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ABSTRACT

It is difficult for the firm investing in information technology (IT) to appropriate all of the benefits from its investment for itself: it is very easy to imitate innovations in IT. Airlines have installed computerized reservations systems (CRSs) in travel agencies in order to appropriate the returns from their investments in information technology. The airlines expected to obtain a number of benefits from this strategy including increased efficiency, possible bias in favor of the CRS owner on the part of the travel agent, and fees from other airlines for making reservations for them. The purpose of this paper is to evaluate the impact of the indirect (non-fee) benefits to CRS owners from deploying systems in travel agencies. These indirect benefits should be seen in the vendor airline's market share between cities and in the overall performance of the airline at an industry level. This paper models airline performance as a function of CRS ownership at two levels: for selected city-pairs and at the overall level of the firm. The city-pair analysis employs a multinomial logit market share model using five years of data on 72 routes. The industry model uses longitudinal data for a panel of ten airlines for twelve years. The results of both analyses support hypotheses that CRS ownership is positively related to airline performance. It appears that strong airlines have appropriated the indirect benefits of their CRSs, turning them into highly specialized assets for further travel-related innovation.

KEYWORDS: Appropriability, agency automation, airline performance, business value of IT, computerized reservation systems, CRS, corporate strategy, market share models

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1. INTRODUCTION[1]

There is a large and growing body of research which seeks to demonstrate benefits from investing in information technology (IT). The purpose of this paper is to determine if a firm can appropriate the benefits from its investment in information technology for itself. In particular we focus on a firm's ability to capture indirect benefits from investing in IT to achieve critical mass in highly competitive markets. These benefits extend beyond the traditional measures of cost savings and revenue directly attributable to a technology investment.

1.1 Research Framework

A firm faces a number of problems in obtaining a return from its investment because IT innovations are very hard to protect. Teece (1987) provides an insightful analysis of the innovator's problems and the choices available for the imitator or follower. He discusses regimes of *appropriability* ranging from weak to strong. Appropriability refers to the innovator's ability to appropriate the benefits of an innovation for itself. It is clear from his analysis that many IT innovations have weak appropriability; it is hard to protect them legally and an imitator or follower can easily copy the functionality of the innovation. Teece also demonstrates that firms sometimes succeed as an innovator or as an imitator because they have specialized assets needed to ensure adoption of an innovation. As an example, one reason that Microsoft's Internet Explorer, a Netscape imitator, has been successful is Microsoft's control of the operating system, a specialized asset a browser needs to operate.

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An innovator attempts to appropriate the direct benefits from an IT investment, those returns originally predicted in undertaking the IT initiative. Direct benefits from an IT investment fall into the category of cost savings, and occasionally revenue generation. The innovator would also like to capture the indirect benefits of a system. Indirect benefits accrue because of some second-order effect of the technology, and often these benefits are unanticipated when the original technology investment is made. Table 1 describes some ways in which indirect benefits accrue to the firm that innovates with IT.

Source of Indirect Benefits	Examples
Making it easier to do business with the innovator	Developing an EDI capability to encourage customers to select the innovator as a supplier
Encouraging business by using technology to create a positive impression of the firm	FedEx Web site for tracking packages may encourage customers to use FedEx for more shipments because of its convenience
Using IT to provide outstanding customer service	McKesson helped its independent drug store customers withstand the threat of drug chains through a variety of initiatives
Using IT to create biased markets	Baxter's order entry system in hospitals

Indirect Benefits of IT Investment
Table 1

In each of the examples in Table 1 a system has had a second-order impact for its developer. An EDI capability saves ordering and order fulfillment costs; it also makes a firm with EDI capability easier for a customer to use. The FedEx Web site is very impressive. The company will reduce costs through less use of its 800 customer service number and the need for fewer service agents. FedEx should obtain indirect benefits as the site encourages customers to place more business with the carrier. McKesson developed its Economost system to reduce its costs and increase volume; by providing superb customer service and innovative programs for its pharmacy customers, it helped keep these independent stores in business (Clemons and Row, 1988). Finally, indirect benefits accrue from *biased markets*, a results of many proprietary order entry systems (Malone, Benjamin and Yates, 1987). Customers find these systems easy and attractive to use; the innovator biases the market by featuring its own products only or by giving them preference.

It is not easy to classify IT investment as direct and indirect without knowing the original justification for the IT initiative. We believe that the indirect benefits in Table 1 were not anticipated when the companies made their original investments; these benefits would certainly have been difficult to forecast *a priori*. In general, the greater the distance in business process terms between where the investment occurs and where benefits appear, the more likely that the benefits are "indirect."

1.2 Airline CRS, Appropriability and Biased Markets

The airline industry provides one opportunity to examine an effort to appropriate the benefits of a technological innovation and to assess the indirect benefits of investing in IT. American developed the first airline computerized reservations system (CRS) in order to prevent an uncontrolled escalation in costs that would result from its manual reservations system when jet travel began (Copeland and McKenney, 1985). However, CRSs have weak appropriability regimes; other airlines, including United, quickly imitated American. IBM offered a packaged system called PARS to any airline based on its joint work with American in developing the SABRE system.

One way for the CRS developer to protect its innovation was to offer the system to travel agents, thus building an installed base of CRS locations. The CRS vendor would gain by creating a biased market favoring its flights. Expanding the system to travel agents also required including more capabilities in the system like the ability to reserve rental cars and hotel rooms. The CRS system, itself, became a highly specialized asset for its vendors that an airline needs to offer further innovative travel services.

In 1976 United and American Airlines began installing terminals, connected to the airlines' computerized reservations systems, in travel agents' offices (Copeland and McKenney, 1985). Several other airlines quickly imitated their behavior. We believe that CRS vendor airlines did so to protect their innovation. They received direct benefits from booking fees and charges to travel agents and obtained indirect benefits through biased markets and outstanding customer service. The airlines strengthened their appropriability regime (their ability to appropriate the benefits of innovation) while turning the reservations systems into highly specialized assets for further travel-related innovation.

Many of the indirect benefits described above are enjoyed by all airlines whose flights are listed in a CRS. What are the indirect benefits to the *owner* of a system? The Economics literature suggest that the value of a network increases as the number of its locations increases (Farrell and Saloner (1986); Saloner and Shepard (1995)). How might indirect benefits accrue to a CRS vendor as its number of agency locations reaches a critical mass? One example is extra bookings due to screen bias. Until it was eliminated by government regulation in 1984, CRS vendors routinely listed their own flights first on the reservations display. Since it has been estimated that over 90% of flights are booked from the first screen, this bias favored the airline. Even though rules by the Civil Aeronautics Board (CAB) at first, and later by the Department of Transportation, attempted to eliminate screen bias, non-CRS vendors have continued to assert that subtle biases in systems favor CRS vendors (Lyle, 1988; Borenstein, 1991).

Another indirect benefit for the CRS vendor is the "halo" effect. Copeland and McKenney (1988) define the halo effect as "a tendency to book more passengers on the flights of the airline that supplies a travel agency's reservations than would otherwise be the case." This favoritism might come about because of more familiarity with the airline and contact with its personnel, a favorable impression of the airline created by its technological capabilities, or the overall benefits of the CRS for the agent. As deployment of the technology reaches a critical mass, these benefits become more likely to occur.

1.3 Hypotheses

We predict that indirect benefits increase a CRS vendor's market share beyond what might be expected in cities where the vendor has high agency penetration. Assuming that CRS technologies alone did not change market demand for airline reservations, a travel agent's favoritism for a CRS vendor's flights increases the vendor's business in a market at the expense of its competitors. Higher market share in enough individual markets should then be reflected in stronger airline performance at the industry level. This reasoning leads to two hypotheses related to the indirect benefits of CRS ownership and deployment in travel agencies:

> *Hypothesis 1:* A CRS vendor's deployment of agency automation in local markets will be positively associated with that airline's market share of revenue-producing passenger miles between the city-pairs comprising its route structure.
>
> *Hypothesis 2:* A CRS vendor's national installed base of agencies will be positively associated with the airline's overall performance.

