Sequential Entry and Strategic Deterrence in the Airline Industry

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Abstract
I extend the literature on entry in oligopoly markets (Bresnahan and Reiss [1990, 1991], Berry [1992], Mazzeo [2002], and Ciliberto and Tamer [2005]) by determining endogenously whether firms play a simultaneous or sequential-move game and whether firms deter new entrants. Moreover, when playing a sequential game, firms are allowed to make "deterrence investments" to prevent new entry (Bernheim [1984]). Using evidence from the US airline industry between 1996 and 2000, I find in preliminary results that incumbents do not systematically deter new entrants in the airline industry.

Keywords: Entry, Deterrence, Airline Industry, Repeated Game.
JEL Classification: L12, L13

1 Introduction

I investigate the effect of firm strategic heterogeneity on market structure when firms play repeatedly with each other. Previous empirical research assumes that firms compete symmetrically with each other, but theories of entry show that incumbents can accommodate some entrants but use predatory tactics with others.¹ In particular, I investigate whether major airline carriers (e.g. American) strategically deter new entry of low cost carriers (e.g. Vanguard). Addressing this question has direct policy implications because where entry is not artificially impeded, competition ensures

¹For example, see Bernheim [1984] or Dixit [1980].
that prices are in the long run reflective of the full cost of efficiently providing airlines services.

To allow firms to deter new entrants, the type of game that airlines play is determined endogenously. In particular, if there are no incumbents or if there is more than one incumbent in the market, then the airlines play a simultaneous-move game. If there is only one incumbent in the market then the airlines play a sequential-move game. A critical difference between a sequential and a simultaneous-move game is that in a sequential game firms can take actions to precommit themselves to aggressive behavior towards their competitors. In particular, firms can make “deterrence investments”, which include all investment that raise barriers to entry, and for which incumbents must incur some investment costs (Bernheim [1984]).

The first contribution of this paper is to extend the literature on entry in oligopoly markets (Bresnahan and Reiss [1990, 1991], Berry [1992], Mazzeo [2002], and Ciliberto and Tamer [2005]) by determining endogenously whether firms play a simultaneous or sequential-move game and whether firms deter new entrants. Bresnahan and Reiss [1990] and Berry [1992] considered a sequential and a simultaneous-move game as alternatives to describe the interaction between car dealers and airlines. However, since they used a cross-section of data, Bresnahan and Reiss and Berry exogenously determined whether firms were playing a simultaneous or sequential-move game. Here, the selection of the type of game played is endogenous.

The second contribution of this paper is to propose a way to determine whether incumbents strategically deter new entrants. To identify deterrence investments, I use changes over time in firms’ entry decisions. The idea is to compare entry decisions across similar markets whose market structures change differently over time. In particular, if there are two markets that have identical observable and unobservable characteristics, and in one there is only one incumbent over time, while in the other

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2 As will be shown in the analysis of the data, the only reasonable empirical hypothesis is that deterrence only occurs when there is only one incumbent in a market.

3 For example, the monopolist can build excess production capacity as a threat against new entrants. As Bernheim explains, the definition of deterrence investment is intentionally ambiguous to abstract from the complex issues that arise with particular theories of entry deterrence, and it includes any barrier that an incumbent raises to prevent entry, and for which the incumbent must pay some investment costs. There are several theories of strategic investment, for example Bulow, Geanakoplos, and Klemperer [1985], Fudenberg and Tirole [1984], Dixit [1980], Schmalensee [1981, 1978], Gelman and Salop [1983], Fudenberg and Tirole [1983], Judd [1985].
there periods with two firms, then it must be the case that the incumbent in the first market can deter new entrants. Using this simple idea, I can estimate the costs that incumbents must face to make “deterrence investments,” and determine if there are some airlines that systematically prevent new entry.

To allow for the type of game played by airlines to be determined endogenously, I use the methodology developed by Ciliberto and Tamer [2005]. This methodology allows multiple equilibria in the number and identity of firms when firms play a simultaneous-move entry game. Multiple equilibria in the number and identity of firms can also exist in a sequential-move game with more than two players since all firms except the incumbent play a simultaneous-move subgame. The methodology developed by Ciliberto and Tamer allows to make inferences on a “class of models” rather than looking for assumptions that pin down a unique model. The estimation strategy is thus directed at a class of models that obey the fundamental equilibrium condition that if a firm enters into a market then it expects to make nonnegative profits. This fundamental condition provides a set of inequality restrictions on regressions that restrict the parameters to a set. Thus, the object of interest is in general a set of parameters of the profit functions that correspond to models with different consistent equilibrium selection rules.

I use panel data from the US airline industry between 1996 and 2000 and investigate competition between major airlines (e.g. American) and low cost carriers (e.g. Vanguard), with a special focus on their interaction in markets to and from the major airlines’ hubs (e.g. Dallas Fort Worth). To identify the ability of the major firms to deter low cost carriers to enter into profitable markets from other barriers to entry that low cost carriers face, I collected original data on institutional restrictions that low cost carriers face at several airports in the largest metropolitan statistical areas in the United States.

2 The Entry Game Played by the Airlines

The game played by the airlines is here assumed to be a static game that is repeatedly played over time, with time being denoted by \( t = 1, \ldots, T \). Airlines are assumed to know each other strategies and payoffs, thus this is a complete information game.
Airlines must decide whether or not to enter into a market. There are \( I \) airlines, indexed by \( i = 1, \ldots, I \), that must decide whether to enter into market \( m = 1, \ldots, M \) at time \( t = 1, \ldots, T \). Let \( y_{imt} = 1 \) if the firm \( i \) enters in market \( m \) at time \( t \) and \( y_{imt} = 0 \) otherwise. Let \( \pi_{imt}(y_{mt}) \) denote the profit made by firm \( i \) in market \( m \) at time \( t \). Finally, let \( y_{mt} = (y_{1mt}, \ldots, y_{Imt}) \) denote the vector of firms’ strategies.

