness to pay is ambiguous, our parameter estimates indicate that, on average, willingness to pay for slots increases with distance at a rate of just over a dollar per mile.

Results

The assertion that dense markets would outbid sparse markets is only partially supported by the empirical evidence. If density is taken to mean the number of passengers in the city-pair market, it is a function of, *inter alia*, city size, distance and the number of flights (which in turn is a function of city size). While willingness to pay is higher, *ceteris paribus*, for larger cities and longer city-pair markets, it is lower for markets with more flights.

There are two other factors that affect willingness to pay which are not incorporated in the above analysis. First, if there are long run economies of scale in aircraft size, markets with larger aircraft would exhibit a higher willingness to pay for slots. Second, one component of fixed costs is the slot fee that is paid to land at the origin airport. Hence a higher slot fee at the origin city implies a lower willingness to pay for a slot fee at the destination airport. These two factors tend to have opposite effects: flights in dense markets generally use larger aircraft but, under a market, they would probably pay higher slot fees at the origin airport.

V. The Misallocation Loss

In general, slot allocation by the FAA is not optimal, if only because the agency lacks the needed information on changing flight demand and cost schedules. However, the resulting misallocation would be corrected by a slot market. If an airline that received a slot were not in the best position to use it, a slot market would allow the sale of the slot to the carrier that could use it most efficiently. Such a sale would benefit both the buyer and seller of the slot and is therefore welfare enhancing. Such benefits are lost because a slot market is prohibited. 31/

We can estimate this misallocation loss by comparing our estimates of the actual loss that occurred when slots become scarce at St. Louis in 1981 to our estimates of the loss that would have occurred if a slot market had been allowed. The third and fourth columns of Table 4 show, respectively, the July number of flights and the post-PATCO strike reduction in slots, for each restricted hour. 32/

Table 4.

The Welfare Loss Arising from Slot Misallocation
(in dollars per day)

Time CDT	Airline	Initial Slots	Reduction in Slots	Loss w/o Mkt	Loss w/ Mkt	Missallocation Loss
8 am	TW	15	7	2,495		
	OZ	18	8	814		
	RC	1	0			
	DL	1	0			
	AA	4	2	602		
	EA	1	0			
	total	40	17	3,911	3,511	400
11 am	TW	14	5	4,213		
	OZ	1	0			
	DL	1	0			
	AL	1	0			
	TI	1	0			
	EA	1	0			
	total	19	5	4,213	2,722	1,491
12 noon	TW	3	0			
	OZ	7	1	313		
	RC	1	0			
	DL	1	0			
	EA	2	1	973		
	total	14	2	1,286	703	583
1 pm	TW	11	4	3,923		
	RC	1	0			
	NW	1	0			
	AA	5	3	3,750		
	OZ	15	7	2,495		
	total	33	14	10,168	7,158	3,010
3 pm	TW	14	8	7,672		
	OZ	10	7	2,325		
	DL	2	1	462		
	EA	1	0			
	RC	1	0			
	total	28	16	10,459	8,959	1,500

Table 4 (continued)

5 pm	TW	19	12	18,000		
	NW	1	0			
	DL	3	2	1,823		
	OZ	3	2	1,257		
	AA	6	4	3,959		
	EA	1	0			
	TI	1	0			
	total	34	20	25,039	20,120	4,914
6 pm	TW	10	5	4,942		
	RC	2	1	599		
	FL	1	0			
	EA	1	0			
	AL	2	1	144		
	DL	1	0			
	OZ	6	2	426		
	total	23	9	6,111	3,733	2,378
city total				61,187	46,906	14,281

Airlines:

AA - American
AL - U.S. Air
DL - Delta
EA - Eastern
FL - Frontier
NW - Northwest Orient
OZ - Ozark
RC - Republic
TI - Texas International
TW - Trans World

The fifth column in Table 4 is the estimated loss that each airline (and its passengers) suffered from reducing the number of its flights as required by the FAA, in the absence of a slot market. To construct these estimates, we assume that each airline dropped its least profitable flights (those with the lowest value to consumers) during each restricted hour, as predicted by equation (7). 33/ The total loss for all airlines serving St. Louis (and their passengers) is the value of all cancelled flights. As can be seen at the bottom of column five, our estimate of the total loss without a slot market is $61,187 per day.

