Appropriating Value From CRS Ownership in the Airline Industry

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ABSTRACT

It is difficult for the firm competing through information technology (**IT**) resources to gain a sustainable advantage because systems are easy to imitate and often substitute resources are available to competitors. The innovator may be unable to appropriate all of the benefits from IT investments. 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 appropriation of value by CRS owners from deploying systems in travel agencies. These benefits, beyond fees from travel agents, 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 (**MNL**) market share model that analyzes five years of data on 72 city-pair 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 benefits of their CRSs, turning them into highly specialized assets for further travel-related innovation. This work offers useful theoretical extensions and methodological approaches for the study of similar kinds of network technology innovations that are currently being deployed in association with electronic commerce on the Internet.

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

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1. INTRODUCTION

There is a growing body of Information Systems (**IS**), Organizational Theory and Economics research which seeks to demonstrate benefits from investing in information technology (**IT**). The purpose of this paper is to show how firms can appropriate the benefits from investments in IT for themselves, rather than see all benefits accrue to others parties such as imitators and late entrants. This paper views the challenge of attaining and sustaining an advantage from technology using theories of resource-based competition (Barney, 1991; Mata, Fuerst and Barney, 1995) and innovation (Teece, 1987). In particular the research focuses on a firm's ability to capture benefits from investing in IT to achieve critical mass in highly competitive markets. Such benefits extend beyond the traditional measures of cost savings and revenue that are directly attributable to a technology investment. Examples in electronic commerce on the Internet occur when a firm that creates a website for selling goods or services in a new distribution channels finds that its website has become something of a standard in the marketplace (such as the websites of eBay, Amazon.Com, FairMarket.Com and Yahoo), or when the outstanding quality of its "virual services" create a new basis for acquiring and maintaining effective customer relationships (Gateway 2000, Travelocity and Expedia, and AutoByTel).

1.1. Research Framework

Firms use their resources in a variety of ways to develop competitive and strategic advantage. To attain and sustain an advantage, firms need valuable, rare, imperfectly imitable and non-substitutable resources (Barney, 1991). Some companies that have applied resources to developing innovative applications of IT include Baxter (now Allegiance), American Airlines and Merrill Lynch. Firms apply financial, human and knowledge resources to innovate using technology, and in doing so, create a new technological resource that can become a basis for differentiation and competitive advantage. However, an organization faces a number of problems in obtaining a return from these investments because IT innovations are very hard to protect; IT applications, as we have recently seen with Amazon.Com and Barnes and Noble (through www.barnesandnoble.com), are easily imitated. In fact, Mata, Fuerst and Barney (1995) argue that the only resource-based IT advantage comes from unique IT management skills as "the technology" will become available to all. We believe there are other ways to obtain a resource-based advantage with IT, if one combines theories of resource-based advantage from Barney and innovation and appropriating benefits from Teece.

Value Appropriation. Teece (1987) 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. The innovator wants to obtain initial and ongoing benefits from its efforts; it wants to attain and sustain an advantage. It is clear from Teece's analysis that many IT innovations have weak appropriability; it is hard to legally protect their value 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 co-specialized assets needed to ensure adoption of an innovation. As an example, one reason that Microsoft's Internet Explorer, a Netscape imitator, has been so successful is Microsoft's control of the operating system, a co-specialized asset that a browser needs to operate. (Microsoft's competitors sought legal remedies, as a last-ditch attempt to protect their innovations.)

One way that a company can sustain a competitive advantage from IT, then, is to gain control of co-specialized assets needed for success. This strategy also denies these assets to competitors. Dos Santos and Peffers (1995) examined the rewards of technology innovations in automated teller machines (**ATMs**) using a framework that is partially based on Teece (1987). They argued that banks which innovated with ATMs first gained control of the best locations, a co-specialized asset needed for a bank's electronic banking service network to be successful. These benefits appeared and persisted in later years, even after the banks merged their proprietary networks into national networks. The competition for corporate auction listings that is currently underway between market-leading eBay and an upstart competitor, FairMarket.Com, is another good example where corporate members are the co-specialized assets. This has also true for the major Internet-only travel agencies, such as E-Travel, Preview Travel, Expedia Travel, GetThere.Com (formerly the Internet Travel Network (ITN)) and others, who fiercely compete for corporate travel relationships.

Most innovators attempt to appropriate the benefits from their IT investments, especially those returns that are originally predicted when undertaking the IT initiative. The predicted benefits from an IT investment often fall into the category of operational and business process cost savings, and occasionally revenue generation, too. Innovators would also like to capture the collateral benefits of the systems they invest in. In many cases, there is additional value for the firm to appropriate because of some second-order effects of the technology, and often these benefits were unanticipated when the original technology investment was made. For example, Mukhopadhyay and Mangal (1997) found that an IT innovation in toll collection had an unexpected, though beneficial effect on productivity. Labor turnover became less of a problem with the use of a new system since it reduced learning time for replacement workers. And in the airline industry, when American Airlines and United Airlines implemented their first generation computerized reservation systems (**CRSs**) in the late 1970s, the primary motivation for doing so was productivity gains that would result from displacing the call center reservation-taking workforce. Only

Table 1. The Sources of Benefits from IT Investment

SOURCE OF BENEFITS	EXAMPLES
Making it easier to do business with the innovator	SPS Commerce is working with Sears, Dayton Hudson and JoAnn Stores to develop XML-based EDI capabilities for e-business on the World Wide Web to make it easier for buyers and suppliers to share business process information, and strengthen business relationships.
Encouraging business by using technology to transform the nature of the product that is consumed	FedEx and UPS Web sites for tracking packages encourage customers to use carriers for more shipments because of tracking convenience and informational advantages.
Creating demand side network externalities for technology adopters through standard solutions	Nationsbank/Bank America has pushed the "Gold Standard" solution of a consortium-led firm called Integrion Inc., to create a basis for bank and vendor adoption of electronic bill presentment and payment innovations.
Using IT to provide outstanding customer service	Cisco Systems, Land's End and Dell use mass customized selling techniques on the World Wide Web to enable their customers to configure their own product purchase bundles.
Using IT to create biased markets	Various websites' use of low price-finding intelligent agent software that favorably compares the vendors' prices to other competitors' prices.

later would the innovations with CRS technology create opportunities to implement and leverage revenue yield management systems for revenue side productivity and price recovery.

The Sources of Benefits from IT Investment. Table 1 describes some ways in which other collateral benefits accrue to the firm that innovates with IT. (See Table 1.)

In each of the examples in Table 1 a system has had a collateral impact for its developer. A well-implemented EDI capability saves ordering and order fulfillment costs; it also makes a supplier firm with EDI capabilities easier for a buyer to use. When the Extensible Markup Language (**XML**) is used as a basis for EDI on the World Wide Web, it is possible to create value by representing business process-specific knowledge, enhancing connectivity and streamlining interorganizational information sharing. The FedEx and UPS Web sites allow customers to track packages without contacting a company representative. The companies reduce costs through less frequent use of 1-800 customer service numbers and the need for fewer service agents in the presence of a transformed product. Today, FedEx and UPS bundle highly valuable information with their physical service of moving packages. The firms should obtain collateral benefits as the sites encourage customers to place more business with the carrier.