I consider two types of games, a one-shot game and a sequential-move game. In a simultaneous-move game firms choose their actions without observing the other firms’ actions. In a sequential-move game, at least one firm choose her action before the other firms choose theirs, and all other firms can observe the first mover’s choice. Thus, in a sequential-move game the followers’ actions are conditional on the first mover’s actions.

I consider the subgame-perfect Nash equilibrium concept to solve the game that airlines play. A subgame-perfect Nash equilibrium is a combination of firm’s strategies \( y^*_{mt} = (y^*_{1mt}, \ldots, y^*_{Imt}) \) such that no firm can unilaterally benefit from choosing a different strategy at any stage of the game. In an entry game at a Nash equilibrium \( y^*_{mt} = (y^*_{1mt}, \ldots, y^*_{Imt}) \) every firm that enters must make a nonnegative profit, while firms that do not enter expect to make a negative profit should they decide to enter:

\[
\pi_{imt}(y^*_{mt}) \geq 0 \iff y^*_{imt} = 1.
\]

At each period, the entry game is either a simultaneous entry game or a sequential entry game. Airlines play a simultaneous-move game in market \( m \) if at time \( t \) there is no incumbent in the market, that is if the market was not served by any airline at time \( t - 1 \). Airlines play a sequential-move entry game at time \( t \) in market \( m \) if one airline was present at time \( t - 1 \) in the market.

Whether airlines play a simultaneous or sequential-move game is determined endogenously. To see why, consider Table 1, which presents several possible scenarios with three airlines (American, Delta, United) in one particular market. In the first quarter of 1998 none of the three airlines was serving this particular market. Therefore, in the second quarter of 1998, there was no incumbent, and thus the three airlines played a simultaneous-move game. Among the possible equilibria, the airlines ended up in the one where American entered into the market, while Delta and United did
not enter. In the third quarter of 1998, American is now the incumbent and moves first. Delta and United follow. The interpretation of the game in the other quarters is analogous.

[TABLE 1 APPROXIMATELY HERE]

Consider now the game played in the second quarter of 1998 by the three firms. American is the incumbent and thus American must decide whether or not to enter before Delta and United take their decisions. Figure 1 shows two games, one where American cannot deter new entrants (the upper game), and one where American can make "deterrence investments" to prevent new entry in the market (the lower game).

[FIGURE 1 APPROXIMATELY HERE]

Consider first the game where American cannot deter new entry, which is Figure 1a. American can decide whether to enter or not, and then Delta and United play a simultaneous move against each other after observing American’s decision. To determine the one-shot equilibrium of the game, the game is solved through backward induction. First we determine the Nash pure strategy equilibria in the last stage of the game, the one played by Delta and United, for any given entry decision made by American. Then, we determine the optimal choice of American. For the equilibrium to be subgame perfect, American will enter if in any of the equilibria in the last stage of the game American makes nonnegative profits.

Consider, for example, the situation where there are two equilibria in the simultaneous-move game, which is the game that the three firms would be playing if American did not have a first-mover advantage. Let the first equilibrium be \((y_{AA}, y_{DL}, y_{UA}) = (0, 1, 1)\): American does not enter, while both Delta and United enter into the market. Let the second equilibrium of the last stage game be \((y_{AA}, y_{DL}, y_{UA}) = (1, 0, 1)\): American enters, Delta does not enter, United enters. In the sequential game where American moves first, there will be a unique equilibrium, \((y_{AA}, y_{DL}, y_{UA}) = (1, 0, 1)\).

Generally, the fact that American moves first does not imply that there exists a subgame perfect equilibrium where American is in the market. However, this is where the role of deterrence comes to play. Following Bernehim [1984], I will assume
that an incumbent can opt to deter new entrants when the game is sequential. An incumbent firm $i$ can make deterrence investments by paying a deterrence cost $c_i$ at time $t$ and ensure that it will be a monopolist at time $t+1$.

To understand the role of the deterrence investments, consider again the example of the strategic interaction between American, Delta, and United illustrated in Table 1. Figure 1b presents the game with deterrence. In the third quarter of 1998, American must decide first whether to deter new entrants. If American pays a deterrence cost $c_{AA}$, then American can deter new entrants and make the monopoly profit $\pi_{AA}^M$ minus the deterrence cost. If American does not pay the deterrence cost, then the airlines play the sequential game illustrated in Figure 1a.

American will deter new entrant if the cost of deterrence is lower than the monopoly profit and if the profit that American makes under deterrence, $\pi_{AA}^M - c_{AA}$, is not smaller than the lowest profit that American would make in any of the subgame perfect equilibria of the sequential game played by airlines should American not deter new entrants (the game in Figure 1a). Therefore, American will not always deter new entrants even when she can do so.

Whether airlines play a simultaneous-move game, a sequential-move game, or a sequential-move game with deterrence is determined endogenously in this framework. The objective of this paper is to show that we can use repeated observations over time across markets to identify whether firms are able to deter new entrants.

### 3 Identification of Strategic Deterrence

There are several reasons why we only observe one firm for a long period of time in a market that are completely unrelated to strategic deterrence. First, there might only be space for one firm in the market, in the sense that two firms would not be able to make nonnegative profits. Second, there might be multiple equilibria with different number of firms in a market, and we might simply observe the equilibrium with one firm rather than one with two or more firms.

The fundamental question is then how to identify from the revealed actions of the airlines whether in the data there is one firm because the incumbent deters new entry or because of other reasons unrelated to strategic deterrence.
The first two columns of Table 2 illustrate how to identify strategic deterrence. There are two firms that compete against each other in one market, and for simplicity of exposition I consider American and Delta as the two competing firms. At time 0 neither firm is present in the market, because neither firm makes nonnegative profits. Then at time 1 there is a positive shock and either one but not both of the two firms can enter into the market. American enters. At time 2 there is another positive shock and both American and Delta can enter into the market. However, we observe only American in the market. At time 3 there is a negative shock and American must exit the market. At time 4 there is a positive shock and either one but not both of the two firms can enter into the market. This time Delta enters. At time 5 there is another positive shock and both American and Delta enter into the market.