The loss that would have occurred if a slot market had been allowed is the value, during each restricted hour, of the same number of lowest valued flights predicted by equation (7), but without regard to airline. These estimates, which are presented in the sixth column of Table 4, total $46,906 per day for all restricted hours at St. Louis. The difference between the totals of columns 5 and 6 is the misallocation loss caused by the FAA ban on slot sales. As seen in the seventh column, the estimated misallocation loss is $14,281 per day.

Relaxing two of our assumptions would likely have significant effects on these results. First, if passengers are less sensitive to arrival time than is assumed here, both the actual and hypothetical losses arising from the slot restrictions will be lower, since many passengers would shift from peak to off-peak flights and would incur only the losses associated with the less convenient arrival time. If passengers are completely indifferent to arrival time and all passengers could be accommodated at some time of the day, there would be no loss at all. 34/ Second, we have ignored international flights, commuter flights and cargo flights. The estimated welfare loss from prohibiting slot sales would be even greater if these flights were included in our sample. These flights comprise approximately 18 percent of the total flights to St. Louis. If the excluded flights had an average willingness to pay for slots that was the same as that of the flights in our sample, the misallocation loss would be about 18 percent higher than our estimate. If, on average, the willingness to pay of these omitted flights differs from the willingness to pay of the flights in our sample, the gains from sales will be more than 18 percent greater than our estimates, since the average difference between the value of a slot to the selling airline and its value to the buying airline would be greater. 35/

VI. The Entry Barrier Loss

In a city-pair market where one or both airports are slot constrained, incumbent airlines face a reduced threat of entry to the extent that other airlines incur added costs to obtain the slot needed to enter. If there were a market for slots, any airline could obtain slots at the market price. Because carriers can only obtain slots through barter, entry will require incurring extra transaction costs to obtain the marginal slot at the constrained airport, or paying a higher price for an inframarginal slot. To the extent that incumbents can maintain fares above the level that would cover average cost (including the cost of obtaining the marginal slot), the prohibition of a slot market results in a welfare loss. This entry barrier loss is in addition to any loss arising from a misallocation of slots.

The ability of incumbents to maintain fares above average costs depends both on concentration and on barriers to entry. In highly concentrated markets where actual competition is weak, the threat of entry tends to restrain incumbent sellers' pricing behavior. 36/ Where entry barriers are low, concentrated markets may have prices that are little higher than those in unconcentrated markets. By contrast where there are high entry barriers, prices should rise in concentrated markets relative to those in less concentrated markets. Thus, in addition to their familiar effect on the price level, entry barriers should strengthen the relationship between concentration and price, because absent potential competition, the ability to raise fares is more dependent on the intensity of actual competition. Some recent research provides evidence that is consistent with this conclusion and with the notion that a slot market ban creates a barrier to entry into city-pair markets.

Graham and Kaplan (1982) examined the relationship between airline fares and market structure. 37/ Included in their model are measures of the following structural variables: distance; the volume of passenger traffic; 38/ the Herfindahl concentration index (to measure actual competition); the product of the per capita incomes in the city-pair; and dummy variables for tourist markets (those involving Florida, Hawaii, Las Vegas, and Reno), markets served by newly certificated airlines, and the three cities that were slot-constrained before the PATCO strike (New

York, Washington, and Chicago). The results of estimating the model are presented in Table 5. 39/

The coefficients of the Herfindahl index are of particular interest; they are positive and significant at the 95 percent level for all five quarters. Of additional interest is the small magnitude of these coefficients for the samples covering the third quarter of 1980 through the second quarter of 1981. If the air transportation markets in the samples were perfectly contestable, concentration would have no effect on fares, because the threat of potential competition would always keep them at the level of costs. 40/ The small but significant coefficients during the pre-strike period indicate that, while the markets are not perfectly contestable, an increase in concentration leads to only a small increase in fare. By contrast, the results for the second quarter of 1982, after the PATCO strike, show a coefficient for the Herfindahl index that is 1.8 to 2.5 times higher than for the pre-PATCO samples.