Nationsbank, now merged with Bank America, was an early leader in technological innovations to support electronic bill presentment and payment. It built a consortium of banking, technology and vendor firms that will broadly benefit from the development of industry "standard" solutions for handling billing via the World Wide Web. The technology solution, called the "Gold Standard," was formulated in the context of a consortium provider for electronic billing services, Integrion Inc. (www.integrion.com), with the intent that additional network externality-based value is developed in the marketplace through widespread adoption. The benefits associated with vendor and banking firm adoption of Integrion's services will be based on the extent to which the technology solution provides connectivity in the marketplace, and not just through the productivity and cost displacement effects of using the World Wide Web. Similar to McKesson's early development of its Economost system to reduce costs,
increase volume, and provide superb customer service for its pharmacy customers (Clemons and Row, 1988), today we see many firms utilizing the Internet to take advantage of the capabilities of new technological innovation to foster customer intimacy, one-to-one marketing and mass customization. Cisco, Dell and Land's End have all learned to effectively use this new distribution channel of the Internet to increase their revenues and provide outstanding customer service.

Finally, other appropriable benefits accrue from *biased markets*, a result of many proprietary order entry systems (Malone, Benjamin and Yates, 1987). Customers find these systems easy and attractive to use; they offer greater control and valuable process integration. But the innovator biases the market by featuring only its own products or by giving them preference. Biased markets were evident in the late 1970s in the airline industry, leading up to congressional legislation in the early 1980s to ban biased fare presentations in the major CRSs. Today we see biased markets with intelligent agent software that is used by firms that sell on the World Wide Web to cast their less-than-competitive prices in a favorable light relative to the competition.

The reader should note that the benefits in Table 1 were not necessarily expected when the companies made their original investments in the various IT innovations; in fact, for the most part these benefits would certainly have been difficult to forecast *a priori*. In general, we believe that the greater the distance in business process terms between where the investment occurs and where benefits appear, the more likely that the benefits are to be viewed within the firm as collateral benefits (Davern and Kauffman, forthcoming).

1.2. Airline CRS, Value Appropriation and Resource-Based Advantage

The airline industry provides a unique opportunity to examine resource-based competitive advantage by appropriating a variety of benefits from a technological innovation.

The Early Days of Airline CRSs. American Airlines 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, 1988). American chose to solve its reservations problems by applying financial, human and knowledge resources to develop a new technology; it began to move along a path that provided major benefits for the airline at each step.

After the initial investment, the SABRE system became a technological resource for American that was valuable and rare (Barney, 1991). Unfortunately for American, however, it was imitable and eventually substitutable. American's CRS had extremely *weak value appropriability* as a group of other airlines, including United, quickly imitated American. Later, IBM offered a packaged system called PARS to any airline, based on its joint work with American in developing the SABRE system. The challenge was clear: how could American and other CRS developers both create and sustain an advantage from their reservations systems, and appropriate high levels of business value in the process?

Until the advent of the World Wide Web in the 1990s, there were just two historic channels for selling airline reservations: the airlines themselves, and travel agencies. The deployment of bank ATMs provides insights on channel competition in the airline industry. For example, Dos Santos and Peffers (1995) argued that banks which first invested in ATM technology acquired *co-specialized assets* that would not be available to followers, in this instance, the best locations for ATMs. Later, as shared electronic banking networks emerged, banking members became important co-specialized assets for the ATM network (Kauffman, McAndrews and Wang, forthcoming). Once acquired, a network provider blocked any other competitor from delivering services on behalf of the member bank's customers, limiting opportunities for imitation. The national electronic banking networks, CIRRUS and PLUS, chose "universality" (a transaction switching and sharing regime) in the 1980s that replaced the "duality" of the 1980s (two separate but equal networks, two different operating infrastructures, etc.) (Kauffman and Wang, forthcoming). Apparently the separate systems had reached the "glass ceiling" of co-specialized asset value.

The Co-Specialized Asset Analysis. How can this co-specialized asset analysis be applied to airline CRSs? One way for the CRS developer to protect its innovation, to make it more difficult for competitors to imitate or substitute for its CRS resource, was to offer the system to travel agents and lock in this distribution channel. Through this strategy the CRS vendor "acquired" a co-specialized asset in the form of the most successful and desirable travel agencies. The airline also denied these assets to competing CRS vendors, making its reservation system less imitable and less substitutable.

Similar to the banks, the airlines also created very high switching costs so that once acquired, the travel agent could not easily move to another vendor. Five-year service contracts that were extended for another five years any time new equipment was installed were not unusual, and liquidated damages clauses in the CRS contracts made it very expensive for a travel agency to switch CRS vendors. The CRS vendors also came to recognize the channel power they could effect by developing markets that were biased in their favor, for example, by listing their flights first on the reservations screens (Copeland and McKenney, 1988).

Expanding the system to travel agents also created economies of scope through the inclusion of more capabilities in the system; the capabilities came to include those that are common in most industry global distribution systems (**GDSs**) today. These include the ability to reserve rental cars and hotel rooms. As airlines with CRSs invested more resources in the technology, the CRS system, itself, became a highly specialized asset that an airline needed to offer further innovative travel services. This continued path of development and enhancements helped the CRS resource become more valuable, rare and more difficult to imitate or substitute for; and these characteristics turned the reservations system into a resource for competitive advantage (Barney, 1991). Reflecting the value in the marketplace that was being contested, the competition among CRS vendors and non-vendor airlines has been intense and, at times, even bitter; there have been many lawsuits and appeals for regulation during the history of these systems.

Resource-Based Advantages for First Movers. In 1976 United and American Airlines began installing terminals, connected to the airlines' CRSs, in travel agents' offices (Copeland and McKenney, 1988). Several other airlines quickly imitated their tactics. Some observers argue that CRS vendor airlines did so to protect their innovations and to keep competitors from imitating them. The CRS vendors received immediate benefits from booking fees and charges to travel agents. And, if the various lawsuits and legislative directives of the early 1980s are any indication, the vendors also obtained other unpredicated but highly valuable benefits through the biased markets made possible with their CRS . As a result, the airlines strengthened their *appropriability regime* (i.e., their ability to appropriate the benefits of technological innovation) through their influence on travel agencies (the co-specialized assets in this instance), while turning their reservations systems into highly specialized resources for further travel-related innovation. These CRS vendor airlines followed a unique path in applying their resources; once the majority of travel agents had chosen a CRS vendor, another airline would have great difficulty following the same path to obtain or equalize the competitive advantage of the first-movers (Barney, 1991; Mata, Fuerst and Barney, 1995). In fact, most CRS vendors required the exclusive use of their system by a travel agent during the time period of this study.

Many of the benefits described above are enjoyed by all airlines whose flights are listed in a CRS. What are the benefits to the *owner* of a system? The economics literature on externalities suggests that the value of a network increases as the number of its locations increases (Farrell and Saloner, 1986;

Saloner and Shepard, 1995). How might 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 for the vendor with a large installed base of terminals. Until it was eliminated by government regulation in 1984, CRS vendors routinely listed their own flights first on the reservations display. Copeland and McKenney (1988) report that by 1983 over 70% of flights were booked from the first screen and more recent estimates put this number at 90% to 95%. Screen bias favored the CRS host airline that displayed its flights first. Even though rules by the Civil Aeronautics Board (**CAB**) at first, and later by the Department of Transportation (**DOT**), 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 benefit for the CRS vendor has been referred to as 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 greater familiarity with the airline and more 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 a technological innovation reaches a critical mass, these benefits become more likely to occur, illustrating the role of IT as a differentiator in the market.