The paper first presents a city-pair model to assess the impact of CRS ownership and deployment on the vendor's market share in selected cities. Then we formulate a firm-level econometric model of airline performance to estimate the impact of agency automation on the overall performance of ten major domestic airlines.

2. PRIOR RESEARCH

This section presents an overview of selected prior research on IT and firm performance; it also examines literature on the economics of the airline industry to develop our models of the impact of CRS on firm performance.

2.1. The Impact of Technology on Performance

As early as the 1970s, there was interest in the impact of information systems on firm performance; see Table 2. Lucas (1975) found that information system usage was not a very good predictor of performance among more than 200 California bank branches. Cron and Sobol (1983) found that surgical warehousing companies making extensive use of information technology (IT) were either very strong or very weak financial performers. Turner (1985) reported little evidence to suggest that mutual savings banks which made relatively larger investments in IT compared to industry competitors performed better.

After these early studies, researchers began to study specific industries in depth. Venkatraman and Zaheer (1990), for example, reported that insurance agencies that adopted new technology generated more new business, though these agencies also started out with a better record on new business than matched firms that had not yet implemented the new system. Harris and Katz (1991) looked at the use of information technology in the insurance industry as well, and reported conflicting results on the impact of IT.

In banking, Banker and Kauffman (1988) also found little evidence of value from investments in automated teller machine (ATM) network technology. Instead, their empirical results showed that ATM deployment helped to protect a bank branch's deposit base rather than extend it greatly; only a very restricted set of competitive conditions were found to be conducive to the creation of this kind of business value through ATM deployment. Dos Santos and Peffers (1995) have conducted a rigorous econometric study using time-series data from the Federal Reserve Bank to determine the business value of electronic banking. The results of this study were also mixed in terms of the return from investing in ATMs; early adopters of IT were able to increase profitability and market share, but late adopters were only able to increase profitability, not market share.

Authors	Sample	Theory/Model	Findings
Lucas (1975)	Bank branches	Proposed model of IS use and performance	Usage not a strong predictor of performance
Cron and Sobol(1983)	Surgical warehouse firms	An evaluation framework for IS	Highest users of IT either strong or weak performers
Turner(1985)	Mutual savings banks	Proposed theory of job design	Little relationship between investment in IT and better performance than competition
Venkatraman and Zaheer (1990)	Insurance agencies	Quasi-experimental design; theory of strategic advantage	Agencies with new IT generated more new business, but they had been best performers before automation
Harris and Katz (1991)	Life insurance firms	Strategic value of IT impacts	Conflicting results: weak positive relationship between IT and performance
Banker and Kauffman (1988)	Banks	Strategic value of IT	Market share model showed little added value from ATM investment; protected competitive position
Dos Santos and Peffers (1995)	Banks	Value chain and econometric analysis	Mixed results from adopting ATMs
Loveman (1994)	Manufact-uring firms	Cobb-Douglas production function	Little relationship between IT investment and sector output
Weill (1992)	Valve manufact-uring firms	Proposed model of use and performance	Found IT investment related only to transactions processing applications
Barua, Kriebel and Mukhopadhyay (1995)	Manufact-uring firms	Microeconomic model at SBU and firm level	Greater impact found at SBU than firm level
Brynjolfsson and Hitt (1996,1994)	Industry level data	Cobb-Douglas production function	High positive return at the firm level for IT investments

Summary of Selected Business Value Research
Table 2

In manufacturing, Loveman (1994) showed IT created little value in terms of the sector's output productivity, despite his use of well-accepted econometric methods and a solid data set. For valve manufacturing firms, Weill (1992) found that the only relationship between investments in technology and firm performance was for transactional applications. Here, a firm could obtain direct cost savings, for example, through a materials requirements planning system. Also in manufacturing, Barua, Kriebel and Mukhopadhyay (1995) examined the value of IT by modeling performance at two levels. At the business process level, they found that IT improved capacity utilization and inventory turnover, and supported quality control; however, there was little impact on new product introduction. Overall the firm level effects of IT, including return on assets and market share, were much weaker.

Brynjolfsson and Hitt (1996), using firm-level data across a large number of companies, found a surprisingly high return from firms' investments in information technology, 54% in manufacturing and 68% combining manufacturing and services firms. These results are somewhat controversial, in spite of the methodological care taken by the authors in modeling firm performance. In studies that employ this level of analysis, aggregation of the data make it very difficult to ensure that information technology investments are measured in a consistent manner across firms. For example, the database in this research appears to have contained only centralized expenditures on IT, not decentralized spending at the department level.

A study by the same authors found that IT was associated with increased productivity. Capital investments in technology had a high return of 87%. However, IT investment was not related to shareholder return, return on equity or return on assets (Brynjolfsson and Hitt, 1994).

In general, research on the level of the individual firm has not found a consistent and strong relationship between investments in IT and firm performance, though some of the more recent studies show more positive results. There is a popular belief, as witnessed by cover stories in leading business magazines (*Fortune*, June 17, 1994), that IT does have a payoff. Brynjolfsson (1993) provides reasons why a negative view of returns from investing in IT may be the result of definitional, measurement and data problems. It is also possible that it has taken longer than expected for investments in technology to show a return, and that more carefully designed IT value research is now beginning to find a payoff from investing in IT.

2.2. Research on Airline Performance

There have been a number of studies of the airline industry, a few of which have performed econometric analyses of airline performance; see Table 3. Caves, Christensen and Tretheway (1981) estimated total factor productivity for 11 major

Study	Theory/Model	Key Variables	Results
Caves, Christensen and Tretheway (1981)	Total factor productivity	Three passenger and two freight outputs, five categories of inputs	Higher productivity associated with longer average stage lengths and higher load factors
Sickles (1985)	Nonlinear production function	Capital, labor, materials and energy related to capacity ton miles	Capital and labor contribute to productivity growth
Sickles, Good and Johnson(1986)	Input-output model of allocative efficiency for multi-output firms	Capital, labor, energy and materials predict revenues	Deregulation lowered total costs and improved allocative efficiency
Cornwell, Schmidt and Sickles (1990)	Frontier production function	Same as above including stage length	An increase in efficiency after regulatory changes
Department of Transportation (1988)	Production function	Revenue share predicted by departures and overrides	Overrides and departures are associated with revenue share for an airline
Borenstein (1991)	Production function for market share (linear)	Revenue share predicted by airport dominance, tourist traffic, schedule and airline CRS share	Dominant airline at airport had disproportionate share of traffic; CRS coefficient insignificant
Banker and Johnston (1995)	Multiplicative competitive interaction model (MCI) for airline market share	Airline market share in city-pairs, CRS deployment	CRS deployment in agencies positively related to market share

Summary of Airline Performance Research
Table 3

airlines. These researchers looked at five output variables primarily related to revenue, and five inputs. They estimated a total factor productivity index for each airline and analyzed differences in productivity. These authors found that airlines with longer average stage lengths (average length of flights on the airline) and higher load factors had higher productivity.

Sickles (1985) tested a nonlinear model of technology and specific factor productivity growth on a panel of sixteen domestic US airlines from 1970 to 1978. His model includes estimates of capital, labor, energy and materials inputs. Sickles used these variables to estimate a cost function describing the firm's production technology. During this time period, the growth rate in factor productivity averaged about 2.6% a year, with capital and labor being the dominant causal factors. He noted that time-specific random effects on performance were small, but that firm-specific effects were important.

Sickles, Good and Johnson (1986) extended the data set in the study above to include quarterly figures from 1970 through 1981 in order to evaluate airline deregulation. They constructed a model of airline performance for thirteen carriers using capital, labor, energy and materials as input to predict passenger and cargo revenues. The results suggest that deregulation lowered total costs and improved allocative inefficiency. Cornwell, Schmidt and Sickles (1990) used the same data set for eight airlines and included seasonal dummies in their equation along with average stage length and a quality measure. They found an increase in efficiency from 82% in 1972 to 95% in 1980.