Table 5

Estimated Relationships Between Market Structure Characteristics and Fares

Independent Variables	3rd quarter 1980	4th quarter 1980	1st quarter 1981	2nd quarter 1981	2nd quarter 1982
intercept	8.189	8.050	7.407	8.041	8.733
ln distance	-.481	-.463	-.436	-.483	-.498
	(.003)	(.003)	(.003)	(.003)	(.004)
ln passengers (fitted)	-.017	-.012	-.003	-.021	-.011
	(.003)	(.003)	(.004)	(.003)	(.005)
ln Herfindahl	.080	.078	.109	.086	.198
	(.010)	(.009)	(.010)	(.008)	(.012)
newly certificated	-.251	-.212	-.205	-.212	-.276
	(.010)	(.010)	(.010)	(.010)	(.012)
tourist	-.095	-.073	-.112	-.096	-.060
	(.006)	(.005)	(.005)	(.005)	(.007)
ln per capita income	.021	.012	.060	.053	
	(.009)	(.009)	(.009)	(.008)	
New York	.055	.046	.046	.062	.020
	(.013)	(.014)	(.014)	(.013)	(.018)
Chicago	.008	.021	.021	.040	.038
	(.011)	(.011)	(.011)	(.020)	(.015)
Washington	.063	.030	.030	.041	.042
	(.014)	(.013)	(.013)	(.018)	(.017)
R2	.889	.870	.842	.868	.897

Standard errors are in parentheses. The standard errors for 2nd quarter 1982 are biased upwards very slightly due to the use of two-stage least squares.

ln = logarithm

Sources: Graham and Kaplan (1982) and special model run for 2nd quarter 1982 by Kaplan and Osmolskis.

From the post-strike increase in the strength of the concentration-price relationship, we can draw inferences about the entry barrier created by a slot-market ban. The second quarter 1981 (pre-strike) Herfindahl coefficient implies that a city-pair market with a single airline would have fares 8.6 percent higher than a market with four equal-sized carriers. By contrast in the same quarter in 1982 (after the strike), the single airline market would have fares 19.8 percent higher than the market with four carriers. This increase is consistent with the hypothesis that the FAA's slot-market ban creates an entry barrier which reduced the contestability of airline markets after the PATCO strike and increased incumbent carriers' ability to exert monopoly power over fares.

The potential welfare loss arising from creating entry barriers in city-pair markets can be obtained by comparing the monopolist's long run price, as given by equation (6), and the price that would be charged in a perfectly contestable market, which equals average cost including the slot scarcity value (see equation (8)). The linear approximation of this dead-weight welfare loss, W, is 41/

$$(14) \quad W = \frac{1}{2} (F' - c) \, [q(c) - q(F')].$$

We estimated this loss for each of the restricted-hour St. Louis flights that we predict would have continued after the PATCO strike if there were no initial misallocation of slots (i.e., if the FAA allocation were the market allocation). With no slot misallocation, the scarcity value of each slot would be its market price (see Table 3). In the second column of Table 6, we present, for each of the seven restricted hours, the welfare loss that would result from insurmountable entry barriers. The total estimated welfare loss for all restricted-hour flights to St. Louis is $84,468 per day.

Of course, even absent a slot market, city-pair markets serving slot-constrained airports are not free from actual and potential competition, nor would they necessarily be perfectly contestable with a slot market. In fact, if we relax our assumption that passengers are highly sensitive to arrival time, an important source of actual competition for restricted-period flights is flights during unrestricted hours. Hence the figures in the second column of Table 6 represent the upper bound of the welfare loss that occurs when entry barriers are created. If the prohibition of a slot market imposes moderate, but not insurmountable, entry barriers, the welfare loss would be less. For example, if barriers to entry were high enough to enable incumbent airlines to maintain fares that are 10 percent above costs (or the monopoly price if that is less), the linear approximation of the entry barrier loss would be given by the figures in the third column of Table 6, yielding a total (for all restricted hours) welfare loss of $11,844 per day. 42/

Table 6.

The Potential Welfare Loss Arising from Entry Barriers
(in dollars per day)

Time CDT	Welfare Loss due to Insurmountable Entry Barriers	Welfare Loss due to Moderate Entry Barriers
8 am.	6,468	749
11 am.	10,799	1,452
12 noon	3,524	409
1 pm.	17,810	2,624
3 pm.	16,380	2.181
5 pm.	10,338	2,069
6 pm.	19,144	2,386
Total	84,486	11,844

VII. Summary and Conclusions

In this paper we derive and estimate an airline demand schedule for slots and use it to evaluate some benefits that would accrue to consumers if the FAA permitted a slot market. These benefits result because of the superiority of a market system to a system of initial allocation by the FAA and restrictions on the subsequent sale of slots among carriers. The benefits take two forms: substitution of high-valued flights for low-valued flights and elimination of a barrier to entry into city-pair markets. For a sample of flights to St. Louis, we estimate that these benefits would amount to thousands of dollars per day, or millions of dollars per year.