In summary, from the perspectives of Barney and Teece, certain airlines had the resources and foresight to develop CRSs; but they faced an environment with weak appropriability as the innovation was imitable and substitutable. Through deployment of CRS terminals in high volume travel agencies, they gained control of crucial co-specialized assets, strengthening the appropriability regimes of their IT innovations. They saw the potential of the systems and became the eventual "winners" in the CRS battles. The CRS vendors illustrate the path-dependent nature of a resource-based competitive advantage; these vendors developed a system for their own use and deployed it to travel agents to establish and sustain an advantage. CRS vendors added features for travel agents that made the reservations system an even more valuable resource, one capable of providing a sustained advantage. Today, it would be prohibitively expensive and a major technological challenge for a competitor to create the kind of CRS required for travel agency use.

1.3. Hypotheses and Key Features of the Study

Based on the reasoning above, we believe that the CRS vendors obtained significant benefits from the resources they invested in IT and their efforts to strengthen their regimes of value appropriability.

Hypotheses. We predict that benefits accruing from (1) the technological innovation, (2) the co-specialized assets developed by the airlines, (3) the network externalities, and (4) the outstanding customer service associated with the CRSs increased a CRS vendor's market share beyond what might be expected in cities where the vendor has high agency penetration. Under these conditions the CRS vendor controls one channel for reservations and the system becomes a kind of governance mechanism within the market. A high market share of CRS installations effectively blocks imitators from appropriating the benefits of CRS deployment to travel agencies. In addition, assuming that CRS technologies alone did not change market demand for airline reservations, a travel agent's favoritism for a CRS vendor's flights further increases the vendor's business in a market at the expense of its competitors (even in the absence of screen bias). Higher market share in enough individual markets should then be reflected in stronger airline performance at the aggregate industry level.

This reasoning leads to two hypotheses related to the benefits of CRS ownership and deployment in travel agencies and the co-specialized assets thus created:

- ***The Enhanced Market Share Hypothesis:*** *A CRS vendor's deployment of agency automation in local markets produces a co-specialized asset that is reflected in a positive association between CRS agency locations and that airline's market share of revenue-producing passenger miles between the city-pairs comprising its route structure.*
- ***The Overall Airline Performance Hypothesis:*** *A CRS vendor's national installed base of agencies produces an aggregate co-specialized asset that will be positively associated with the airline's overall performance.*

Key Features of the Study.[1] This article first presents a city-pair model to assess the impact of CRS ownership and deployment on the vendor's market share in 72 selected city-pairs. 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. Two levels of analysis help to ensure that: (1) the results are developed on the basis of a well thought out approach to the discovery of the main effects, (2) the results reflect the extent to which disaggregated regional and city-pair-specific results actually aggregate up to the level of national performance, (3) there is logical consistency between the kinds of theoretical and methodological perspectives that are used, and (4) evidence and insights from prior research at various levels of analysis can be exploited to the fullest.

In spite of the fact that there are only 7 carriers that deployed CRS in our data set among 37 airlines in total, there is substantial variation in the marketplace: (1) the CRS vendors did not concentrate on deploying in all the same markets to the same extent, (2) some are better represented with agency automation than others in specific markets, (3) the competitive balance for the CRS vendors changed

[1] The authors thank the anonymous reviewers and the associate editor for suggestions on the positioning of the theoretical, methodological and applied aspects of this research, as reflected in this Introduction to the article.

over time in various markets, and (4) CRS deployment was but one aspect of more complex set of marketing mix decisions by the airlines that varied by region over time. These aspects, in combination with our discussion of endogeneity and simultaneity in IT investment, and other threats to the validity of our study, should provide confidence in the results. We also believe that the results of this research are useful in understanding value appropriation for technological innovations in electronic commerce in the emerging "fourth channel" of the Internet, a subject that we discuss at greater length in the Conclusion.

2. PRIOR RESEARCH

There are three streams of literature which are relevant to the present study: research on IT value, economic analyses of airline firm and airline industry performance, and studies that highlight the mechanics of technology adoption and firm development of new distribution channels.

2.1. The Impact of Technology on Organizational Performance

There has been significant interest in the problem of establishing the business value of IT since the 1970s (e.g., Lucas (1975)).

IT Value from an Industry Study Perspective. Some of the more useful studies in the literature have focused on specific industries in depth, and are aligned with the kind of analysis approach that we are taking in this article. 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. More recently, Davamanirajan et al. (1999) examined the extent to which electronic integration in trade finance and letter of credit operations in international banking delivers value for banking firms. Their econometric results were indicative of the value of IT at various levels in business process and organizational contexts.

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 significant return from firms' investments in information technology, 54% in manufacturing and 68% combining manufacturing and services firms. These estimates of return are unusually high. 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. Another 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). It has proven difficult to trace investments in technology to aggregate performance measures.

Causality in IT Value Research. Generalizing from the studies we just reviewed, it is fair to say that empirical research at 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 have shown more positive results. Brynjolfsson (1993) provides reasons why the apparently lackluster estimated returns from investing in IT may be occurring. He points to 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.

The larger issue is *causality* (Lucas, 1993 and 1999). Causality becomes an issue in IT value research at several different levels of analysis. For example, drawing on the well-known work of Cohen, March and Olsen (1972), Lucas (1999) characterizes the process of IT investment *within the firm* as a "garbage can model." Many IT investment initiatives of the firm should not be misconstrued as the purposeful plans that develop out of well-defined tactical and strategic thinking. Instead, Lucas reminds us that many highly effective IT investments result from learning-by-doing, adjustments made to a business process, and managerial learning from "the accidents of prior experience" (Lucas 1999, p. 26). The picture he sketches about firm investments in IT is further complicated by disparate agendas of various stakeholders who do not always equally divide the value that accrues from IT.

A second aspect of the causality problem for IT investments and value has been pointed out often by Strassmann (1990), who emphasizes that causal relationships between investment and returns must be interpreted in the context of managerial strategy and implementation success as "return on management This point of view ties in well with our own: managerial strategy for the firm in the marketplace plays a significant role in determining returns on investments in agency automation in the airline and travel industries. For this reason we stress the role of co-specialized assets relative to CRS deployment, and the extent to which installed base of the systems in travel agencies is an enabler of value.

One of the key challenges that we face with this research is that of "reverse causality," as discussed by Weill (1992). *Reverse causation* occurs when firm performance, in some way, is the primary determinant of IT investment. In the valve industry setting that the author investigated, it was unclear to what extent prior firm performance created resources for new IT investment. As a result of their prior performance, some firms were able to invest more in IT, with the result that the observed greater levels of IT investment were associated with higher levels of firm performance. The issue, as we see it, is whether the analyst is able to establish *precedence relationships for IT value* over time. Thus, one should analyze IT investments in periods prior to the current period to find performance associations, instead of in the same period, when causation is less likely to have been expressed. Without the appropriate precedence relationship in place between investment and value, the results of empirical work on IT value are always subject to questions about causality.

2.2. Research on Airline Firm and Airline Industry 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 2.)

Table 2. Summary of Airline Performance Research

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 (**MCI**) model for airline market share	Airline market share in city-pairs, CRS deployment	CRS deployment in agencies positively related to market share

Caves, Christensen and Tretheway (1981) estimated total factor productivity for 11 major 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. The authors found that airlines with longer average stage lengths (average length of flights on the airline) and higher load factors had higher productivity levels.