The first two columns of Table 2 show that American was able to prevent the entry of Delta when American was the incumbent, while Delta was not able to prevent the entry of American when Delta was the incumbent.

[Table 2 approximately here]

The type of evidence provided in Table 2 implies that American must face lower deterrence costs than Delta and that American did deter Delta from entry at time $t=2$. The last column of Table 2 shows how the identification strategy discussed in the first two columns of Table 2 can be used to identify the cost that airlines must incur to deter new entrants. Since American deterred Delta from entry at time $t=2$, then it must be that $\pi^M_{AA} - c_{AA} > \pi^D_{AA}$, that is the profits that American makes in this market when it deters Delta are higher than the profits that it would make as a duopolist. On the contrary, $\pi^M_{DL} - c_{DL} > \pi^D_{DL}$, the profits that Delta would make as a monopolist in this market are not large enough to justify the deterrence costs.

The variation across and within markets identifies $\pi^M_{AA}$, $\pi^D_{AA}$, $\pi^M_{DL}$, $\pi^D_{DL}$, $c_{AA}$, and $c_{DL}$. In a static model it is possible to identify only $\pi^M_i$ and $\pi^D_i$ from the variation across markets in the number (and identity) of firms. Clearly it is possible to identify deterrence only in a repeated static game because of the variation in the number and identity of firms over time across and within identical markets.

The critical feature of this stylized model is that the incumbent faces a trade-off. The incumbent can deter new entrants, but only at a cost $c_i$. Whether the
incumbent will actually deter new entrants will depend on the characteristics (and unobservables) of the market and of the new entrant.

4 Econometric Model

4.1 Basic Methodology

The estimation methodology adapts Ciliberto and Tamer [2005] to a panel dataset.

Consider a $k$-player binary game where the strategy of player $i$ is $y_i = 1$ or 0 depending on whether the $i$’s profit crosses a threshold. For player $i$, this can be written as

$$y_i = 1 \text{ if } \Pi_i(x_i, y_{-i}, \theta, \epsilon_i) \geq 0$$

where $y_{-i}$ is the $k - 1$ binary zero-one vector of other players’ strategies, $x_i$ is a vector of regressors, and $\epsilon_i$ is the part of player $i$’s utility that is unobserved by the econometrician.$^4$ $y_i$ and $y_{-i}$ are observed, while the profits, $\Pi_i$ and $\Pi_{-i}$, are unobservable.

The observed part of profit $\Pi()$ is known up to the finite dimensional parameter $\theta$ and the unobserved part of the profit function (the $\epsilon$’s) is independent of $x$. $\epsilon$ is known to the players but unobserved to the econometrician, thus this is a game of complete information. The data consist of a random iid sample of observations (markets) $(y_i, x_i)$ for $i = 1, \ldots, N$. In addition, $\epsilon = (\epsilon_1, \ldots, \epsilon_k)$ is a mean zero random variable, independent of $x$, and has a known (up to a finite dimensional parameter $\Omega$) distribution $F_\Omega$.

I consider panel data, and thus there should be a strong correlation over time in the unobservables that determine firms’ decisions. New entrants might never enter into a market because the market is always unprofitable for two firms. The econometric analysis allows for the market unobservables to be constant over time. Firms’ unobservables are also correlated over time, and low cost carriers might never enter because they suffer bad shocks in that market.

I write the unobservable error $\epsilon_{int}$ as follows:

$^4$For simplicity, there are no market and time specific subscripts in this section.
\[ \epsilon_{imt} = \nu_m + \xi_{mt} + \eta_{im} + \zeta_{imt}. \]

\( \nu_m \) represents market unobservables that are constant over time to capture, for example, the fact that in market \( m \) there is a large share of business passengers. \( \xi_{mt} \) is a market shock that changes over time, and which affects firms in the same way, for example changes in the demand for travel over time. \( \eta_{im} \) is a time invariant market specific airline shock, to allow different firms to face different unobservables in the same market, for example some airlines might see a larger share of business passengers in the same market than other airlines do. Finally, \( \zeta_{imt} \) are time variant firm specific shocks.

The model provides the following inequality restrictions on regressions:

\[ H_1(x, \theta) \leq \Pr(y|x) \leq H_2(x, \theta) \]

where \( \Pr(y|x) \) is a \( 2^k \) vector of of choice probabilities that can be consistently estimated using the data and the inequalities are interpreted element by element. The \( H \)'s are functions of \( \theta \) and the distribution function \( F_\Omega \) where \( \Omega \) is part of the vector \( \theta \). Heuristically, the identified set, \( \Theta_I \), is the set of parameter values that obey these restrictions for all \( x \) almost everywhere and represents the set of economic models that is consistent with the empirical evidence. For a given parameter value, the estimator is based on minimizing the distance between this vector of choice probabilities and the set of predicted probabilities. On the set \( \Theta_I \), this distance is minimized.