The Department of Transportation (1988) developed a model of an airline's share of revenue from agents using its CRS for one year, focusing on commission overrides paid by the airlines. The independent variables in this model included the vendor's share of scheduled departures in a market, the square of the vendor's share of scheduled departures, and a series of dummy variables indicating whether the travel agent received an override (an extra payment for booking a flight on that airline) from each airline in the model (US Department of Transportation, 1988).

This model was estimated for travel agents using a CRS for the year 1986 in 57 consolidated metropolitan statistical areas containing large and medium hubs. The study found an association between the CRS vendor airline's share of scheduled departures and the share of revenues it receives from agents using its CRS. Overrides were associated with higher bookings for the airline offering them and fewer bookings for competing airlines.

Borenstein (1991) studied the advantage that a dominant airline has in a particular market. His study is one of the few that has examined airline market share for specific cities. His model included airport dominance measures, tourist traffic, schedule convenience, and airline CRS share. Borenstein's CRS variable measured the proportion of revenues on all CRSs in a city that are conducted on a carrier's system. He used data from 1200 city-pair markets in the U.S. for the second quarter of 1986. Borenstein's measure of market share was based on an airline's share of the round-trip traffic between two cities. The model explained 15% of the variance in market share, and the CRS coefficient was small and insignificant in predicting market share. In general the dominant airline at an airport attracted a disproportionate share of traffic, though the magnitude of this advantage was small and difficult to assess.

Finally, there is one study by Banker and Johnston (1995) that modeled airline market share in selected cities using a multiplicative competitive interaction (MCI) model. MCI models use production function modeling and analysis techniques to represent the relative strengths of competitors' marketing mix choices in achieving market share. A second model examined the impact of the use of a CRS on its owner's costs of providing reservations services. Independent variables in the study included the number of travel agencies using a CRS vendor's system, the average fare per revenue passenger mile, number of destinations served, frequency of flights, advertising, hours of reservations labor and travel agent commissions. Data for the study covered quarters from 1981 to 1985 and included 23 airlines. The MCI model explained 95% of the variance in market share during the period. The contribution of the CRS variables was positive and significant in predicting market share.

2.3 Summary of CRS Results: Findings and Limitations

A relatively small number of studies have addressed the impact of airline computerized reservation systems on airline performance. The researchers employed varied theoretical and evaluative perspectives drawn from microeconomics and marketing science, including the analysis of airline production and market shares. Their research designs varied from large single period cross-sectional analysis, to more extensive, multi-quarter and multi-year panel data analysis. Only two of three studies that mention CRS actually focus on them; the DOT (1988) was interested in commission overrides rather than CRS impact. A CRS independent variable predicting airline market share is significant in only one of two studies that included it. Research to date, either on business value or airline performance, has provided only limited evidence for the indirect benefits accruing to airline CRS vendors from deploying their reservations systems in travel agencies.

3. RESEARCH MODEL, MODELING ISSUES AND DATA

Prior research on the business value of IT and airline performance has drawn on multiple theoretical perspectives, including strategic management, organizational behavior and microeconomics. Studies that utilized economic theory often adopted some form of production function relating airline performance output measures to various input factors such as capital and labor. They also employed techniques such as total factor productivity assessment, Cobb-Douglas production function estimation, econometric analysis of the business process and the value chain, and market share modeling.

3.1 The General Model

Our study, consistent with almost all of the airline performance and some of the business value research we reviewed, relies on production economics. We model the indirect impact of CRS in terms of four dependent variables, including *market share, revenue passenger miles, load factor* and *operating profits.* We perform analyses of CRS value at two levels of aggregation: at the city-pair level and at the industry level. To estimate market share effects of airline agency automation at the city-pair level, we adapted a model from the marketing science literature (Cooper and Nakanishi, 1988). This model allows us to test for network size-dependent value in regional competition, and incorporate the possibility of a "threshold" or "critical mass" effect for CRS deployment. This specification of the model was chosen to tie in closely with our framework explaining how a firm appropriates benefits from an IT investment. To assess the indirect impact of CRS ownership on the overall performance of an airline at the industry level, we employ several different econometric models.

The independent variable for testing our hypotheses, *CRS locations,* measures the number of travel agencies using a particular CRS vendor's system in each year of the study. The model also includes other explanatory variables which were the most significant in prior research, and which appear to be important control variables in estimating an airline's ability to appropriate the benefits of CRS deployment. Average *stage length* summarizes information about an airline's fixed and variable costs of operation for a given route structure. A longer stage length should be associated with lower costs and higher revenues. The *number of departures* measures an airline's accessibility to customers; more departures generally provide greater convenience for travelers, increasing the airline's attractiveness to the market. In general, we expect *advertising* to be weakly associated with performance based on its significance in past research. The presence of a *strike* can significantly disrupt airline operations and impact performance. It is also likely that airline *fares* influence performance, especially market share for leisure travelers.

This study tests two models of airline performance,[2] at the city-pair and the national level, of the general form shown in Equation 1:

$$\text{Airline\_Performance} = f(\text{STAGE}, \#\_\text{DEPARTS}, \text{AD\_EXP}, \text{STRIKE}, \text{FARE}, \text{CRS\_LOC}) \quad (1)$$

3.2 Variables and Data Collection

The two major airline CRS vendors are American and United. These two carriers had about 70% of the agency automation business in the U.S. during the period of the study. Delta, Eastern and TWA also adopted a strategy of agency automation, but their market share was low. The CRS vendor airlines and systems included in this study are American (SABRE), United (APOLLO), Delta (DATAS II), TWA (PARS) and Eastern (SYSTEMONE). Since the purpose of this paper is to assess the ability of airline CRS vendors to appropriate the *indirect* benefits of agency automation, we do **not** consider the revenue generated by reservations systems in the form of charges to other airlines for booking their flights.

Table 4 contains the variables in the study. We model the indirect benefits of CRS ownership by measuring the number of travel agencies, CRS_LOC, using a CRS vendor's system following a strategy first used by Banker and Johnston (1995). This variable measures the penetration of a vendor's CRS into the travel agency market. Copeland has carefully developed time-series estimates of the number of travel agencies with terminals installed by each of the major CRS vendors at the industry level (Copeland and McKenney, 1988). On the local level, a study by an industry research

[2] In any study there is the possibility of omitted variables. The most serious omissions in the present study are the influence of frequent flyer programs (FFP) and commission overrides. There is very little data available on frequent flyer programs and their impact; since all airline had or soon developed these programs, their impact on the industry model over its 12-year period should be minimal. FFPs might influence the city-pair results, but the nature of that impact is difficult to predict. To examine FFPs, one would need quarterly data on enrollment, as well as announcements and responses by rival airlines. Similarly, it is expected that special commission and overrides should average out over the period of the national model, though they could influence the city-pair results.

firm provided data on the distribution of CRS among travel agencies in selected cities for a five-year period.

The average stage length, STAGE, is the average length in miles of all an airline's flights between the city pairs in its route structure. In general, a longer average stage length is associated with better financial performance during the period of the study. A longer stage length implies fewer landings and take-offs per revenue passenger mile of flight. Airlines with longer stage lengths should have lower fixed costs relative to variable costs compared with their competitors.

Variables	Definition	Source	Industry Model	City-Pair Model
Independent				
CRS_LOC	Number of travel agencies nationally with CRS Number of travel agencies in city-pair markets with CRS	Copeland & McKenny (1985); Industry research firm	X	 X
STAGE	Average length in miles of all a carrier's flights	I.P. Sharp	X	
#_DEPARTS	Number of departing flights	I.P. Sharp	X	X
AD_EXP	Advertising/promotion expenses	BAR/LNA	X	X
STRIKE	Occurrence of a strike during period	DOT records; periodical literature		X
FARE	Average fare on route	I.P. Sharp		X
Dependent				
RPM	Revenue passenger miles	I.P. Sharp	X	
LOAD	Load factor	I.P. Sharp	X	
PROFIT	Operating profit	I.P. Sharp	X	
MS	Market share based on RPM for a city-pair route	I.P. Sharp		X

Data Sources
Table 4

A major source of data for this study is the I.P. Sharp electronic airline database (Reuters/I.P. Sharp Ltd, 1988a and b). This database is derived from the Department of Transportation Form 41, and includes comprehensive information on many aspects of airline operations and finance that are used in making decisions about airline regulations. It also includes a 10% sample of all airline tickets used in the U.S.--what the DOT calls the "OD1A Database" in its raw form-- and maintains a file of true origin-destination data describing an airline's operations. The Sharp database provided information on average stage length for each airline in the study.