Sickles (1985) tested a non-linear model of technology and specific factor productivity growth on a panel of sixteen domestic American 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 (**DOT**) (1988) developed a model of an airline's share of revenue from agents using its CRS for one year, focusing on *commission overrides* -- an extra payment for booking a flight on that airline -- 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 from each airline in the model. This model was estimated for travel agents using a CRS for the year 1986 in 57 consolidated metropolitan statistical areas (**MSAs**) 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 offering airline and fewer bookings for competing airlines. Data of the sort used in this research only has been available to researchers who are working in conjunction with the regulators of the airline industry.

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 shares 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, Banker and Johnston (1995) 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.

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 reviewed above, relies on production economics.

Four Dependent Variables and Two Levels of Modeling Aggregation. We model the impact of CRS in terms of four dependent variables, including *market share, revenue passenger miles, load factor* and *operating profits.* Although market share and load factor are relative measures of performance, they are appropriate because they are founded on absolute measures of production. Market share, for example, is market share of ticketing revenues, which are influenced by various production and pricing choices aimed at maximizing profit and minimizing costs. By the same token, load factor is founded on ticketed seats relative to airline fleet capacity. Again, airline firms aim to maximize profit through ticketing revenues, while minimizing excess capacity.

We perform analyses of CRS value at two levels of aggregation: at the city-pair level and at the industry level. As discussed in the Introduction we expect to see both disaggregated market-level effects and aggregate national effects. Each model incorporates different methodologies to provide greater rigor.

"Critical Mass" CRS Deployment and Independent Variables. 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 makes it possible 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 for explaining how a firm appropriates benefits from an IT investment: co-specialized assets and network externalities accruing to a CRS vendor through agency automation create a resource that, over time, ought to exhibit a critical mass effect for an airline in its markets.

To assess the impact of CRS ownership on the overall performance of an airline at the industry level, we employ several different econometric models. The primary independent variable that we selected for testing the hypotheses, *CRS locations,* measures the number of travel agencies using a particular CRS vendor's system in each year of the study. Our general approach to modeling is to also include 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. Prior research has demonstrated that these variables are associated with airline performance, and we include them in the model to isolate the effects of CRS locations on performance.

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.

Omitted Variables and Airline Size. All empirical research is subject to the criticism of omitted variables: variables that the researchers did not include in their model because they were unaware of them or because they could not be measured. In some cases, the effects are severe, while in others they are benign. In this study, we know of two omitted variables that could affect the results: *frequent flyer programs* and *fare overrides for travel agents*. The airline industry is highly competitive, and the roll out of one airline firm's frequent flyer program most often led to a similar program by the competition. Measures that we had available to us included the dates of announcements of frequent flyer programs, and whether a particular carrier had a program in effect in a given year. We experimented with these variables in both the national and the city-pair models that we will soon describe in detail, and found that frequent flyer programs were typically a function of airline size, more than anything else. The larger the airline, the more likely the airline was to have a frequent flyer program, and the earlier it was implemented.

Our theory argues that frequent flyer programs are imitable, and we believe that over a multi-year period, any short-term advantage from frequent flyer programs was competed away. The same is probably true for fare overrides and other behind-the-scenes deals and incentives that the CRS vendors offered. These arrangements are based on private contracting, and were not reported in any data source to which we had access. Anecdotal evidence that we picked up in our field study suggested that when such fare overrides were in place, other airlines respond quickly with discounted tickets and other kinds of travel agent incentives. Thus, based on past research, we believe that the included in our models and the nature of airline competition minimize the difficulties associated with omitted variables.

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

$$\text{Airline Performance} = f\,(\text{Stage Length, Number of Departures, Advertising, Strikes, Fares, CRS Locations}) \qquad (1)$$

3.2. Variables and Data Collection

The two major airline CRS vendors during the period of our study were American and United. These two carriers had about 70% of the agency automation business in the U.S. at that time. Delta, Eastern and TWA also adopted a strategy of agency automation, but their market shares were lower. The large CRS vendor airlines and systems included in this study are American (**SABRE**), United (**APOLLO**), Delta (**DATAS II**), TWA (**PARS I and II**) and Eastern (**SYSTEM ONE**), as well as several other smaller ones. Since the purpose of this paper is to assess the ability of airline CRS vendors to appropriate the benefits of agency automation through co-specialized assets, we do **not** consider the revenue generated by reservations systems in the form of charges to other airlines for booking their flights. The study encompasses the 1976-1987 time period when the CRS vendor airlines implemented their strategy of deploying reservations terminals in travel agencies. Table 3 contains the variables used in the study. (See Table 3.)

We model the benefits of CRS ownership by measuring the *number of travel agencies or CRS locations* -- **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; and it represents the extent to which a co-specialized asset can protect against imitators and strengthen appropriability. 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. (See Copeland and McKenney, 1988, for details.) On the city level, a proprietary study by an independent industry research firm provided us with data on the distribution of CRS among travel agencies in selected cities for a five-year period.

Table 3. Data Sources

VARIABLES	DEFINITION	SOURCE	INDUSTRY MODEL	CITY-PAIR MODEL
Independent Variables:				
CRS_LOC	Number of travel agencies nationally with CRS Number of travel agencies in city-pair markets with CRS	Copeland & McKenny (1988); proprietary database from an 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	Arbitron 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
Δ_VEH_MILES	First difference of air transportation vehicle miles between years t and t-1	DOT and BTS records	X	
Dependent Variables:				
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

The *average stage length* variable -- **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, as mentioned above. A longer stage length also 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.

We obtained data on average stage length for each airline from the I.P. Sharp electronic airline database (Reuters/I.P. Sharp Ltd., 1988a and 1988b), a major source of data for this study. This database is derived from the Department of Transportation (**DOT**) 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 describing an airline's operations. The number of departures variable -- **#_DEPARTS** -- is likely to be correlated with airline revenue, and was also available from I. P. Sharp. 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 schedule. The number of departures is also a good proxy measure for airline size, since larger airlines have more flights in general.

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 (**ATAA**) conference proceedings (1987), and industry periodicals. The STRIKE variable was not included in industry-level models; based on prior research, we learned that limited duration strikes had little or no impact on aggregate airline performance. Moreover, the air traffic controllers' strike, the largest event of this sort to occur during the time frame of our study, did not appear to affect yearly performance statistics differentially by airline, based on checks we performed. 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 change in vehicle miles variable (**Δ_VEH_MILES**) is the first difference of air transportation vehicle miles for each year in the data set. It is included as a control variable for growth in business in the national model.

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 for this variable, as they are not considered controllable in the short run. As we mentioned earlier, fees from CRS subsidiaries are also excluded from this measure; we subtracted the "Miscellaneous Revenue" account on Form 41 where CRS fees are reported from revenues to ensure that our assessment of CRS impacts was not confounded by this highly direct measure.

The final dependent variable is *market share* (**MS**), which is 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 on for each city-pair.

4. THE CITY-PAIR LEVEL: MODEL AND RESULTS

The first hypothesis to be addressed in this research is whether a CRS vendor's deployment of agency automation in local markets yields a co-specialized asset that is reflected in a positive association of agency CRS locations with that airline's market share of revenue-producing passenger miles between the city-pairs in its route structure. We explore this relationship using market share modeling methods from Marketing Science.