The estimator is a sharp two step minimum distance estimator: in the first step the conditional choice probabilities are estimated non-parametrically, and in the second stage the estimates of the set \( \Theta_I \) are obtained. This sharp set contains all the possible parameter values that are consistent with the set of economic models that obey our fundamental assumption. In general games, it is not possible to derive these functions analytically since that would entail solving for the equilibria of the game, a task that can be very complicated. To obtain an estimate of these functions for a given \( x \) and a given parameter value, a simulation procedure is provided in Ciliberto and Tamer [2005]. I will simulate random draws of \( \nu_m, \xi_{mt}, \eta_{im}, \) and \( \zeta_{imt} \) from four independent normal distributions with mean zero and variance equal to 1.
4.2 Specification

I assume the following profit function for firm $i = 1, \ldots, I$ in market $m = 1, \ldots, M$ at time $t = 1, \ldots, T$:

$$
\pi^*_{imt} \simeq \alpha^i_0 + \alpha^i X_{mt} + \beta^i Z_{imt} + \sum_{j \neq i} \delta^i_j y_{jmt} + \epsilon_{imt},
$$

where $X_{mt}$ are exogenous determinants of profits. $\epsilon_{imt}$ is the part of firms’ profits that cannot measured but that firms observe and act on. $Z_{imt}$ is the measure of observable heterogeneity for the airlines. The parameters $\delta^i_j$ measure the effect that the presence of one of the other airlines has on the probability of observing firm $i$ in the same market. For example, the parameters $\delta^i_i$ could measure a particular aggressive behavior of one airline (e.g. American) against another airline (e.g. Southwest). $\delta^i_j$ captures the effect that the entry by airline $j$ has on $i$’s unobserved profits. In this way, the analysis captures the possibility that the firms’ profits might change with the number and identity of entrants. Here, $\theta = (\alpha_0, \alpha_X, \beta, \delta)$, where $\alpha_0$ is a $I \times 1$ vector of parameters; $\alpha_X$ is $I \times k$ matrix of parameters (with $k$ exogenous determinants of demand); $\beta$ is a $I \times 1$ vector of parameters; $\delta$ is matrix of $I \times I$ parameters.

The empirical specifications consider the competition between airline alliances. In particular, the first airline alliance is made of American Airlines and TWA. If American or TWA is in the market, then $y_{AA} = 1$, otherwise $y_{AA} = 0$. The second airline alliance is the Star Alliance, and is made of United and USAir, and is indexed by $y_{SA} = 1$ if one of these two firms is in the market; the third airline alliance is Sky Team, and is made of Continental, Delta, and Northwest, and is indexed by $y_{SK} = 1$ if one of these three firms is in the market; then there is Southwest, indexed by $y_{WN}$. Finally, there is an indicator variable $y_{LCC} = 1$ if at least one of the other low cost carriers is in the market. Let $\Upsilon = \{AA, SA, SK, WN, LCC\}$.

4.2.1 Statistical Model 1: Firms Play A Simultaneous-Move Game

When airlines play a simultaneous-move game I estimate the following statistical model, which I call Statistical Model 1:
\[ y_{i,mt} = 1 \left[ \pi_{i,mt}^{SIM} = \alpha_0^i + \alpha_i^X X_{mt} + \beta^i Z_{i,mt} + \sum_{j \in \Upsilon / \{i\}} \delta_j^i y_{j,mt} + \epsilon_{i,mt} \geq 0 \right], i \in \Upsilon. \quad (1) \]

This is the most general specification of a simultaneous-move game. \( \pi_{i,mt}^{SIM} \) is the profit made in the simultaneous move game. Each firm has a different effect on the competitors’ entry decision. For example, the effect of American’s presence on Southwest is given by \( \delta_{WN}^{AA} \) and on the members of the Sky Team (e.g. Delta) is given by \( \delta_{AA}^{SK} \). The dummies introduce a measure of heterogeneity, as they capture how each firm affects the entry decision of the other firms. Second, observe that we can also allow for heterogeneous effects of market presence. For example, \( \beta^{AA} \) measures the effect that American’s market presence has on American’s decision to enter. The model also here allows for multiple equilibria in the number of firms.

4.2.2 Statistical Model 2: Firms Play A Sequential-Move Game

Consider now the case when one firm, say firm \( h \), was the only firm in the market at time \( t - 1 \). Then firm \( h \) has a first-mover advantage. I consider first the case when firm \( h \) cannot make deterrence investments (possibly because they are prohibitively expensive).

The statistical model for a sequential-move game is complicated to write, because firm \( h \) can move first and because the equilibrium must be subgame perfect. If there is at least one subgame perfect pure strategy equilibrium where firm \( h \) makes nonnegative profits, then the statistical model (Statistical Model 2) is given as follows:

\[
\begin{align*}
\left\{ \begin{array}{l}
y_{i,m} = 1 \left[ \pi_{i,mt}^{SEQ} = \alpha_0^i + \alpha_i^X X_{mt} + \beta^i Z_{i,mt} + \delta_i^h y_{j,mt + \epsilon_{i,mt} \geq 0} \sum_{j \in \Upsilon / \{i,h\}} \delta_j^i y_{j,mt} + \epsilon_{i,mt} \geq 0 \right] \\
\text{conditional on } \pi_{h,mt}^{SEQ} = \alpha_0^h + \alpha_h^X X_{mt} + \beta^h Z_{h,mt} + \sum_{j \in \Upsilon / \{h\}} \delta_j^h y_{j,mt} + \epsilon_{h,mt} \geq 0,
\end{array} \right. \\
i \in \Upsilon / \{h\}. (2)
\end{align*}
\]

Otherwise, if there is no subgame perfect equilibrium with \( h \) in the market, the statistical model is given by:

\[ \]
\[ y_{i,m} = 1 \begin{cases} \pi_{imt}^{SEQ} = \alpha_0^i + \alpha_X^i X_{mt} + \beta^i Z_{i,mt} + \sum_{j \in \mathcal{Y} / \{i,h\}} \delta_j^i y_{j,mt} + \epsilon_{i,mt} \geq 0 \\ \text{conditional on } \pi_{hmt}^{SEQ} = \alpha_0^h + \alpha_X^h X_{mt} + \beta^h Z_{h,mt} + \sum_{j \in \mathcal{Y} / \{h\}} \delta_j^h y_{j,mt} + \epsilon_{h,mt} \geq 0, \\ \end{cases} \]

4.2.3 Statistical Model 3: Firms Play A Sequential-Move Game with Deterrence

Finally, firms might decide to make deterrence investments when they have a first-mover advantage. Consider again the case where firm \( h \) moves first, but now firm \( h \) can make deterrence investments.