We also estimate the equilibrium prices of slots during restricted hours of the day at St. Louis. Such prices would provide two important signals: they would encourage airlines to shift flights to less congested hours, and they would indicate which airports and which times of the day suffer from the greatest scarcity--thereby aiding the FAA in allocating resources to the expansion of the air traffic control system.

Finally, our finding that airline willingness to pay for slots increases with distance has an implication for FAA restrictions on the stage length of flights at certain airports. For example, it implies that the FAA's policy of restricting the use of Washington National airport to non-stop flights of less than 1000 miles (previously 650 miles) and Orange County's John Wayne airport's policy of restricting operations to non-stop flights of less than 500 miles results in an inefficient use of the airspace at those airports.

FOOTNOTES

* The authors are, respectively, Foreign Service Officer, Department of State, and Deputy Assistant Director for Regulatory Analysis, Federal Trade Commission. The views expressed in this paper are their own and do not necessarily represent the views of the Department of State, the Federal Trade Commission, nor any individual Commissioner. While the paper has been improved by comments from several colleagues, including Keith Anderson, Doug Davis, John Hilke, Pauline Ippolito, and Mark Plummer, any remaining errors are solely the authors'.

1/ A slot is a right to use the navigable airspace for an airline operation--a take-off or a landing--at a given airport during a given hour of the day. In this paper, we focus solely on landing slots.

2/ In 1969 the FAA promulgated the High Density Airport Rule, in response to increasing airspace congestion (14 CFR 61.1). This regulation imposed limits on the take-offs and landings per hour at four airports: Kennedy, LaGuardia, National, and O'Hare. Operations that did not involve these four airports were not restricted.

In 1981, in response to the PATCO strike, the agency established reduced schedules for 22 airports, including the four that had been constrained under the High Density Rule (46 FR 44424, 9/4/81). The number of landings per hour was reduced by a percentage chosen by the FAA, which varied across airports and by time of day. While off-peak hours appear to have been largely unaffected, reductions for busier hours ranged up to 67 percent of prestrike schedules.

3/ For the purposes of our study, St. Louis has two important characteristics. First, it had not been restricted before the PATCO strike. Thus, unlike New York, Washington and Chicago, pre-strike air travel to St. Louis was not affected by the FAA's High Density Airport Rule. Second, St. Louis has relatively little international travel. Since data on international travel are not as complete as those available for domestic travel, we felt it best to minimize the effect of international travel on slot demand.

4/ Ideally, we would estimate the flight demand function (or at least the city-pair demand function) for our sample of flights into St. Louis in July, 1981. Unfortunately, we are unable to do so because, since airline deregulation, we are unable to observe the fares that passengers actually pay. The use of the coach fare or some measure of average fares is appropriate when passengers on each flight pay the same fare or when the fraction of each type of fare is the same on each flight. Since this is no longer the case, we are unable to estimate the demand due to inadequate fare data. We know of no estimates of demand functions using data for the post-deregulation period.

5/ Among the features of Ippolito's specification that we believe are important for obtaining good estimates of a demand function are: (1) the possibility for fare elasticity to vary with distance (the relationship between fare elasticity and distance is discussed in Section IV); (2) the inclusion of load factor and flight frequency as quality of service variables; and, the use of two-stage-least-squares to account for the endogeneity of these variables.

6/ This extreme assumption, although useful, is obviously not realistic. To the extent that passengers are indifferent to arrival time, airline willingness to pay for slots during peak periods is reduced.

7/ Our analysis could be made without assuming highly time sensitive passengers. Under the Loschian model of spatial competion, firms assume that their market shares are fixed. This assumption implies that firms match other firms price changes (i.e. the conjectural variation is one). Thus, instead of assuming time sensitivity in order to hold market shares constant, we could assume constant market shares and explain the assumption based on Loschian price behavior. For a comparison of various assumptions concerning market shares in spatial models, see Capozza and Van Order (1978).

8/ Since the diurnal distribution of passenger demand is not necessarily equal to the distribution of flights, the market shares of flights in a city-pair are not necessarily equal. One possibility for obtaining the flight demand function from the city-pair demand function is to let delta equal each flight's share of passengers in the market. However, we observe that some of the peak in demand is reflected in the form of higher fares for peak period flights. Thus, demand for peak period flights is higher than would be indicated by passenger shares. Since the higher demand would affect the flight's willingness to pay for slots, we take account of it for empirical purposes by letting delta equal each flight's share of market revenues--as opposed to market passengers. Revenue shares are based on each flight's total passengers and the coach fare (or night coach fare when appropriate).