4.1. The Intuition Behind Market Share Models.

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. For the most part, users of market share modeling methods typically include the major ingredients of a firm's "marketing mix": its advertising, product pricing, sales force effort, product features and quality, and so on in their analysis. The variables are typically observable in the marketplace to the firm's consumers and that are controllable by the seller. As a result, marketing mix choices reflect firm strategies, and they can be analyzed on a period-to-period basis taking into account the changing conditions in the marketplace. They may also reflect the fact that a prior period's elements in the mix may be important, especially where there is the likelihood of "critical mass" effects. In this article, we use CRS installed base and other independent variables from Table 3 to constitute each airline's strategy or "marketing mix." The variables in the model -- especially the number of CRS locations deployed as a proxy for a firm's co-specialized assets -- determine the relative likelihood of the consumer of flying on the airline. Agency automation infrastructures through the CRS locations are unlikely to have an immediate impact on firm performance. It requires some time for an agency to train its personnel and to integrate the CRS into workflows. As a result, one might expect that it would take a period of months -- or even up to one year -- for the full range of benefits to be captured by the agency and by the airline.

4.2. The City-Pair Route Market Share Model

Market share models offer a number of highly desirable features for their use in the econometric analysis of marketing mix data. *First,* one 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, for example). Nonetheless, analysts have used such models to gain insights into a variety of related issues: the current state of market competition, the relative effectiveness of different marketing mix approaches, the strength of one competitor relative to another to a group of others, the impact of new production introduction and more (Cooper and Nakanishi, 1988).

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 about the structure of the econometric estimation problem. Market share models that enable logically consistent estimates are usually specified in ratio form (e.g., 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.

4.2.1. Specifying a Model.[2] In order to use a model of the form shown in Equation 2 to estimate the impact of the number of CRS locations deployed on city-pair market shares, we made several tactical decisions that would allow us to provide evidence for the appropriability of the benefits.

[2] A number of questions came up in the review process for this article about the *ratio specification* of the market share modeling approach that we have used here, and the choices we made about measurements for the variables that are included in the model. We stress that the modeling choices that we have made are generally consistent with approaches in the literature on Marketing Science (e.g., Cooper and Nakanishi, 1988). Also, wherever we found an

- **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;* other functional forms are possible as well.
- **Second was to determine how to most appropriately handle what we know about elasticity of market share.** 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 about 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 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. We next discuss the variables in the MNL model.

4.2.2. Variables in the City-Pair Model. The dependent variable for the city-pair analysis is market share. This measure is 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, as we commented earlier, there is likely to be a learning curve for agency personnel that will create

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opportunity, we have leveraged choices that we had about handling functional form, variable specification including lags (by tying them in with perspectives that were developed in our field study and other studies), and our knowledge of the information structure of the data set relative to market competition. Including independent variables such as lagged market share or a linear time trend for market share were not appropriate, since they move the intuition of our model away from its core elements: the representation of the marketing mix of the airline firm.

limits to the immediate appropriation of value. We expect that the full impact of automating a travel agency should be felt during the year after the automation occurs. The reader should note that the installed base of terminals was growing each year for the CRS vendors 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, and endogeneity as well, in our model. Based on prior findings from Doganis (1985), we expect to find a weak association between advertising and market share. We also expect fares to influence market shares at the city-pair level because airlines are quite competitive on given routes. In addition, a strike, rare though they may be, can have a major impact on the market share of an airline between two cities. Finally, average stage length, a variable that is often used in prior 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.

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

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 the 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 arithmetic 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.)

4.3. 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) out of a possible set of 240 city-pairs worth of proprietary CRS location data that were made available to us by a private research organization (16 origins by 15 destinations). The extent of the penetration of agency automation by multiple vendors in the sixteen cities was widespread, especially in the city-pair competition we model, as shown in Table 4. (See Table 4.)

Our initial data set included over 25,000 records. We later culled that data to include just 2,309 observations that were relevant to our analysis by 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 in our data set all of the origin and destination cities that act as hubs for a carrier since a carrier will be more likely to be dominant, or act as though it is in a non-contestible market in that city than its competitors would (e.g., Newark, Dallas/Fort Worth, Atlanta, St. Louis, and Houston.) By contrast, the non-operational hubs of Denver, Detroit and Seattle were omitted because of missing data on agency automation.
- **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 36, and often many fewer in some city-pairs.
- **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 make estimating an intercept an attractive proposition: the coefficient estimates would have been very unreliable.

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 none of these cities was an "operational hub" during the period of this study, we do not include an independent variable to reflect the associated excess concentration in the marketplace. The steps yielded 72 city-pairs (9 origins by 8 destinations) for analysis, when pairs with identical origins and destinations were eliminated. The resulting data set covers the time when CRS vendors were most actively competing for an installed base

Table 4. Representation of CRS Vendor by Origin City By Year for Sixteen Origin Cities, 1983-1987

CITY	RESERVEC	SABRE	DATAS II	SODAS	SYSTEM ONE	TYMSHARE	PARS I / II	APOLLO
YEAR	83 84 85 86 87	83 84 85 86 87	83 84 85 86 87	83 84 85 86 87	83 84 85 86 87	83 84 85 86 87	83 84 85 86 87	83 84 85 86 87
ATL	- - - - X	- - - - X	- - - - X	- - - - X	- - - - X	- - - - X	- - - - X	- - - - X
BOS**	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
CHI**	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
DAL	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
DEN	- X X X X	- X X X X	- X X X X	- X X X X	- X X X X	- X X X X	- X X X X	- X X X X
DET	- - - X X	- - - X X	- - - X X	- - - X X	- - - X X	- - - X X	- - - X X	- - - X X
DC**	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
HOU	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
LA**	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
MIA**	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
NYC**	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
PHL**	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
SD**	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
SF**	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
SEA	- X X X X	- X X X X	- X X X X	- X X X X	- X X X X	- X X X X	- X X X X	- X X X X
STL	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X

Notes:

- **Coding.** We assigned an "X" to mean that there were CRS locations deployed by a specific CRS vendor in an origin city in a specific year, and "-" otherwise.
- **Data Source.** The data were obtained from an independent research firm, whose owner cannot be disclosed by prior agreement written agreement.
- **Omitted CRSs.** This table includes data for all CRSs with the exception of SMART, PACER, DART/ACURES, and PEGASUS 2000, for which no data were available from the data source.
- **Cities Included in City-Pairs Analyzed.** We included Boston, Chicago, Los Angeles, Miami, New York, Philadelphia, San Diego, San Francisco and Washington, DC (marked with "**"). The remaining cities were excluded for various reasons: lack of available data on CRS locations, monopoly or duopoly competition, or other problems with the data. The CRSs RESERVEC, SODAS and TYMSHARE were not represented in our city-pair data set, though we show market coverage information here.
- **Carriers in the Data Set Deploying CRS.** The city-pair data set has six carriers that deployed CRSs -- American, Continental, Delta, Eastern, TWA and United, and 37 that did not. However, not all of the carriers (CRS and non-CRS airlines alike) are represented in every city-pair in every year.

in travel agencies. Copeland and McKenney (1988) indicate that by 1987 an estimated 95% of agencies were automated and the competition changed to displacing an existing vendors' CRS in order to install one's own.

Figure 1 shows the variation in the number of CRS locations on city-by-city basis, for the nine origin cities. These graphs demonstrate that there is extensive variation in the deployment of CRSs in travel agencies by the different carriers in each origin city. The figure also illustrates that among the five major CRSs, only SABRE and APOLLO were consolidating market share of CRS locations. (See Figure 1.)