The statistical model is even more complicated now because the first mover must decide whether to make the deterrence investments or not. If there is a subgame perfect equilibrium where firm \( h \) makes nonnegative profits and where the profits are larger than those that firm \( h \) would make with deterrence investments then, the Statistical Model 3 is written as:

\[ y_{i,m} = 1 \begin{cases} \pi_{imt}^{SEQ} = \alpha_0^i + \alpha_X^i X_{mt} + \beta^i Z_{i,mt} + \sum_{j \in \mathcal{Y} / \{i,h\}} \delta_j^i y_{j,mt} + \epsilon_{i,mt} \geq 0 \\ \text{conditional on: } \pi_{hmt}^{SEQ} = \alpha_0^h + \alpha_X^h X_{mt} + \beta^h Z_{h,mt} + \sum_{j \in \mathcal{Y} / \{h\}} \delta_j^h y_{j,mt} + \epsilon_{h,mt} \geq 0, \\ \pi_{hmt}^{SEQ} \geq \pi_{hmt}^{DET} = \alpha_0^h + \alpha_X^h X_{mt} + \beta^h Z_{h,mt} - c_h + \epsilon_{h,mt}. \end{cases} \]

(3)

If, however, firm \( h \), the first mover, makes higher profits when it deters new entrants, then the statistical model is given as follows:

\[ y_{i,m} = 1 \begin{cases} \pi_{hmt}^{DET} = \alpha_0^h + \alpha_X^h X_{mt} + \beta^h Z_{h,mt} - c_h + \epsilon_{h,mt} \geq 0 \\ y_{i,m} = 0 \text{ for } i \in \mathcal{Y} / \{h\} \\ \text{conditional on } \pi_{hmt}^{DET} > \pi_{hmt}^{SEQ}. \end{cases} \]
5 Data

5.1 Ticket and Passenger Trip Data

Fare and passenger data are from the Origin and Destination Survey (DB1B), which is a 10 percent sample of airline tickets from reporting carriers. These are quarterly data from the first quarter in 1996 to the third quarter in 2000. The data are organized by market and carrier.

A market is defined as a trip between two airports, regardless of origin and destination, and regardless of connections. For example, a trip from Atlanta (ATL) to Miami (MIA) and a trip from Miami to Atlanta are considered as trips in the same market ATLMIA, regardless of the whether the trip was on nonstop, direct, or connecting flights. Trips from the same city but different airports are treated as different markets. Therefore, the market between Atlanta and Chicago O’Hare, ATLORD, is different from the market between Atlanta and Chicago Midway, ATLMDW. The dataset includes markets between the airports of the largest 50 metropolitan statistical areas in terms of population. There are 422 markets.

There are 8018 market-year-quarter observations. Table 3 reports the summary statistics for the variables used in the analysis.

As discussed when presenting the econometric model, there are five players in this game, which correspond to the three alliances, Southwest and a type called Low Cost Carriers. The members of the three alliances are given in Table 3, which provides summary statistics by the quartiles of the size of the market. Market size is measured by the log of the product of the population at the endpoints (Berry [1992]). In this table I have split the market size in 4 quartiles (large, medium large, medium small and small).

[TABLE 3 APPROXIMATELY HERE]

5 The details of how to construct the data used in this paper are given in Ciliberto [2005], and Ciliberto and Tamer [2005].
6 Because of the computational burden associated with the methodology used in this paper, I draw a random sample with replacement of 500 markets to limit the number of markets.
7 Any carrier that is independently owned is included in the dataset, even if it serves as a regional carrier of one of the major airlines in one market.
The first row shows summary statistics for the variable \( AA \), which is equal to 1 if either American or TWA are in the market. We observe that American or TWA serve half of the market-year-quarter observations in the sample. This percentage does not change by market size. The interpretation is analogous for the rows Star Alliance, Sky Team, Southwest, and LCC.

The second set of variables are the measures of firm heterogeneity, which is equal to the percentage of the total markets out of an airport that an alliance serves. In particular, this percentage is calculated as the fraction of the average across airports and across members of an alliance, divided by the total number of markets that are served in a given quarter and in a given year from the end point airports. Notice that firm heterogeneity does not vary by market size.

The last four rows of Table 3 show the summary statistics for the exogenous determinants of profits. The first exogenous characteristics is income, which is computed as the log of the average of the average personal income at the endpoints. Markets of different size do not differ by income.\(^8\) Then I present the nonstop market distance between the endpoints, which does not differ across markets of different sizes. Tourist is a categorical variable that takes a value equal to 1 if the market involves an airport in either Florida or California. Smaller markets are less likely to be tourist markets. HubMarket is a variable that is equal to 1 if one of the endpoints is the hub of one of the major airlines.\(^9\) Small markets are less likely to involve a hub airport.

Table 4 presents the distribution of these five types of firms across markets of different sizes.

\[\text{[TABLE 4 APPROXIMATELY HERE]}\]

The table suggests that there is no clear relationship between market size and number of firms in a market (Ciliberto and Tamer [2005]). This suggests that multiple equilibria in the number and identity of firms exist.

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\(^8\) The continuous variables presented in Table 3 are discretized in quartiles in the empirical analysis.\(^9\) Following Borenstein [1990], hub airports are Chicago O’Hare (American Airlines and United Airlines); Dallas Forth-Worth (American Airlines); Houston International (Continental); Phoenix (America West); Detroit and Minneapolis/St. Paul (Northwest); St. Louis (TWA); Charlotte and Pittsburgh (USAir); Denver (United Airlines); Atlanta (Delta Airlines).
The critical variation that is needed for the econometric analysis concerns entry and exit from airline markets. In order to identify the role of strategic deterrence it is crucial to see firms entering in markets that were not previously served by any airline and firms entering in markets that are already served by other airlines. This variation in the market structure within markets over time is crucial to identify the effect of strategic deterrence on market structure from the role that sunk costs, operating costs, and demand changes have on market structure.