9/ The major problems inherent in estimating city-pair economies of scale are the lack of city-pair specific cost data and the endogeneity of density and service quality.

10/ They note, however, that passenger preference for frequent service is a countervailing force that mitigates the relationship between economies of scale with respect to aircraft size and economies of scale with respect to city-pair market size.

11/ The most important reason why seat mile cost comparisons overstate economies of scale is that larger aircraft are generally used on longer routes. Since costs per mile decrease with distance (see below), part of the apparent economies of scale is due to the longer average stage length of larger aircraft. In addition, CAB regulations resulted in the use of jet aircraft in markets for which they were not really suited. Deregulation and rising fuel prices (which increased the relative efficiency of turboprop aircraft for short-haul markets) have resulted in the replacement of jet aircraft with more appropriate turboprop aircraft in many markets. For a thorough discussion of this shift, see Meyer et al. (1982).

12/ If there were no advantage to larger aircraft, airline passengers could be served individually with frequent, convenient service and airline markets could be, absent barriers to entry, competitive and not merely contestable.

13/ Aircraft in our sample range from the 76 seat BAC-1-11-200 to the 272 seat Lockheed L-1011 with 268 of the 309 planes in the sample being either B-727s, B-737s or DC-9s. Interestingly, the two flights by a certificated carrier in the thinnest market in our sample (Cape Girardeau, Mo.) used DC-9s as did 16 of the 21 flights in the densest market (Chicago). Of course, the smaller aircraft operated by commuter airlines may suffer a cost disadvantage although this disadvantage is presumably small since the commuters appear to be able to compete with the larger aircraft used by certificated carrers.

14/ By long run we mean the period in which airlines can alter both their schedules and aircraft fleets in response to changes in market conditions.

15/ The specification of costs as a function of the logarithm of distance is used to allow costs per mile to decline with distance. Such a concave cost function with respect to distance was implicit in the regulated fares that had fare per mile declining with distance. The economic evidence (e.g. Douglas and Miller (1974), Bailey and Panzar (1981), and Meyer, Oster, Morgan, Berman and Strassmann (1982)) indicates that costs actually declined at a faster rate than the regulated fares.

16/ The seat-mile costs are airline and aircraft specific as given in Civil Aeronautics Board (1982).

Of course the cost per mile of operating each aircraft is not constant with distance so that the marginal cost per mile is not everywhere equal to the average cost per mile. However, we are assuming that each airline operates its various types of aircraft at roughly the distance where costs per mile are at a minimum for each type of aircraft. This is a reasonable assumption for the long run. At this point, average costs per mile approximate marginal costs per mile.

17/ Olson and Trapani (1981 and 1982) calculate seat-mile costs for city-pair markets in a similar manner.

18/ The assumption that flight costs are one-half of total costs is arbitrary but not unreasonable. Graham and Kaplan (1982) estimated that, for the year ending in June, 1981, flight specific costs were slightly less than 60 percent of total costs for trunk carriers and about 55 percent for three former intrastate carriers. However, they included all cabin crew costs as flight specific while we believe that there is a variable component to such costs.

19/ We view the number of flights as being endogenously determined in the city-pair market, but exogenous to the pricing decision of each airline for each of its flights.

20/ For a detailed examination of contestable markets, see Baumol, Panzar and Willig (1982).

21/ This conclusion must be modified if there is no slot market. In that case, the fare on a flight in a perfectly contestable market could exceed costs by the scarcity value of a slot--by the scarcity rents being earned in its current use by the slot that would be used to establish a competing flight--without attracting entry.

22/ Note that in the Chamberlinian model of monopolistic competition, this tangency is the long run equilibrium. In that case, airlines would be unable to pay any more than the equilibrium scarcity value of the slot. However, Baumol, Panzar and Willig (1982, pp. 329-332) demonstrate that the tangency is not necessarily the equilibrium in a contestable market. The equilibrium may be an intersection of the demand and average cost curves to the right of the tangency. Thus, airlines may be willing to pay more than the equilibrium scarcity value of the slot.

23/ The result that the willingness to pay is independent of whether entry barriers are insurmountable or zero does not depend on the demand and cost functions assumed here. General specifications of demand and cost functions yield the same result although the willingness to pay for slots cannot be derived as an explicit function of exogenous variables for all demand and cost functions.

24/ Instead of using the actual load factor, we use a load factor of 60 percent to be consistent with our cost function estimates.