The number of departures, #_DEPARTS, is also generally correlated with airline revenue. Borenstein (1991) discusses several studies which have showed that airlines with a large share of capacity on a route receive a disproportionate share of traffic. One explanation is that customers are aware of this dominance and call the airline they assume will have the most convenient departure. This effect has diminished over time, however, as more reservations are made through travel agents.

Data on airline expenditures on print advertising were obtained from a major advertising firm's Leading National Advertiser's (LNA) database, and data on broadcast expenditures were obtained from the Arbitron Ratings Company Broadcast Advertiser's Reports (BAR). These expenditures for each airline on print and broadcast advertising were summed to create the advertising variable, AD_EXP.

We also considered the effects of strikes through a dummy variable, STRIKE, representing the presence or absence of a strike in a given year in the city-pair data set. Strikes were identified from Department of Transportation records, the Air Transport Association of America conference proceedings (1987), and industry periodicals. The STRIKE variable was not included in our industry level models; limited duration strikes had little or no impact on aggregate airline performance. Moreover, the air traffic controllers' strike did not appear to affect yearly performance statistics differentially by airline. For example, load factors and revenue passenger miles fell from 1979 through 1980 and generally began to increase again in 1981. However, the pattern was similar across all of the carriers in the study. Because the city-pair data encompass fewer years, strikes are considered in the analysis at this level.

We modeled an airline's ticket prices using a variable called FARE, to represent the *average fare between two cities* in the city-pair analysis. This variable is also based on I. P. Sharp data, and was computed by dividing total revenue on a city-pair route by the number of paying passengers for each carrier.

The next three variables in Table 3 are airline performance measures, and were also taken from the I.P. Sharp database. Revenue passenger miles (RPM) is the total number of miles flown by paying passengers on the airline each year. A revenue passenger mile is defined as a paying passenger flying one mile on the airline; it is not a direct measure of revenue as it only shows the fact the passenger was paying, not how much was paid. Load factor (LOAD) is the average percentage of seats filled with paying passengers during the year. If a plane has 100 paying passengers and a capacity of 200 passengers, the load factor for that flight is 50%.

For this study, operating profit (PROFIT) is defined as operating revenues minus expenses and is a short-term measure. Expenses related to aircraft depreciation and leasing have been removed as they are not considered controllable in the short run. As mentioned earlier, fees from CRS subsidiaries are also excluded from this measure by subtracting the "miscellaneous revenue" account on Form 41 where CRS fees are reported, from revenues.

The final dependent variable is market share (MS) defined as an airline's percentage of total revenue passenger miles for all carriers between two cities. We were able to compute an airline's market share of revenue passenger miles with reference to the origin-destination data from the DOT's OD1A database.

4.0 THE CITY-PAIR LEVEL: MODEL AND RESULTS

Market share models enable the evaluation of the relationship between variables describing a firm's decisions about how to configure itself to sell products and services, and its resulting market share. We use CRS installed base and other independent variables from Table 4 to constitute each airline's strategy or "marketing mix". The variables in the model determine the relative attractiveness to the consumer of choosing to fly on the airline.

4.1. The City-Pair Route Market Share Model

A desirable feature of a market share model is that it should provide predictions of equilibrium market shares that firms should achieve based on the marketing mixes they select, as the market moves towards equilibrium. Unlike analytical models of market share, empirical models are not intended to depict the process by which equilibrium results, nor can we necessarily expect them to guarantee predictions that match what we might expect to see occur in equilibrium (as a game theoretic model might yield).

A second desirable feature of a market share model is that its estimates are logically consistent with what we know about the mechanics of market share. Thus, a model which produces market share estimates that are either greater than 100% or less than 0% -- which is likely to happen with simple linear models of market share -- fails to incorporate relevant information. Market share models that enable logically consistent estimates are usually specified in ratio form (Cooper and Nakanishi, 1988; Jain and Mahajan, 1979), as follows:

$$MS_{ic} = \frac{f(X_{ic}, \beta)}{\sum_{i=1}^{I} f(X_{ic}, \beta)} \qquad (2)$$

This particular form of a market share model incorporates the function f(.) in the numerator to measure the strength of airline i's marketing mix, represented by a vector of variables X, to achieve market share on a city-pair route c, weighted by the denominator which reflects the set of decisions made by all I competitors in the market. Taken together, the numerator and denominator in the model act to normalize the resulting estimates of market share and ensure logically consistent estimates.

4.1.1. Selecting a Model. In order to use a model of the form in Equation 2 to estimate the impact of CRS on city-pair market shares, we made several tactical decisions that would allow us to provide evidence for the appropriability of the benefits from CRS deployment. The first was to determine the form of the function f(.).

When a multiplicative function is selected the resulting model is a ratio of two simple Cobb-Douglas production functions and is called a *multiplicative competitive interaction (MCI) model.* Similar to Cobb-Douglas function analysis, the coefficients for the marketing mix variables have a straightforward interpretation as percentage changes in market share for unit changes in their values. The MCI model has been found to be a useful modeling approach in numerous studies during the past decade (Ghosh and Craig, 1983; Nakanishi and Cooper, 1974; Banker and Kauffman, 1988; Cooper, 1988; and Banker and Johnston, 1995). When an exponential function is selected, the resulting model is called a *multinomial logit (*MNL*) model; o*ther functional forms are possible as well.

Different functional forms result in quite different market share elasticities (Cooper and Nakanishi, 1988), some of which are better suited than others for providing evidence of the importance of installed base and critical mass in agency automation. Market share elasticity is defined as the ratio of the relative change in market share corresponding to a change in a marketing mix variable. Assuming k = 1,..., K marketing mix variables in set K for airline i, we can express the point elasticity, e, of airline i's market share, MS_i, with respect to any single variable, x_{ki}, as:

$$e_{MS_i} = \frac{\partial MS_i \; / \; MS_i}{\partial x_{ki} \; / \; x_{ki}} \qquad (3)$$

For unit changes in the value of a marketing mix variable, the respective point elasticity estimates for the MCI and MNL models are $\beta_k(1-MS_i)$ and $\beta_k(1-MS_i)x_{ki}$. The MCI elasticity expression declines monotonically as increases in x_{ki} lead to improving market share. On the other hand, the MNL elasticity increases over some range of values of x_{ki}, and then declines, suggesting a threshold impact on market share. This pattern is consistent with our belief that a CRS vendor's agency automation program needs to achieve a critical mass before there are impacts on market share, and that eventually the CRS impact on market share should decline. Thus, in contrast to Banker and Johnston, we have chosen an MNL model which takes into account both the installed base and the need for a critical mass of CRS locations.

4.1.2. Variables in the City-Pair Model. The dependent variable for the city-pair analysis is market share based on each carrier's percentage of revenue passenger miles between an origin and destination city. We expect that market share is a function of agency automation, as well as several other independent variables included in past airline performance research.

The independent variable of most interest to us is the number of travel agencies using a vendor's CRS, our measure for the installed base of reservations systems. Terminals are installed during the year and there is likely to be a learning curve for agency personnel. Thus, the full impact of automating a location should be felt during the year after the automation occurs. Note that the installed base of terminals is growing each year for the CRS vendor during the study period. Consequently, the models use a lagged CRS locations variable.