Table 5 illustrates this type of variation in the data.

There are 1217 new entries over the time period. Some patterns are clear from the table. First, 40 percent (489 out of 1217) of these new entries occur where there is more than one incumbent in the market. Second, there is half as much entry where a Low Cost Carrier is the only incumbent in the market than where one of the three major alliances is in the market. There is even less entry where Southwest is the only incumbent in the market. Finally, Southwest enters disproportionately in markets where there is more than one incumbent.

In light of the discussion of Section 3, Table 5 provides a useful set of stylized facts that should serve as a roadmap for the econometric analysis. Table 5 suggests that incumbents generally might be able to deter new entry, and that Southwest in particular is able to deter new competitors. Naturally, these are simple cross tabulations which do not control for market characteristics.

### 5.2 Institutional Barriers to Entry

A critical set of market characteristics that might determine the entry patterns described in Table 5 are institutional barriers to entry. In an extensive analysis of airline competition, the United States General Accounting Office reported in 1990 the results of surveys among airport administrators and travel agents on industry practices that limited entry in the airline industry (GAO [1989, 1990, 1990b, 1996]). The survey found that limited access to airport facilities acted as barriers to entry.

As a result of the governmental, public and academic concern with the existence of barriers to entry in the airline markets, on April 5, 2000, President Clinton signed
the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century (AIR 21) into law. AIR 21 identified a set of “major airports” that had to be available on a reasonable basis to all carriers wishing to serve these airports. AIR 21 provided that beginning in fiscal year 2001, no passenger facility fee could be charged by a “major airport” and no federal grant could be made to fund an airport unless the airport had submitted a written competition plan. The competition plan had to include information on the availability of airport gates and related facilities, leasing and sub-leasing arrangements, gate-use requirements, patterns of air service, gate-assignment policy, financial constraints, airport controls over air- and ground-side capacity, whether the airport intends to build or acquire gates that would be used as common facilities, and airfare levels (as compiled by the Department of Transportation) compared to other large airports.10

[TABLE 6 APPROXIMATELY HERE]

As a result of AIR 21, most of the major airports have compiled competition plans, which they have made available over the internet. I collected information from these competition plans in the spring and fall of 2004 and organized it as described in Table 6.

The first row of Table 6 reports the percentage of airports and markets that involve one of the airports singled out by the AIR 21. 50 percent of the airports in the dataset had to provide competition plans, and 81 percent of the market-year-quarter observations involved at least one of these airports.

The second row of Table 6 reports the average number of gates (NUMBERGATES) at the airports included in the sample. Airports that had to compile competition plans had a larger number of gates, and thus a larger capacity of flights to and from them. However, as reported in the second row of Table 6, only 16 percent of their gates were for common use. Information on the percentage of gates for common use at other airports is not available since they were not required to compile competition plans.

The third row of Table 6, reports the percentage of gates (PCTCOMMON) that were for common use. Common gates are those gates that airports can freely assign.

---

10Section 155.f.(1-2), H.R. 1000.
to airlines. Other gates are leased on a preferential or exclusive base. The higher
the percentage of gates that are common, the easier should be for new entrants to
enter into a market. Only 16 percent of the gates were for common use. The data do
not show any type of relationship between the number of firms and the percentage
of gates that are common. This variable is discretized in quartiles in the empirical
analysis.

Airlines can sublease their gates to other airlines. The fourth row of Table 6
shows the summary statistics for the variable LIMIT, which is equal to 1 if airlines
can sublease gates but they cannot charge fees in excess to limits established by
airports. In 58 percent of the airports identified by the AIR 21, the airport had
introduced a limit to the sublease fees that could be charged by the airlines. Notice
that only 10 percent of the markets involved an airport that had introduced limit on
the sublease fees.

The fifth row shows the summary statistics for the variable ADMINLIMIT,
which is the actual limit on sublease fees when a limit exists. In the empirical analysis,
ADMINLIMIT is a categorical variable equal to 1 if the sublease fee is larger than
100 percent. Among the airports that imposed limits on sublease fees, 68 percent of
them imposed limits larger than 100 percent.

The sixth row of Table 6 shows the summary statistics for the categorical variable
MII, which is equal to 1 if the airport has a Majority-in-Interest Agreement with
any of the airlines at the airport. It turns out that most of the airports identified by
the AIR 21 did have an MII in place.

6 Empirical Analysis

The empirical analysis develops specifications that are increasingly general. All spec-
ifications allow for firm strategic heterogeneity. However, to show the effect of adding
control variables I will start with simpler specifications where the models do not in-
clude observable firm heterogeneity and do not include institutional barriers to entry.
6.1 Baseline Specifications

Table 7 presents the results of the estimation of Statistical Models 1, 2, and 2 when I do not include firm heterogeneity and measures of institutional barriers to entry.

TABLE 7 APPROXIMATELY HERE]

The first column of Table 7 presents the coefficient bounds for the Statistical Model 1. In this Table, the effect of one firm, say American, on the other firms, SA, SK, WN, and LCC is the same. Therefore $\delta^{AA}_{DL} = \delta^{AA}_{WN}$, for example. I estimate the effect of American on the other airlines to be included in $[-4.160, -3.551]$. The effect is negative, as expected: American’s presence in the market reduces the probability that we observe one of the other four airlines in the market. The results are similar for the other firms. The effect of United or USAir (the Star Alliance) on the other firms is included in $[-5.518, -4.754]$; the effect of Continental, Delta, and Northwest is included in $[-4.273, -3.828]$; the effect of Southwest is included in $[-2.977, -2.081]$; and the effect of Low Cost Carriers is included in $[-3.089, -2.452]$. Through the comparison of these coefficients, we conclude that the presence of the major airlines has a stronger negative effect than Southwest or Low Cost Carriers on competitors.