4.3.1. Econometric Issues

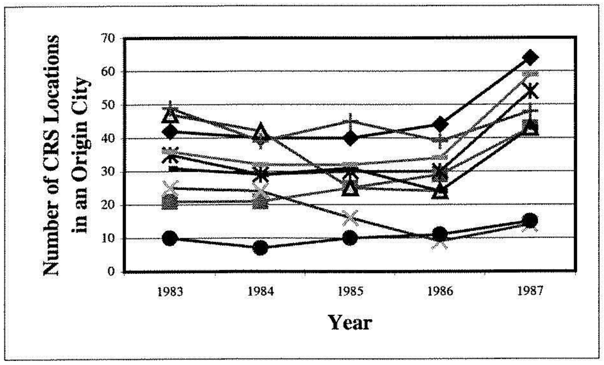
The econometric issues we addressed prior to estimation of the model included *omitted variables* (as previously discussed), *native collinearity* (both pairwise correlation and multicollinearity), *model-induced multicollinearity*, *autocorrelation*, *heteroskedasticity* and *endogeity*. We performed a number of diagnostics. 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.[3]

We also addressed the possibility of *autocorrelated disturbances*. One approach is to first-difference the data (as in the MCI model of Banker and Johnston, 1995). Another is to move 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. The panel of data was wide, but not long. A second alternative, to correct the covariance matrix for autocorrelation using Kmenta's (1986) procedure, would have resulted in the loss of many more observations due to our unbalanced sample. It also would have left just the very large airlines. We settled on a diagnostic alternative in which we selected individual years cross-sectionally, and then ran a sub-sample with an earlier (e.g, 1984) and then a later year (e.g., 1987) of data. This process enabled us to examine the cross-sectional stability of the coefficient estimates across various sub-samples. With this "jackknifing" approach," we observed stable coefficient estimates throughout, with only minor exceptions, and these seemed to be unrelated to the CRS locations variable.

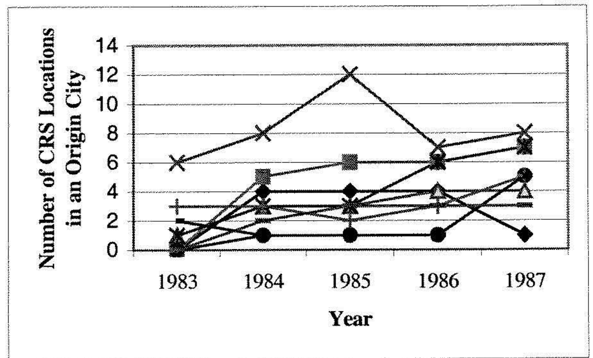
[3] Although we analyzed this data using the heteroskedasticity-corrected models whose results are discussed later in this section, we were only able to do so by cumulating the observations to establish a "unit" or "small carrier" intercept. The "small carrier" intercept was insignificant, however, and further analysis of some 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.

Figure 1. Number of CRS Locations in Nine Origin Cities for Five Major Carriers, 1983-1987

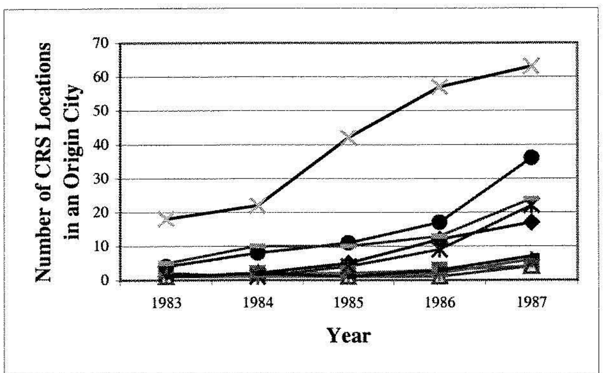
a. American Airlines (SABRE)



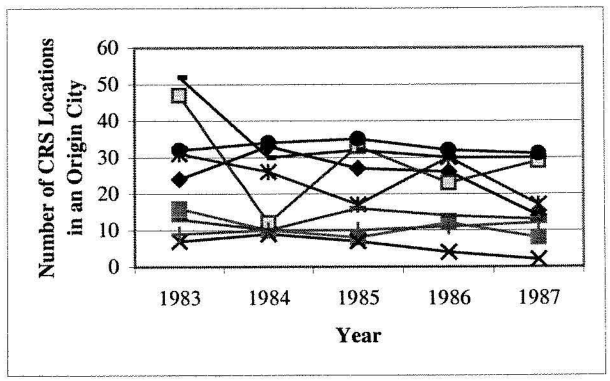
b. Delta Airlines (DATAS II)



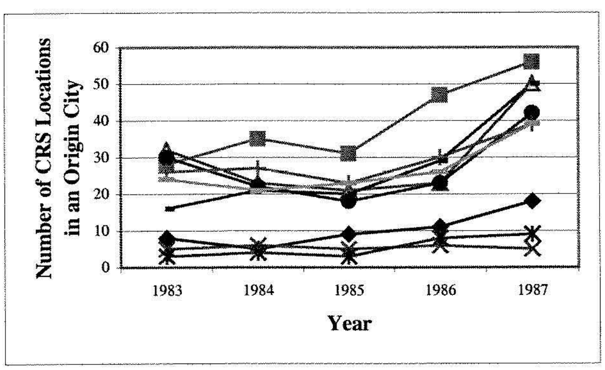
c. Eastern Airlines (SYSTEM ONE)



d. Trans World Airlines (PARS I & II)



e. United Airlines (APOLLO)



Note: There are nine lines in each of the air carrier / CRS vendor CRS location graphs shown here. Each line represents the number of CRS locations for an origin city in the 72 city-pairs. Each carrier's CRS location variable in the MNL model for the marketing mix at time t is built from its number of CRS locations in the origin city at time t-1. Each carrier's number of CRS location is then adjusted by the artithmetic mean of all carriers' CRS locations in the market. The origin cities are Boston, Chicago, Washington D.C., Los Angeles, Miami, New York, Philadelphia, San Diego and Seattle. The graphs show the variation in numbers of CRS locations in the various origin cities. In addition, it shows that Sabre and Apollo were consolidating their market shares of CRS locations in the city-pair markets during the 1983-1987. Information on Continental's SODAS CRS is not presented, because it only began deploying locations in late1986 and early 1987.

The next issue was *heteroskedasticity.* The city-pairs included in our analysis exhibit two-firm market shares that varied between 69% and 89%, as was common during the period, 1983 to 1987. Such oligopolistic competition essentially 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. We then corrected the data for heteroskedasticity using White's (1980) estimator to obtain an appropriate covariance weighting matrix to apply to the data, which then produces unbiased ordinary 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. Moreover, 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 simple intuition of a proportional effect. Breusch-Pagan (1979) is tailored to situations where it is difficult to identify what might cause heteroskedasticity.

The final issue that deserves comment here is *simultaneity and endogenous variables.* According to Judge et al. (1985), "*endogenous, or jointly determined variables*, have outcome values determined through joint interaction with other variables in the system; ... *endogenous variables* affect the outcomes of the exogenous variables, but their values are determined outside the system." (p. 564). In the airline CRS context, one might argue that CRS deployment is *jointly determined* by the dependent variable, market share of revenue passenger miles. Senior managers at airline firms are aware that it generally pays to deploy agency automation where the impact is likely to be the greatest. (We note that this is generally the case in most IT investment settings.) In situations where such *simultaneity* occurs, a number of methods are available to the analyst to enable the data to be handled appropriately. (See, for

[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, $Var[\varepsilon_t | \varepsilon_{t-s}]$, 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, however, since we were unable to establish a basis for its measurement with data to which we had access.