We include the following variables, x_k, from among the marketing mix variables shown in Table 3 in our city-pair market analysis:

- number of travel agencies with a vendor's CRS ($x_{CRS\_LOC,\,t-1}$);
- number of departures from the origin city ($x_{\#\_DEPARTS}$);
- advertising expense (x_{AD_EXP});
- average fare on the route (x_{FARE}); and,
- occurrence of a strike during the period (x_{STRIKE}).

The number of departures has been found to be correlated with airline performance (U.S. Department of Transportation, 1988). An airline with more departures should have a larger market share, indicating a potential source of heteroskedasticity in our model. Based on prior findings (Doganis, 1985) we expect to find a weak association between advertising and market share. We also expect fares to influence market share at the city-pair level because airlines are quite competitive on given routes. A strike can have a major impact on the market share of an airline between two cities. Average stage length, a variable in past airline performance research, is a constant since each competitor flies the same number of miles between a given city-pair; therefore, it is not included in the city-pair model.

Equation 4 shows the fully specified form of the model for the city-pair analysis; it includes the one-year lagged value of CRS locations in the origin city of the city-pair along with advertising, number of departures, fare and strikes.

$$MS_{ict} = \frac{f(x_{AD\_EXP,ict}, x_{\#\_DEPARTS,ict}, x_{FARE,ict}, x_{STRIKE,ict}; x_{CRS\_LOC,ic,t-1})}{\sum_{i=1}^{I} f(x_{AD\_EXP,ict}, x_{\#\_DEPARTS,ict}, x_{FARE,ict}, x_{STRIKE,ict}; x_{CRS\_LOC,ic,t-1})} \tag{4}$$

The multinomial logit estimation form of this model includes an exponential attractiveness function of the marketing mix variables, which ensures that our assumption about elasticity of market share will hold. Ratio models cannot be estimated directly using ordinary least squares (OLS) regression because they are non-linear. However, one can perform ordinary least squares estimation after a log-centering transformation. This process involves taking logarithms of the differences between the values of the independent variables and their arithmetic means. For the dependent variable, the raw value for market share is divided by the geometric mean market share, and then the logarithm of that expression is taken. Following this transformation, the model becomes a special case of other log-linear market share models, as discussed in Cooper and Nakanishi (1988). See Appendix A for additional details.

4.2. City-Pair Selection and Data Set Refinement

We obtained data for the city-pair model covering all 132 of the DOT's OD1A-listed domestic carriers in the five year period from 1983 to 1987, for 210 city pairs (15 origins by 14 destinations). The data set was culled to include 2309 observations in the following four steps:

- **Step 1 – Elimination of Airline Hubs:** Although the city-pairs we considered are all designated as "large hubs" by government regulators (U.S. Department of Transportation, 1988; U.S. Senate, 1989), not all of these cities are used as "operational hubs" by the airlines. We eliminated from consideration all origin and destination cities that acted as "operational hubs" for a carrier (e.g., Newark, Dallas/Fort Worth, Atlanta, St. Louis, and Houston.)[3]

- **Step 2 – Elimination of One Year of Data Due to Lag:** By lagging the CRS locations (CRS_LOC) variable one year (t-1), we lost the observations for 1983.

- **Step 3 – Elimination of Irrelevant Competitors:** We also eliminated from consideration all carriers whose market share in a given city-pair was less than or equal to 1%. This step narrowed the list of admissible airlines from the DOT's 132 OD1A-listed airlines for the five-year period down to about 30-35.

- **Step 4 – Elimination of Carriers with Insufficient Observations:** Based on additional diagnostic work on the data set, we determined that separate intercepts for approximately 15-20 minor carriers could not be estimated. In most cases, their market shares were either just above our 1% cutoff or the airline had a slightly larger share, but was not represented in enough time periods or in enough city-pairs to estimate an intercept. Although we analyzed this data using the heteroskedasticity-corrected models whose results are discussed in Section 4.3., we were only able to do so by cumulating the observations to establish a "unit" or "small carrier" intercept. The "small carrier" intercept was insignificant, however, and further analysis of these observations as potential outliers suggested that we omit them from further consideration. The most notable omission for this reason was Pacific Southwest Airlines.

This process resulted in data from nine cities: Boston, Chicago, Los Angeles, Miami, New York, Philadelphia, San Diego, San Francisco and Washington, D.C. (Because these cities were not "operational hubs" during the period of this study, we

[3] By contrast, the non-operational hubs of Denver, Detroit and Seattle were omitted because of missing data on agency automation.

do not include a hub independent variable.) The steps yielded 72 city-pairs (9 by 8) for analysis, when pairs with identical origins were eliminated. The resulting data set covers the time when CRS vendors were actively competing for an installed base in travel agencies. Copeland and McKenney (1988) indicate that by 1987 an estimated 95% of agencies were automated and competition changed to displacing an existing vendors' CRS in order to install one's own.

4.3.1. Econometric Issues

The econometric issues we addressed prior to estimation of the model included native collinearity (both pairwise correlation and multicollinearity), model-induced multicollinearity, autocorrelation, heteroskedasticity and omitted variables. A pairwise correlation analysis ensured that no two variables were too highly correlated, and the Belsley-Kuh-Welch test (1980) suggested multicollinearity was not a problem. In addition, with the many airline intercepts included in the model, there was a strong possibility of model-induced multicollinearity. However, Steps 3 and 4 of our data selection process resolved this issue.

The possibility of autocorrelated disturbances is somewhat more difficult to address effectively. There could be potential gains from first-differencing the data (as in the MCI model of Banker and Johnston, 1995) or moving to a first-order autoregressive (e.g. AR(1)) specification for the error term disturbance. However, in this study we had insufficient observations in our time-series to make first differencing work. A second alternative, to correct the covariance matrix for autocorrelation (e.g., using Kmenta's (1986) procedure), would have resulted in the loss of many more observations due to our unbalanced sample, leaving just the very largest airlines. The diagnostic alternative we chose was to examine individual years cross-sectionally, then run a sub-sample with the first (1984) and the last (1987) years of the data, and, finally, examine the stability of the coefficient estimates across all the sub-samples. We observed stable coefficient estimates throughout, with only minor exceptions that were unrelated to the CRS locations variable.

The city-pairs included in our analysis exhibit two-firm market shares that varied between 69% and 89% during the period, 1983 to 1987. Such oligopolistic competition almost guarantees the presence of heteroskedastic errors.[4] We confirmed the presence of heteroskedasticity and obtained unbiased estimators in two ways:

- *First*, we used the Goldfeld-Quandt (1965) F-test with the observations split on the basis of rank-ordered number of departures from the origin city in a city-pair (#_DEPARTS), to proxy for larger and smaller firms. We tested both with and without an appropriately sized holdout sample of "middle-sized" firms and obtained similar confirmatory results.[5] Next, we used #_DEPARTS as the weighting variable to correct for heteroskedasticity. Then, we performed weighted least squares (Greene, 1990).
- *Second*, we used the less restrictive Breusch-Pagan (1979) χ^2 test of homoskedasticity. The test results prompted us to reject homoskedasticity, so we corrected the data for heteroskedasticity using White's (1980) estimator, which produces unbiased least squares estimates.

In both cases, the estimation models yielded reasonable and similar results. We prefer the results of the second analysis, especially given its treatment of variables that may be omitted from our analysis. It is difficult to know the "right" functional form that relates the proxy variable for firm size to the error variance, though we prefer the

[4] A second potential source, similar to what is seen in macroeconomic studies of inflation and unemployment, occurs when the variance of the forecast error depends on the size of prior disturbances, Var[ε_t | ε_{t-s}], s=1,...,S. For example, it is possible that an omitted variable (such as announcements about the move to deregulation in the industry, with its different effects on different size firms), might have had an effect that persisted over time. Our model does not consider this form of heteroskedasticity.

[5] Omitting observations increases the power of the test up to a point. Harvey and Phillips (1974) indicate that no more than one-third of the observations should be dropped, while Goldfeld and Quandt have demonstrated applications involving 15% to 20% holdout samples.

simple intuition of a proportional effect. Breusch-Pagan (1979) is tailored to situations where it is difficult to identify what might cause heteroskedasticity.