Market size is positively related to entry, since the coefficient of log population is included in $[0.613, 0.876]$. Similarly, distance is also positively related to entry, since the coefficient is included in $[1.679, 2.045]$. Finally, entry is more likely in tourist markets than in other markets, since the coefficient is included in $[0.791, 1.429]$.

The second column of Table 7 presents the coefficient bounds for the Statistical Model 2. Firms can gain a first mover advantage in this framework, and then the game can become a sequential-move game. The effect of all firms is now stronger than when the game is a simultaneous-move game. For example, the effect of American is now included in $[-4.749, -4.253]$ while before the effect was included in $[-4.160, -3.551]$. Since the two sets do not overlap, we can conclude that the effect of American is stronger when we allow firms to play a sequential-move game.

The last column of Table 7 presents the coefficient bounds for the Statistical Model 3. These are the first set of results that address the question of this paper. The first five rows of the column show the coefficient bounds for the strategic interaction terms. The effects for American and the Star Alliance are stronger than those
estimated in the second column, while the effect of the other three firms (Sky Team, Southwest, and LCC) are similar to those estimated in the third column.

Consider now the second set of coefficients, which measure the Deterrence Cost that each airline must face to deter new entrants when the airline is the only incumbent in the market. Consider American. American must face a deterrence cost included in $[-8.432, -8.094]$ to deter new entrants. The entry of Sky Team in the market where American is the only incumbent decreases the profits made by American by an amount included in $[-4.872, -4.859]$, which is smaller than the cost of the deterrence investment. Therefore, American will not make the deterrence investments to prevent the entry of Sky Team. In fact, American will not make deterrence investments to prevent any of its competitors, since the cost of the deterrence investments is not smaller than the largest possible loss for the entry of Star Alliance, which is included in $[-8.485, -8.137]$. A similar argument can be used to show that none of the carriers make deterrence investments. The costs of the deterrence investments are too large for all carriers.

6.2 Specifications with Institutional Barriers To Entry [In Progress]

6.3 Specifications with Airline Heterogeneity [In Progress]

7 Conclusions

In preliminary results, I find that I find that the estimated costs of the deterrence investments are large, relative to the coefficient estimates of the strategic interaction effects, suggesting that firms will not make the deterrence investments when they have the opportunity to do so.

8 References


Figure 1: The Sequential Move Game

Figure 1a: The Game Without Deterrence

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<tr>
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</thead>
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</tr>
<tr>
<td>No Enter</td>
<td>$\left(\pi_{AA\text{Duopoly}}, 0, \pi_{DL\text{Duopoly}}\right)$</td>
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</tbody>
</table>

Figure 1b: The Game with Deterrence

<table>
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<td>$\left(0, \pi_{UA\text{Duopoly}}, \pi_{DL\text{Duopoly}}\right)$</td>
</tr>
<tr>
<td>No Enter</td>
<td>$\left(0, 0, \pi_{DL\text{Monopoly}}\right)$</td>
</tr>
</tbody>
</table>

Note: This Sequential-Move game represents a game equivalent to that played by AA, DL, UA in the third quarter of 1998 in Figure 1.
<table>
<thead>
<tr>
<th></th>
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<td>1</td>
<td>1</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>UA</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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</table>

Type of Game
- … simultaneous
- sequential AA moves first
- simultaneous
- simultaneous
- sequential DL moves first

Note: Observable and unobservable market conditions change over time.
<table>
<thead>
<tr>
<th>Time</th>
<th>Possible Firms in Equilibrium</th>
<th>Actual Firms Observed in the Data</th>
<th>Profits of the Firms</th>
</tr>
</thead>
<tbody>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>AA or DL</td>
<td>AA</td>
<td>$(\pi_{AA}^M, 0)$</td>
</tr>
<tr>
<td>2</td>
<td>AA and DL</td>
<td>AA</td>
<td>$(\pi_{AA}^M - c_{AA}, 0)$</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>AA or DL</td>
<td>DL</td>
<td>$(0, \pi_{DL}^M)$</td>
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<td>5</td>
<td>AA and DL</td>
<td>AA and DL</td>
<td>$(\pi_{AA}^D, \pi_{DL}^D)$</td>
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Possible Firms in Equilibrium indicates the identity of the firms that could be making nonnegative profit in equilibrium. Actual Firms in Equilibrium indicates the identity of firms that are observed in the data.
Table 3: Summary Statistics