[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.

example, Kennedy, 1985, pp. 126-137.) The method that we selected for this study, given the availability of the data, was to lag the CRS location variables. As Judge et al. (1985) point out, "[l]agged variables may be placed in the same category as exogenous variables since for the current period the observed values are predetermined" (p. 565).[6]

4.3.2. Estimation Results

Table 5 presents the results from the MNL market share analysis using White's covariance matrix correction. (See Table 5.)

Based on 2309 observations, the model explains over 55% of the variance in log-centered market share. 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. Moreover, 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.

[6] The reader should understand that we do **not** denythe presence of simultaneity, and the possibility that *reverse causation* may be present. This problem occurs in many IT investment settings, not just here. However, econometric methods provide a spectrum of choices for balancing the complexity of the econometric model with the structure of the information contained in the data set, and the availability of data to supporta chosen approach.

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 EXPRESS[7]	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:

1. **Significance Levels:** **** = p<.01, ** = p<.05 and * = p <.10.*
2. **Model fit:** R^2 = 56.7%; Adjusted R^2 = 56.2%; F[19,2289] = 15.71.
3. **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.
4. **Intercepts:** None for American Airlines included to avoid perfect collinearity; through its omission, American acts as base case comparison with other carriers.
5. **Heteroskedasticity:** Diagnosed via the Breusch-Pagan (1979) Lagrange multiplier test for the hypothesis that the model is homoskedastic, i.e., $\gamma = \mathbf{0}$ in $\mathrm{Var}[\varepsilon_i] = \sigma^2_i = \sigma^2 f(\gamma_0 + \gamma' \mathbf{z}_i)$, 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.
6. **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., $\mathrm{Var}[\varepsilon_i] = \sigma^2_i = \sigma^2\omega_i$, 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.

[7] A natural question to ask about the results we present relates to the potential influence of "out-of-market" providers. The reader should recognize that there are two interpretations of "out-of-market" in this context. The usual interpretation is with respect to those carriers that price "out-of-market," such as People's Express in the 1980s, and more recently Southwest Airlines. Another interpretation is that a carrier is "out-of-market" because it is unlisted on most CRSs. Such examples as Sun Country Airlines and Vanguard Airlines come to mind. However, with respect to the OD1A database that was used to build our data set, no carrier is "out-of-market": 10% samples of all carriers' flights are included by the Department of Transportation. Moreover, with our 1% market share inclusion rule, discussed in Step 3, Section 4.2, we ensured that any potentially "out-of-market" carrier was included. The reader should note the positive and significant on the People's Express intercept, which may reflect it own strategic positioning in the marketplace during the time frame to which our results pertain.

The positive coefficient in Table 5 for FARE is somewhat surprising, though it is consistent with past research. This variable is never pairwise-correlated at any higher than 65% with any other variable, so collinearity did not result in an unstable coefficient estimate. Still, one would think that lower rather than higher fares would be associated with higher market shares. Were the larger airlines exercising market power? Or were their customers exhibiting their willingness-to-pay for building frequent flyer miles? Were customers just insensitive to price? Other researchers have considered these issues in greater depth. For example, Borenstein (1989) and Morrison and Winston (1989) showed that an airline which has a large market share for a particular city-pair is able to raise its prices. In addition, Stephenson and Fox (1992) estimated that frequent flyer programs have raised ticket prices by 10% to 15%. Our model, and the data that form the airline FARE variable are not disaggregated enough to enable us to pursue this question in greater depth.

4.4. Implications

The results of the city-pair modeling analysis support Hypothesis 1, which predicts an *association* between a CRS vendor's deployment of agency automation in local markets -- which produces a co-specialized asset -- and that airline's market share of revenue-producing passenger miles between the city-pairs comprising its route structure. We believe that these disaggregated results illustrate how the 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' national installed base of agencies yields an aggregate co-specialized asset that is reflected in a positive association with the airline's overall performance.

5.1. The Industry Model

To answer this question, we tested a model with the variables shown in Table 2 using three dependent variables:

- LOAD factor: a measure of efficiency;
- RPM, revenue passenger miles: a measure of revenue generation (measured in millions of miles);
- 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;
- advertising expenditures, AD_EXP, for each carrier (measured in thousands); and
- a control variable for industry growth, $\Delta\_VEH\_MILES_t$, the first difference at time t of total air transportation industry vehicle miles: $VEH\_MILES_t - VEH\_MILES_{t-1}$.

The functional form of the industry model is:[8]

$$y_t = \alpha_1 + \beta_1 \, CRS\_LOC_{t-1} + \beta_2 \, STAGE_t + \beta_3 \, \#\_DEPARTS_t + \beta_4 \, AD\_EXP_t + \beta_5 \, \Delta\_VEH\_MILES_t + \varepsilon_t \quad (5)$$

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

8 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 we obtained for Davidson and MacKinnon's J-test (1981). Moreover, although we explored various adjustments to the raw values of the independent variables, we were unable to identify any convincing reasons for rescaling them. We also benefited from an anonymous reviewer's recommendation to incorporate a measure, such as Δ_VEH_MILES, to ensure that the coefficient estimates for our industry models are not adversely affected by industry growth, for which we do not otherwise control.

β_5 = a coefficient for the control variable for industry growth; 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 discussed earlier.[9]

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 7.0, which enabled us to test for problems with the data that we discussed earlier; these problems can 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 deal with autocorrelation, heteroskedasticity and cross-sectional groups 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.[10]

$$\begin{aligned} RPM_t = & \underset{(-.912)}{-12{,}137} + \underset{(8.433)^{***}}{1.22\ CRS\_LOC_{t-1}} + \underset{(8.45)^{***}}{22.04\ STAGE_t} \\ & + \underset{(18.29)^{***}}{0.49\ \#\_DEPARTS_t} + \underset{(.56)}{0.20\ AD\_EXP_t} - \underset{(-.70)}{0.97\ \Delta\_VEH\_MILES_t} \end{aligned} \quad (6)$$

*Model = GLS; R^2 = .97; t values in parentheses beneath the coefficient, with *** = p<.01, ** = p<.05 and * = p <.10.*

[9] The reader should note that the error terms for each firm in each time period across the three models are likely to be correlated : the same environment determines the outcome, the same management team is in place, and the firms face the same competition. Seemingly unrelated regression (**SUR**) was inappropriate, however, because the independent variables in each of the three models were the same. SUR GLS regression only provides a gain in the efficiency of coefficient estimates unless the independent variables are different. Thus we estimated the simpler model.

[10] 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 to 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 differences in the slope of this independent variable after the elimination of bias. It is likely that the advantages to having a CRS in a travel agent's office exceed the obvious benefits of display bias.

$$LOAD_t = \underset{(1.36)}{50.92} + \underset{(1.52)}{0.39}\, CRS\_LOC_{t-1} + \underset{(1.21)}{0.57}\, STAGE_t$$

$$+ \underset{(3.41)^{***}}{0.16}\, \#\_DEPARTS_t - \underset{(-1.93)^{*}}{0.12}\, AD\_EXP_t + \underset{(1.256)}{0.31}\, \Delta\_VEH\_MILES_t \qquad (7)$$

Model = GLS; Adjusted $R^2 = .32$.

$$PROFIT_t = \underset{(-.51)^{*}}{-167{,}083} + \underset{(3.88)^{***}}{36.90}\, CRS\_LOC_{t-1} - \underset{(-.46)}{78.14}\, STAGE_t$$

$$+ \underset{(6.32)^{***}}{1.11}\, \#\_DEPARTS_t - \underset{(-.68)}{1.59}\, AD\_EXP_t + \underset{(2.81)^{***}}{257.19}\, \Delta\_VEH\_MILES_t \qquad (8)$$

Model = GLS; Adjusted $R^2 = .68$.