25/ Most notably, former Secretary of Transportation Drew Lewis has expressed this concern (see Koran and Ogur (1983), p. 27).

26/ The partial derivative of per capita income can be shown by substituting Y for X in equation (11). Recall from Table 1 that the coefficients of both population and per capita income were positive and statistically significant at the 99 percent level.

27/ An increase in the number of flights leads to an increase in the number of passengers. However, as long as the percentage increase in passengers is less than the percentage increase in flights the number of passengers per flight declines. DeVaney (1975) found that for markets with three or more airlines the number of passengers per flight would increase with more flights while it would decrease with more flights in markets with one or two airlines. More recent studies of monopoly markets by Olson and Trapani (1981) and Ippolito (1981) found evidence consistent with the notion of fewer passengers per flight in markets with more flights. Since we are concerned with the monopoly portion of the demand curve (recall that the willingness to pay is determined by either assuming monopoly pricing behavior or that the slot price is at the level where the monopoly price is charged by an airline in a contestable market) and since regulated fares were set at or above the profit maximizing level (see Olson and Trapani (1981)) the evidence supports the notion of decreasing passengers per flight with more flights.

28 By service quality we mean schedule convenience which depends on flight frequency. For a discussion of the components of schedule convenience and its determinants, see Douglas and Miller (1974, ch. 6).

29/ Verleger (1972), DeVaney (1974), Abrahams (1980) and Ippolito (1981) all found that the price elasticity of demand increases with distance. The intuitive reason for this is that the full price of travel includes both the fare and time. Since the fraction of the full price attributable to the fare rises with distance, the effect of a percentage change in fare on the full price increases with distance and hence so does the fare elasticity.

30/ Two factors influence the relationship between demand and distance: the total travel between two cities declines with distance because more distant cities have fewer ties, but the proportion of the travel that is by air increases with distance since the time advantage of air travel increases relative to its price disadvantage.

31/ The current FAA rules that permit trading of slots allow some of the loss associated with a misallocation of slots to be eliminated.

32/ The calculations are based on each airline reducing its hourly arrivals according to FAA requirements (48 FR 44426). There was an eighth hour of the day that was restricted. However the 12 percent restriction for 7:00 a.m. flights does not affect any of the carriers according to the FAA's rules since no carrier had more than three flights and reductions could be rounded to the nearest whole number.

33/ If the airlines had not been free to choose which flights to cancel, this loss would have been even greater.

34/ The fact that reductions were needed during only seven hours of the day indicates that the problem was not necessarily one of inadequate daily air traffic control capacity. Rather, the problem was primarily one of providing air traffic control during the peak hours of the day. Of the 309 flights in the sample, 191 of them were scheduled during the seven busiest hours. Even with the reduction, the St. Louis airport handled between 12 and 23 arrivals per hour by the carriers in our sample during the restricted periods.

35/ Since commuter airlines were net sellers of slots during the six week period in 1982 when slots could be sold, we believe that there is a difference in willingness to pay between the various types of airlines.

36/ See F.M. Scherer (1980, p. 266) and Baumol, Panzar and Willig (1982, p. 222).

37/ Fares are measured by the logarithm of operating revenue per passenger mile.

38/ Since traffic is endogenous, they used a two-stage least squares technique of regressing traffic against the exogenous variables in the model and then using the fitted value of traffic in the yield equation.

39/ The results for 3rd quarter 1980 through 2nd quarter 1981 are from Appendix L of Graham and Kaplan (1982). The results for 2nd quarter 1982 were provided by Dan Kaplan and Tadas Osmolskis, at our request.

40/ One explanation why some airline markets are not perfectly contestable, absent slot restrictions, is that until recently the different treatment of local service carriers and trunks prevented competition between the two in short-distance markets. See Bailey and Panzar (1981).

41/ Since the demand curve, equation (2), is ordinary as opposed to compensated, this expression actually represents either the equivalent or compensating variation, depending on the direction of the price change. However, Willig (1976) found that the change in consumer's surplus is between, and very close to, the equivalent and compensating variations when the change is small relative to income.

42/ Our implicit assumption that barriers to entry might occur only for flights during restricted hours probably understates the consumer's surplus change estimates. Flights that arrive in St. Louis during restricted periods may also be able to elevate fares above costs if the flight landed at the origin city during a restricted period for the origin airport. In other words, if restrictions exist for either end of a city-pair market, entry may be made more difficult.

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