4.3.2. Estimation Results. Table 5 presents the results from the MNL market share analysis using White's covariance matrix correction. The results support Hypothesis 1: the lagged CRS variable is significant at the .001 level and has a positive coefficient, indicating a positive relationship to market share of revenue passenger miles. This coefficient represents the impact on log-centered market share of the difference between the number of CRS locations deployed by airline i and the mean number of all competitors' CRS agency locations in the origin city at time t. The CRS coefficient is second in significance only to the number of departures.

Based on 2309 observations, the model explains over 55% of the variance in log-centered market share. Four of the five main effects coefficients were significant in our primary tests, and the effects were also evident in our secondary tests; only advertising expenditures were not significant. The number of departing flights, as expected, is positively related to market share, while strikes, although seldom occurring during the period, appear to do visible harm.

The positive coefficient in Table 5 for FARE is somewhat surprising, though it is consistent with past research. One would think *a priori* that lower rather than higher fares would be associated with market share. Are the airlines exercising market power? Are their customers exhibiting their willingness-to-pay for building frequent flyer miles? Or, are they just insensitive to price? Although our model does not enable us to answer these questions, others have considered them. Borenstein (1989) and Morrison and Winston (1989) showed that an airline which has a large market share

Table 5
City-Pair Airline Marketing Mix Analysis

Variable	Coefficient	Standard Error	t-Ratio
Airline Firm Intercepts (α_i):			
BRANIFF	-0.255	0.0725	-3.513 ***
CONTINENTAL	0.617	0.0523	11.784 ***
DELTA	-0.132	0.0571	-2.304 **
EASTERN	0.239	0.0563	4.244 ***
MIDWAY	1.037	0.0768	13.499 ***
MIXED	-0.680	0.1236	-5.506 ***
NORTHWEST	-0.240	0.0482	-4.978
PAN AM	0.368	0.0923	3.990 ***
PEOPLE'S EXPRS	0.321	0.0913	3.513 ***
PIEDMONT	-0.140	0.0854	-1.634 *
REPUBLIC	-0.657	0.0556	-11.823 ***
TWA	-0.205	0.0593	-3.453 ***
UNITED	0.335	0.0506	6.631 ***
USAIR	-0.926	0.0578	-1.600
WESTERN	-0.113	0.1086	-1.040 ***
Marketing Mix Variables (β_k):			
ADV_EXP	0.340E-09	0.167E-08	0.203
#_DEPARTS	0.563E-04	0.277E-05	20.355***
FARE	0.483E-02	0.884E-03	5.465***
STRIKE	-0.13394	0.638E-01	-2.101**
CRS_LOC_{t-1}	0.288E-01	0.155E-02	18.574***

Notes:

- **** = p<.01, ** = p<.05 and * = p <.10*
- **Model fit:** R^2 = 56.7%; Adjusted R^2 = 56.2%; F[19,2289] = 15.71
- **Data**: 2309 annual observations, spanning 4 years (1984-1987) for 72 non-hub city-pairs. k=1,...K marketing mix variables, and i=1,...,I airlines; all "small carriers" omitted.
- **Intercepts:** None for American Airlines included to avoid perfect collinearity; through its omission, American acts as base case comparison for other carriers.
- **Heteroskedasticity:** Diagnosed via the Breusch-Pagan (1979) Lagrange multiplier test for the hypothesis that the model is homoskedastic, i.e., $\gamma = \mathbf{0}$ in $Var[\varepsilon_i] = \sigma^2_i = \sigma^2 f(\gamma_0 + \gamma' \mathbf{z}_i)$, with **z** representing a vector of exogenous variables. The value of χ^2 was 152.08 with 19 degrees of freedom. Thus, we rejected homoskedasticity at the 1% level.
- **Alternate Estimation Method:** Based on the observation that firm size might account for heteroskedasticity, we ran a second, less general test attributable to Goldfeld and Quandt (1965), in which the source of the heteroskedasticity is assumed to be known (e.g., $Var[\varepsilon_i] = \sigma^2_i = \sigma^2 \omega_i$, ω_i=#_DEPARTS). Rejecting homoskedasticity again, we performed the related weighted least squares (**WLS**) regression (Greene, 1990). The WLS coefficient estimate for CRS_LOC was unchanged in both magnitude and significance level. Additionally, similar effects were retained for three of the four other core marketing mix variables in WLS estimation, while the variance explained by the model declined to approximately 37%. Although the Goldfeld-Quandt test results are consistent with firm size as a causal factor for heteroskedasticity, the test does not provide proof: we cannot rule out the possibility that other omitted variables produce heteroskedasticity.

a particular city-pair is able to raise its prices. It has also been estimated that frequent flyer programs have raised ticket prices by 10% to 15% (Stephenson and Fox, 1992).

4.4. Implications

The results of the city-pair analysis support Hypothesis 1, which predicts an association between the installed base of CRS locations in a market and the firm's market share. We believe the results illustrate how indirect benefits strengthened the vendors' ability to appropriate value from their investments in CRS through focused, market-specific efforts to create an installed base. The strength of the association with appropriability can be gauged by estimating the leverage that is created on market share for various levels of CRS deployment in capturing revenue passenger miles relative to the competition:

- The marginal value in market share terms of a competitor's installed base of CRS relative to its competition in the marketplace can be computed by transforming the partial derivative of market share with respect to lagged CRS locations ($\frac{\partial MS_t^*}{\partial x^*_{CRS\_LOC,t-1}}$) back to its raw impact on market share.
- It is also easy to solve for the size of the installed base of CRS locations that maximizes elasticity of market share, $x^{VALMAX}_{CRS\_LOC,t-1}$, for each of the markets included in the analysis. This solution indicates whether critical mass deployment was reached in a given market, and allows management to estimate the efficiency of the agency automation strategy in strengthening appropriability.

The interpretative power of such comparative statics analysis is limited by its *ceteris paribus* assumption. By holding "all else constant," one may not recognize the dynamics leading to equilibrium outcomes for firm market shares.

5. THE INDUSTRY LEVEL: MODEL AND RESULTS

The second hypothesis to be addressed in this research is whether CRS vendors' attempts to appropriate the indirect benefits from CRS deployment in travel agencies is related to the vendors' overall performance at an industry level.

5.1. The Industry Model

To answer this question, we tested a model with the variables shown in Table 1 using three dependent variables:

- LOAD factor: a measure of efficiency;
- RPM, revenue passenger miles: a measure of revenue generation (measured in millions of miles); and,
- Operating PROFIT: a measure of financial performance (measured in thousands of dollars).

The three variables described above are modeled as a function of:

- CRS_LOC, the number of travel agent locations using each CRS;
- average STAGE length for each carrier (the average length in miles of all of the airline's flights between city-pairs);
- number of departures, #_DEPARTS, for each carrier; and,
- advertising expenditures, AD_EXP, for each carrier (measured in thousands).

The functional form of the industry model is:[6]

$$y_t = \alpha_1 + \beta_1 \, CRS\_LOC_{t-1} + \beta_2 \, STAGE_t + \beta_3 \, \#\_DEPARTS_t + \beta_4 \, AD\_EXP_t + \varepsilon_t \qquad (5)$$

where

y_t = a dependent variable, representing load factor (LOAD), revenue passenger miles (RPM) and operating profit (PROFIT) in year t, in three separate estimations;

α_1 = a regression constant;

[6] We evaluated whether an additive separable specification of the national model was more appropriate than a log-linear (i.e., Cobb-Douglas) specification for this data. Our selection of an additive model was supported by the results of Davidson and MacKinnon's J-test (1981).

$\beta_1, \ldots, \beta_4$ = coefficients for the independent variables; and,

ε_t = a normally distributed, time-dependent error term.

The variable for the number of agencies in which the airline has reservation terminals, CRS_LOC, is lagged one year following the same logic as the city-pair model.