The CRS_LOC variable is significant in first and third equations above, but is not quite significant in the second, though the sign is in the predicted direction. These results provide evidence in support of Hypothesis 2; the model suggests that the airline strategy of placing its terminals in travel agencies has been successful.

5.4. More on Endogeneity, Simultaneity and Causality

Our belief is that an airline CRS placed in a travel agent's office in a prior period 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?

Predicting Versus Demonstrating Causality. From a modeling standpoint, this question raises the issues of endogenity, simultaneity and causality that we touched on earlier. Many research models predict *causal relationships*: a simple production function suggests that output is "caused" by capital, labor and materials.[11] 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.

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[11] However, even production is often determined in the context of a partial or general equilibrium system, as are price, consumption and investment. See Judge et al. (1985), p. 564. Few papers in the IS literature have handled the econometric analysis of IT investment and firm performance this way, however.

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 the study, that the CRS locations and airline performance variables may simultaneously cause one another. Again, we stress that our overall approach, based on Judge et al. (1985), has been to employ lagged CRS locations, which makes the CRS_LOC variable a predetermined variable, allowing us to treat it as though it is exogenous.

Improving the Case for Causality. To further explore the issue of causality, we conducted two additional analyses. The first used performance variables at time t-1 to predict CRS locations with OLS, and the other used simultaneous equation models estimated with two-stage least squares (**2SLS**). 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 for CRS vendor airlines in our sample, obtaining Equation 9:

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

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

The variable *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, the reader should note that these three variables only explain 15% of the variance in agency automation.*[12]

Next we specified a system of simultaneous equations (Kennedy, 1985) involving the pairing of Equations 6 through 8 with an equation in which LOAD, PROFIT and RPM are used to predict CRS

[12] When 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 of Banker and Johnston (1995), who found that American and United benefitted more from their CRS than other CRS vendors.

locations. In this model, we would like to lag performance variables in predicting CRS locations as above. However, lagging CRS and performance variables eliminates the matching variables in the simultaneous equations model, so all variables are for time t. The results of this analysis, due to the need to drop observations and use proxy variables for lags, did not provide additional information beyond the data shown above. [13]

The research design and data analysis do not allow us to prove or disprove the existence of simultaneity or mutual causation between performance and the deployment of CRS in travel agencies. The data are consistent with a scenario in which the airlines with the most resources, American and United, invested in CRS. To appropriate the benefits of that investment, they deployed CRS in travel agencies, and obtained benefits from doing so.

6. CONCLUSION

The results of this research suggest that healthy airlines with resources to invest were able to appropriate the benefits of their investments in IT through agency automation strategies.

Findings and Contributions. 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 resources in technology and agency automation (Clemons, 1991). Even though American Airlines was healthy, for example, deciding to undertake the SABRE system was difficult and risky. Max Hopper, then senior vice president of American Airlines, described the context of the initial SABRE development decision:[14]

> *"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*

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[13] The 2SLS formulation requires a substantial change in our underlying model: in addition to dropping the lags, we can 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 Continental, Delta, Eastern and TWA. Delta was financially sound, but had smaller market share. Although we worked with twelve years of data for five of the carriers, however, not all of the airlines in the data 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, but the CRS locations variable was significant in only one set of equations. We do not present the results of the 2SLS analysis because they do not allow for the time-lagged impacts of CRS that we think belong in the model -- a key aspect of the information structure of the environment we are modeling;

- we must omit a significant number of observations, reducing the estimation degrees of freedom; and,
- the 2SLS results are weaker than those from our primary model as would be expected from dropping non-CRS vendor airlines and using proxy variables for the lagged variables in Equations 6 through 9

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

> *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."*

This comment is consistent with the view of Mata, Fuerst and Barney (1995) that only IT management skills meet the requirements for obtaining a resource-based advantage. However, the results of this study suggest that other paths to a resource-based advantage exist, for example, by appropriating co-specialized assets and leveraging externality and critical mass in the marketplace so that competitors are at a disadvantage.

The major CRS vendors obtained direct benefits in the form of travel agent charges and booking fees, and benefits as shown from the results of this study. The airlines also turned their CRS into highly successful specialized assets by investing more resources in them (Teece, 1987). CRS platforms became travel "supermarkets" that were valuable, rare, imperfectly imitable and to a great extent, non-substitutable resources (Barney, 1991). 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 path the first-movers in CRS agency automation followed in applying resources to technology is no longer available to others. The value of the CRS 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!

In summary, this study supports our original hypotheses and makes three contributions to our knowledge about the value of IT investments:

- As illustrated by CRS deployment in travel agencies, one effective corporate strategy is to apply resources to IT innovations that become a resource for further competition. Since IT has weak appropriability, the innovator should attempt to control co-specialized assets like the best travel agencies. These assets make it possible to appropriate substantial collateral benefits in addition to the direct returns normally anticipated from an investment in information technology. Our findings support those of Dos Santos and Peffers (1995) on early ATM adoption and co-specialized assets, for example.

- 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.

- CRS locations were significant in an MNL model over four years, building on Banker and Johnston's (1995) MCI model results, and we refined the manner in which elasticity of market share and critical mass deployment are modeled; CRS locations were also significant in a national model using twelve years of data.

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 a strong relationship between IT and firm performance. Moreover, it has done so through rigorous analysis at two different levels with data from multiple sources, and employed two different models. We also used care to test for possible defects in the analysis, by applying a variety of diagnostics. The results provide evidence that an investment in IT has benefits, in this instance through the growth in installed base of CRS terminals in travel agencies. We believe that base created a co-specialized asset for the CRS vendors and allowed them to appropriate the benefits from their IT investments.

Threats to Validity and Future Research. While we have attempted to perform a rigorous and careful analysis, there are several threats to the validity of the study. 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 and non-CRS vendor data did not lend itself to using 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, because (1) we believe that our econometric analysis approach with lagged, predetermined exogenous variables is appropriate, and (2) we obtained consistent results with two different models using independent estimates of CRS locations and two different levels of analysis. A final limitation of this study is that it is based on just one industry during the development of a major IT application. Further research is needed to determine if the strategy employed by the airlines will work in other industries, especially with systems of a smaller scale.

Our findings should be applicable to the current market for electronic commerce-related technological innovations. For the Internet, marketing mix elements (such as the relative reliance on the new channel compared to the traditional channels of distribution) are prominent, and still not well understood by most companies that use the World Wide Web to sell products (Bakos, 1991 and 1998). In fact, there are many situations in which the nature of channel compeitition -- for both Internet-focused and traditional airline and travel reservation providers-- has been transformed by the World Wide Web. The travel industry is currently undergoing a second unprecedented technological transformation (the first being CRSs) by pioneering the creation of new electronic distribution . As Johnson and Vitale (1988) and O'Callaghan, Kaufmann and Konsynski (1992) have pointed out, the deployment of such technological innovations is likely to have significant and lasting effects on the relationships among players in a distribution channel, creating both the opportunity for channel conflict and new levels of profitability. We believe that theories of resource-based advantage, appropriability, and specialized and co-specialized assets can help firms devise strategies for creating and sustaining an advantage from investments in information technology for traditional and Web-based applications.

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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:

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

Included in this model are airline intercepts or 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:

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

where

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

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

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

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

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

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.

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. 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. 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.