<table>
<thead>
<tr>
<th>Market Size:</th>
<th>All</th>
<th>Large</th>
<th>Medium-Large</th>
<th>Medium-Small</th>
<th>Small</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (S.D.)</td>
<td>Mean (S.D.)</td>
<td>Mean (S.D.)</td>
<td>Mean (S.D.)</td>
<td>Mean (S.D.)</td>
</tr>
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<td>AA (TWA,AA)</td>
<td>0.498 (0.500)</td>
<td>0.497 (0.499)</td>
<td>0.623 (0.485)</td>
<td>0.497 (0.500)</td>
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<tr>
<td>Star Alliance, SA (UA,US)</td>
<td>0.655 (0.466)</td>
<td>0.713 (0.420)</td>
<td>0.680 (0.402)</td>
<td>0.790 (0.407)</td>
<td></td>
</tr>
<tr>
<td>Sky Team, SK (CO,DL,NW)</td>
<td>0.308 (0.495)</td>
<td>0.333 (0.453)</td>
<td>0.282 (0.467)</td>
<td>0.162 (0.476)</td>
<td></td>
</tr>
<tr>
<td>Southwest, WN</td>
<td>0.191 (0.498)</td>
<td>0.149 (0.471)</td>
<td>0.202 (0.450)</td>
<td>0.196 (0.368)</td>
<td></td>
</tr>
<tr>
<td>Low Cost Carriers, LCC</td>
<td>0.393 (0.356)</td>
<td>0.220 (0.414)</td>
<td>0.202 (0.401)</td>
<td>0.196 (0.397)</td>
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<tr>
<td>AA Market Presence</td>
<td>0.296 (0.076)</td>
<td>0.303 (0.076)</td>
<td>0.299 (0.073)</td>
<td>0.275 (0.081)</td>
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<tr>
<td>SA Market Presence</td>
<td>0.308 (0.080)</td>
<td>0.308 (0.076)</td>
<td>0.303 (0.074)</td>
<td>0.305 (0.068)</td>
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<td>SK Market Presence</td>
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<td>0.373 (0.062)</td>
<td>0.367 (0.062)</td>
<td>0.364 (0.064)</td>
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<tr>
<td>WN Market Presence</td>
<td>0.147 (0.125)</td>
<td>0.151 (0.118)</td>
<td>0.147 (0.110)</td>
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<tr>
<td>Log(Income)</td>
<td>10.959 (1.162)</td>
<td>10.980 (1.156)</td>
<td>10.944 (1.158)</td>
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<td>Log(Population)</td>
<td>29.531 (1.257)</td>
<td>29.863 (0.617)</td>
<td>28.998 (0.313)</td>
<td>28.015 (0.226)</td>
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<td>Market Distance (Miles)</td>
<td>1119.119 (699.75)</td>
<td>1102.4 (717.799)</td>
<td>1117.033 (647.443)</td>
<td>1002.392 (607.187)</td>
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<td>Tourist Dummy</td>
<td>0.365 (0.481)</td>
<td>0.397 (0.489)</td>
<td>0.310 (0.463)</td>
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<td>Hub Market</td>
<td>0.438 (0.496)</td>
<td>0.514 (0.497)</td>
<td>0.550 (0.498)</td>
<td>0.243 (0.429)</td>
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<td>Number Firms</td>
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<td>1999</td>
<td>2009</td>
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<td>Market-Year-Quarter Observations</td>
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<tr>
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<td>Incumbent AA</td>
<td>Incumbent SA</td>
<td>Incumbent SK</td>
<td>Incumbent WN</td>
<td>Incumbent LCC</td>
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<td>32</td>
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<td>34</td>
<td>...</td>
<td>61</td>
<td>8</td>
<td>21</td>
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<td>...</td>
<td>2</td>
<td>11</td>
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<tr>
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<td>10</td>
<td>7</td>
<td>3</td>
<td>...</td>
<td>10</td>
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<td>New Entry LCC</td>
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<td>18</td>
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<td>By Airport</td>
<td>By Market</td>
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<td>-------------------------------------</td>
<td></td>
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<td>Selected Airports</td>
<td>Other Airports</td>
<td></td>
<td></td>
<td></td>
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<td>Number of Gates (NUMBERGATES)</td>
<td>0.53 (0.50), n=73</td>
<td>0.82 (0.39), n=8108</td>
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<td></td>
<td>70.91 (47.81), n=33</td>
<td>44.34 (34.43), n=32</td>
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<tr>
<td>Common Use (%) (COMMONPCT)</td>
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<td></td>
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<tr>
<td>LIMIT</td>
<td>0.58 (0.50), n=31</td>
<td>0.09 (0.29), n=5168</td>
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<td></td>
<td></td>
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<tr>
<td>ADMINLIMIT = 1 if sublease fee&gt;100% and if LIMIT=1</td>
<td>0.28 (0.461), n=18</td>
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<td></td>
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<td></td>
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<tr>
<td>MII</td>
<td>0.7 (0.47), n=30</td>
<td>0.74 (0.44), n=4978</td>
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</table>

Table 6: Institutional Barriers to Entry, by Market and by Airport
Table 7: Baseline Specifications  
(Without Firm Heterogeneity and Institutional Barriers to Entry)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Specification 1 Coefficient Bounds</th>
<th>Specification 2 Coefficient Bounds</th>
<th>Specification 3 Coefficient Bounds</th>
</tr>
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<tbody>
<tr>
<td>Deterrence Cost AA</td>
<td></td>
<td></td>
<td>[-8.432,-8.094]</td>
</tr>
<tr>
<td>Deterrence Cost SA</td>
<td></td>
<td></td>
<td>[-4.878,-4.864]</td>
</tr>
<tr>
<td>Deterrence Cost SK</td>
<td></td>
<td></td>
<td>[-8.407,-5.000]</td>
</tr>
<tr>
<td>Deterrence Cost WN</td>
<td></td>
<td></td>
<td>[-9.740,-0.485]</td>
</tr>
<tr>
<td>Deterrence Cost LCC</td>
<td></td>
<td></td>
<td>[-9.742,-7.071]</td>
</tr>
<tr>
<td>LogIncome</td>
<td>[0.126,0.336]</td>
<td>[0.012,0.131]</td>
<td>[-0.365,-0.178]</td>
</tr>
<tr>
<td>LogPopul</td>
<td>[0.613,0.876]</td>
<td>[0.326,0.472]</td>
<td>[0.881,1.098]</td>
</tr>
<tr>
<td>Distance</td>
<td>[1.679,2.045]</td>
<td>[3.926,4.053]</td>
<td>[1.673,1.902]</td>
</tr>
<tr>
<td>Tourist</td>
<td>[0.791,1.429]</td>
<td>[-0.038,0.740]</td>
<td>[0.647,1.707]</td>
</tr>
<tr>
<td>Constant</td>
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<td>[-2.943,-2.587]</td>
<td>[7.258,7.845]</td>
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<tr>
<td>Value Function</td>
<td>553.0897</td>
<td>1195.938</td>
<td>713.1787</td>
</tr>
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</table>

This table provides the ``cube'' that contains the set estimates. These set estimates are appropriately constructed level sets of the sample objective function that cover the sharp identified set (which might not be convex) with 95% (See CHT [2004] and appendix 0.1 for more details on constructing these confidence regions.)