5.2. Estimation Issues

Data for testing the industry model cover the time period 1976 to 1987 for the CRS vendor airlines listed earlier in the paper and the following non-CRS vendor airlines: Piedmont, Northwest, USAir, Continental and Western. We used LIMDEP, which enabled us to test for problems with the data that we discussed earlier that make OLS estimates unreliable. We also tested a "fixed effects" variation of our model, that included dummy variables for panel groupings, in this case each airline. When appropriate, we computed the generalized least squares (GLS) solution to obtain statistics to identify the extent to which autocorrelation, heteroskedasticity and cross-sectional groups exist in the data. LIMDEP provides a number of statistics that suggest which model has more efficient coefficient estimates. Note that the industry model involves 10 airlines for 12 years, less one year for a lagged variable; therefore all models are estimated using 110 observations.

5.3. Results and Discussion

Equations 6 through 8 present the results of estimating the model in Equation 5. All three of the models required the use of generalized least squares estimates.[7]

[7]The government attempted to eliminate screen bias in 1984, a possible explanation for the advantages gained by an airline by having travel agents use its CRS. We also estimated equations 6-8 using a dummy variable for the slope of the CRS_LOC variable for the years before and after the elimination of screen bias. The results showed no significant difference in the slope of this independent variable after the elimination of bias. It is likely that the

$$RPM_t = \underset{(-10.53)^{***}}{-14{,}904} + \underset{(8.40)^{***}}{1.16}\ CRS\_LOC_{t-1} + \underset{(13.37)^{***}}{2.60E01}\ STAGE_t$$

$$+ \underset{(21.97)^{***}}{4.88E\text{-}02}\ \#\_DEPARTS_t + \underset{(1.29)}{4.52E\text{-}02}\ AD\_EXP_t \qquad (6)$$

*Model = GLS; R^2 = .96; t values in parentheses beneath the coefficient, with *** = p<.01, ** = p<.05 and * = p <.10.*

$$LOAD_t = \underset{(19.68)^{***}}{49.90} + \underset{(2.05)^{**}}{5.10E\text{-}04}\ CRS\_LOC_{t-1} + \underset{(2.40)^{**}}{8.37E\text{-}03}\ STAGE_t$$

$$+ \underset{(3.85)^{***}}{1.53E\text{-}05}\ \#\_DEPARTS_t - \underset{(-1.91)^{*}}{1.20E\text{-}04}\ AD\_EXP_t \qquad (7)$$

Model = GLS; R^2 = .27.

$$PROFIT_t = \underset{(-1.55)}{-139{,}063} + \underset{(4.62)^{***}}{4.36E01}\ CRS\_LOC_{t-1} - \underset{(-.40)}{4.92E01}\ STAGE_t$$

$$+ \underset{(7.33)^{***}}{1.07}\ \#\_DEPARTS_t - \underset{(-.43)}{1.89}\ AD\_EXP_t \qquad (8)$$

Model = GLS; R^2 = .63.

The CRS_LOC variable is significant in each of the equations above, supporting Hypothesis 2. The model suggests that the airline strategy of placing its terminals in travel agencies has been highly successful.

5.4. Testing for Simultaneity

Our belief is that an airline CRS placed in a travel agent's office leads to higher levels of revenue passenger miles, a greater load factor and higher profits. An alternative explanation for the findings is that only strong or large airlines can afford to develop a CRS and that these airlines would exhibit continued high performance regardless of agency automation. How plausible is this alternative explanation?

From a modeling standpoint, this question raises the issue of causality and simultaneity. Many research models predict causal relationships: a simple production

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advantages to having a CRS in a travel agent's office exceed the obvious benefits of display bias.

function suggests that output is caused by capital, labor and materials. Demonstrating causality with empirical research is problematic and is heavily influenced by research design. We believe that research only provides evidence that causality may exist; it removes doubt that variables are completely independent. An experimental research design in which the researcher controls and manipulates the independent variable provides the most evidence that a causal relationship may exist. A field study with longitudinal data falls between the laboratory experiment and cross-sectional research in addressing causality.

In empirical research of the kind we present in this study, the closest we can come to controlling and manipulating an independent variable is by making choices about the econometric analysis to reflect our understanding of industry dynamics. It seems reasonable, considering the airline industry and CRSs during the time period of our study, that the CRS locations and airline performance variables may simultaneously cause one another. To model this possibility, we specified a system of simultaneous equations involving the pairing of Equations 6 through 8 with an equation in which LOAD, PROFIT and RPM are used to predict CRS locations, eliminating the lag on the CRS locations variable.[8]

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[8] Such a formulation requires a substantial change in our underlying model: we can no longer lag the CRS locations variable to match our belief about how long it takes for IT to have an impact following its deployment. (It also would not make sense to use performance measures at time t to predict CRS locations at time t-1.) We should only include those airlines for analysis where the possibility of simultaneity actually existed. During the period of the study, the most successful automation vendors were United and American Airlines; the weaker CRS vendors during this period were Eastern and TWA. Delta was financially sound, but had smaller market share. These airlines yield twelve years of data for five carriers; however, not all of the airlines in the data set set actually deployed CRS at the beginning of the time period of the study, reducing the total to 48 observations.

We analyzed the structural equations in each of three models using two stage least squares (2SLS) regressions, one that included fixed effects to capture group-wise heteroskedasticity, and a second that included random effects to capture time-specific shocks in the market during the period of our data. The results were consistent with our findings in Equations 6 through 8. However, we do not present the results of the 2SLS analysis because (1) they do not allow for the time-lagged impacts of CRS that we think belong in the model, (2) the

The results of the analysis described above did not provide additional information beyond what we believe to be the most parsimonious explanation of simultaneous causation. Agencies are typically automated during the year, and it is most likely that the airline's performance in a prior year influences its automation budget. Therefore, we lagged the dependent variables in Equations 6 through 8 to predict the number of CRS locations, and estimated a model on the basis of 48 observations, obtaining Equation 9:

$$
\begin{aligned}
CRS\_LOC_t = & -2.00E03 - 7.32E01\ LOAD_{t-1} - 4.06E\text{-}03\ PROFIT_{t-1} \\
& \quad (-0.99) \qquad (-1.70)^{*} \qquad\qquad (-0.02) \\
& + 3.59E\text{-}01\ RPM_{t-1} \\
& \quad (5.37)^{***} \qquad\qquad\qquad (9)
\end{aligned}
$$

Model = Generalized Least Squares, 48 observations, $R^2 = .15$.

Revenue passenger miles is the best predictor of CRS investment, suggesting that larger airlines had the resources to develop competitive CRS and to deploy them in agencies. The weaker finding that higher load factors are associated with a smaller number of CRS locations may indicate that something other than CRS deployment is associated with greater levels of efficiency, such as route structure or type of equipment. The lack of significance for profitability adds to the argument that size matters more than performance in predicting agency automation. However, it should be noted that these three variables only explain 15% of the variance in agency automation.[9]

2SLS results are weaker than those from our primary model, and (3) there is significant autocorrelation present in the analysis. (To eliminate autocorrelation, an alternative analytic approach is to first-difference our data prior to the 2SLS. However, the relatively small number of observations we have at the national level makes this would further reduce the number of observations from 48 to 36.)

[9]If the dependent and independent variables in the industry model are compared for United and American versus other CRS vendors versus other airlines in the study, the results are consistent. For example, during the period United and American had an average load factor of 62.7%, other CRS vendors 58.8% and other airlines 57.3%. The results for the other variables are identical in terms of ranking. United and American have the highest revenue passenger mile figures, number of departures, longest stage length, advertising and operating profits, followed by other CRS vendors followed by the non CRS vendors. These data are also consistent with the findings

6. CONCLUSIONS

While we have attempted to perform a rigorous and careful analysis, there are several threats to the validity of our study. First, we were not able to obtain data or include overrides airlines pay to travel agents to stimulate bookings; it is possible that this omitted variable has an influence on market share. The structure of our model with lagged variables does not lend itself well to simultaneous equations estimation approaches, though it is likely that investment in CRS deployment and airline performance exhibit some joint causality. However, we do not feel that these problems are severe enough to alter the conclusions one can draw from the study, particularly given the consistent results between two different models using independent estimates of CRS locations and two different levels of analysis.

The results suggest that healthy airlines were able to appropriate the benefits of their investments in IT through agency automation strategies. The CRS vendors reached a critical mass in various cities which allowed them to increase market share. Market share in turn led to stronger performance on the national level. These airlines had to decide to take the risk to invest in technology and agency automation (Clemons, 1991). Even though American was healthy, deciding to undertake the SABRE system was difficult. Max Hopper, senior vice president of American, described the context of the initial SABRE development decision:[10]

> *"The initial investment in development costs was $40 million...the figure was equivalent to the cost of four Boeing 707s, which was the largest plane flying in those days...If we had bought aircraft instead, it would have been a 20% increase in the existing jet fleet. So, diverting our capital from jets to exotic technology...was a very major commitment and a significant financial risk for us as a company."*

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of Banker and Johnston (1995) who found that American and United benefited more from their CRS than other CRS vendors.

[10]Videotaped comments at an NYU seminar on November 3, 1992.

The major CRS vendors obtained direct benefits in the form of travel agent charges and booking fees, and indirect benefits as shown from the data in this study. The airlines also turned their CRS into highly successful specialized assets (Teece, 1987), platforms that became travel "supermarkets." It would indeed be difficult for an imitator today to create the specialized asset of a SABRE or APOLLO reservations system on which to offer more travel-related services. The value of this specialized asset became clear in August of 1996 when American turned SABRE into a subsidiary and sold part of it to the public. The overall market value of American Airlines at that time was $6.2 billion and the initial public offering of SABRE valued the subsidiary at about $3 billion, nearly half of the airline's market value!

This study supports our original hypotheses and makes three contributions to our knowledge about the value of IT investments:

1. CRS locations were a significant predictor of four measures of airline performance, in contrast with Borenstein's (1989) findings that CRS deployment was not significant in predicting market share.

2. CRS locations were significant in a MNL model over four years, building on Banker and Johnston's MCI model, and refining the manner in which elasticity of market share and critical mass are modeled; CRS locations were also significant in a national model using 12 years of data.

3. An effective corporate strategy, like CRS deployment in travel agencies, allows a firm to appropriate substantial indirect benefits in addition to the direct returns normally anticipated from an investment in information technology.

The results from the city-pair market share analysis and the industry model are consistent in supporting Hypotheses 1 and 2: the presence of a CRS vendor's system in a travel agency is associated with greater market share and with higher levels of airline performance. This study has found one of the strongest relationships to date between information technology and firm performance. Moreover, it has done so through analysis at two different levels with data from multiple sources, employed two models, and has used careful testing for possible defects in the analysis. The results also provide evidence that an investment in information technology has indirect benefits, in this instance through the growth in installed base of CRS terminals in travel agencies.

Senior managers and academic researchers find that it can be very difficult to evaluate the impact of investments in information technology. The results of this research suggest that it is possible to discover significant benefits from information technology at multiple levels of analysis. In this study, the results help us understand the indirect benefits of airline CRS beyond the direct impact of the booking fees the CRS vendor receives from other airlines. It appears that deploying IT in travel agencies has helped CRS vendors appropriate the benefits of IT innovations. We believe that other firms can and have obtained similar advantages, though it can be a challenge to demonstrate that technology was responsible. While it is difficult to estimate possible indirect benefits when evaluating an IT innovation, management should be aware that such benefits do occur; they may in fact turn out to provide the largest return on an IT investment.

Appendix A: Econometric Specification for the City-Pair Model

The multinomial logit (MNL) city-pair model requires transformation prior to estimation (Cooper and Nakanishi, 1988). To simplify the notation, we indicate the K-1 non-CRS variables with x_{kict} and the lagged CRS locations variable with $x_{CRS\_LOC,ic,t-1}$. The subscripts indicate the marketing mix variables k for airline i at time t, with the exception that CRS locations is lagged one year. The model in simplified notation is:

$$MS_{ict} = \frac{f(x_{kict}; x_{CRS\_LOC,ic,t-1})}{\sum_{i=1}^{I} f(x_{kict}; x_{CRS\_LOC,ic,t-1})} \qquad \text{(A1)}$$

The MNL form of the model incorporates an exponential attractiveness function of the marketing mix variables:

$$MS_{ict} = \frac{e^{(\alpha_i + \sum_{k=1}^{K-1} \beta_k x_{kict} + \beta_{CRS\_LOC} x_{CRS\_LOC,ic,t-1} + \varepsilon_{ict})}}{\sum_{i=1}^{I} e^{(\alpha_i + \sum_{k=1}^{K-1} \beta_k x_{kict} + \beta_{CRS\_LOC} x_{CRS\_LOC,ic,t-1} + \varepsilon_{ict})}} \quad \text{(A2)}$$

Included in this model are airline constants, α_i, for each firm as well as error terms, ε_{ict}, that pertain to the airline i, the city-pair c, and the time period t.

Transformation of this expression for estimation involves taking the logs of both sides, and centering market share on its geometric mean and the independent variables on their arithmetic means:

$$MS^*_{ict} = \alpha^*_i + \sum_{k=1}^{K-1} \beta_k x^*_{kict} + \beta_k x^*_{CRS\_LOC,ic,t-1} + \varepsilon^*_{ict} \quad \text{(A3)}$$

where

$$MS^*_{ict} = \log \left[MS_{ict} \Big/ \left(\prod_{i=1}^{I} MS_{ict} \right)^{1/I} \right] \quad \text{(A4)}$$

$$x^*_{ict} = \sum_{k=1}^{K-1} \beta_k (x_{kict} - (\sum_{i=1}^{I} x_{kict} / I)) = \sum_{k=1}^{K-1} \beta_k (x_{kict} - \bar{x}_{kct}) \quad \text{(A5)}$$

$$\begin{aligned} x^*_{CRS\_LOC,ic,t-1} &= \beta_{CRS\_LOC} (x_{CRS\_LOC,ic,t-1} - (\sum_{i=1}^{I} x_{CRS\_LOC,ic,t-1} / I)) \\ &= \beta_{CRS\_LOC} (x_{CRS\_LOC,ic,t-1} - \bar{x}_{CRS\_LOC,ic,t-1}) \end{aligned} \quad \text{(A6)}$$

$$\alpha^*_i = \alpha_1 + \sum_{j=2}^{J} (\alpha_j - \alpha_1 - \bar{\alpha}) \, d_j, \text{ with } d_j = 1 \text{ if } j=i \text{ and } 0 \text{ otherwise}^{11} \quad \text{(A7)}$$

$$\varepsilon^*_i = \varepsilon_i - \sum_{i=1}^{I} \varepsilon_i / I \quad \text{(A8)}$$

The log-centered dependent variable is denoted with an asterisk. The dependent variables that are marked with asterisks indicate differences from the arithmetic means of the variables. The term x^*_{kict} indicates the difference between the value of marketing mix variable k (for example advertising expenditures) for airline i in city-pair c during time t and the average of this variable's values for all competing airlines operating on this route during that period. When this difference is positive, the marketing mix variable has a beneficial impact on market share, provided its parameter estimate is positive. The most direct interpretation of the coefficient can be made in the context of the market share elasticity expression, presented earlier, which enables the computation of the percentage increase in market share for a unit change in an independent variable.

[11] The effect of the variable d_j here is to ensure that there is only one non-zero airline intercept term for each airline i.

The reader should note that this model includes a set of airline-specific intercept terms, denoted by a_i^*, which leads to a very large number of variables to estimate when there are many airlines. Because models of this sort were initially developed for use with scanner data in the context of brand management, it is important to ensure that a sufficient number of observations exist for each airline i included in the panel data set. If there are insufficient observations, the intercept terms will either be highly unstable, or it will be impossible to create parameter estimates for the model as a whole.

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