MARKET SEGMENTATION AND THE DIFFUSION OF

QUALITY-ENHANCING INNOVATIONS:

THE CASE OF DOWNHILL SKIING

By

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ABSTRACT

We report econometric results concerning the diffusion of detachable chairlifts in the United States that provide the first empirical evidence that the adoption of a technological innovation by a firm decreases the likelihood that a local competitor will also adopt it. We model the effect that an innovation in service speed has on a firm's incentive to differentiate the quality of its service relative to that of its competitors. In our model, the incentive to adopt is negatively related to the number of competitors who have already adopted. Our empirical results support this hypothesis.

I. Introduction

This article analyzes the diffusion of high-speed detachable chairlifts in the U.S. ski industry from the first adoption in 1981 to 1997. We model the effect of a change in service speed on ski areas' incentive to adopt the innovation showing that the incentive to adopt decreases with increased adoptions by local competitors. We also report estimates of a hazard rate diffusion model that support this hypothesis. By contrast, the empirical literature generally finds that the speed of adoption is an increasing function of prior adoptions by local competitors.[1]

The article is organized as follows. Section II summarizes the diffusion literature. Section III presents a model of the service process at ski areas that suggests that (1) the main advantage of adopting the faster chairlift occurs if current capacity is not being fully used and (2) the incentive to adopt is inversely related to the number of prior adopters. Section IV provides regression results supporting the first hypothesis, while Sections V and VI report estimates of a diffusion model that support the second hypothesis. Since 1980 aggregate U.S. lift capacity has increased by approximately 70 percent, while aggregate annual skier-days has remained essentially unchanged. As a result, one might hypothesize that our empirical results are, instead, evidence of the deterrent effect of capacity expansion. In Section VII we argue that this is unlikely to be the explanation for our results. Concluding remarks are in Section VIII.

II. Diffusion Literature

Geroski (2000) and Stoneman (1995) survey the empirical literature relating the timing of the adoption of an innovation to such factors as the size and age of the firm, the demand for the firm's product, market structure, and the extent of adoptions by the firm's direct competitors. The literature consistently finds that larger firms are more likely to adopt before smaller firms. Although the date of the establishment of the firm is generally included as a proxy for the age and developmental stage of the firm, there is little consistency across studies most likely due to the uncertainty of what the variable actually measures. While the literature generally finds support for the hypothesis that increased demand for the firm's product accelerates the adoption decision, the effect of market structure is less clear.[2] According to K-S, theory "does not provide much guide as to the expected sign for this variable" (p. 513).[3] The empirical evidence has also been inconclusive. For example, H-M found a positive relationship between market concentration and the propensity to adopt, K-S found no statistically significant relationship, and L-L-M found a negative relationship.

The empirical literature, however, is essentially unanimous in finding that prior adoptions by competitors increase the propensity to adopt. Both H-M and L-L-M attributed the positive effect of prior adoptions by competitors in their studies to an epidemic effect in local markets.[4] K-S found similar results for computer-controlled machine tools. Despite these results, there is a theoretical literature suggesting that a diffusion process can result from strategic interaction among otherwise identical firms. For example, Fudenberg and Tirole (1985) show, for innovations that lower adopters' production costs, that strategic interaction may even result in an inverse relationship between the propensity to adopt and the extent of prior adoptions by competitors. The lack of empirical evidence that prior adoptions by competitors delay a firm's own adoption of the innovation, however, led K-S to conclude Athe implication of the work reported here is that if [the deterrent effects of prior adoption by competitors] have real-world relevance, it is limited at best to very major innovations." (p. 523).

III. Theoretical Motivation

While the theoretical literature focuses on the diffusion of innovations that reduce the cost of producing a good, much of the U.S. production capacity provides services, not manufactured goods. A major characteristic of the quality of a service is speed of service. In this section we show how an innovation in chairlift speed can further differentiate the quality of service provided in local skiing markets.[5] The detachable chairlift offers skiers features not provided by the older fixed-grip technology, such as easier loading, a potentially more exciting ride, somewhat fewer loading and unloading incidents, somewhat higher actual (as opposed to design) capacity due to lower frequency of breakdowns, while reducing the time needed to go to the top of the hill by approximately one-half.[6] While these characteristics may appeal to many skiers, only 68 of over 400 U.S. ski areas had installed a detachable chairlift by 1997. A major deterrent to adoption is the cost, since the detachable chairlift has remained approximately 40 percent more expensive per unit of capacity relative to the older technology.[7]

Despite the higher cost per unit of capacity, some ski areas may have an incentive to adopt the faster chairlift in order to differentiate the quality of service provided to the avid skier sub-market. Given the limited size of this sub-market and the relatively high cost of the chairlift, the incentive to adopt is likely to decrease as other local ski areas adopt. An important point to be made in this section is that the main benefit of adopting the detachable chairlift occurs at times when the ski area is not operating at full capacity. Our model extends the model of congestion in Barro and Romer (B-R) (1987) by allowing chairlift speed to vary. B-R assumed that ski areas have homogeneous lift capacity and make competitive lift ticket pricing decisions at the beginning of the ski season. Their model considered the effect of heterogeneity of skier types on lift ticket prices. Avid skiers are assumed to have a greater demand for lift rides per day than less avid skiers with ski areas specializing by type of skier. The constraint on the number of ski runs is the wait in the lift line, which always exists due to their full capacity utilization assumption. In their model ski areas specializing in avid skiers charge higher lift ticket prices in order to reduce the number of skiers so that avid skiers can ski more runs per day. They also argue that their results generalize to the case where skiers vary along a continuum of skier types according to their preferences for number of runs per day.[8]

We now show that if the full capacity of the ski area is in use, an innovation that increases chairlift speed, *holding overall capacity constant*, increases the time spent waiting in the lift line without increasing the potential number of runs. In section VII we consider both the technology adoption and the capacity expansion decisions. For the time being, assume that a ski area, whether it is replacing existing capacity or adding to its capacity, decides between two fixed-grip chairlifts or one detachable chairlift.[9] The detachable chairlift is assumed to be twice as fast as the fixed-grip chairlift. Assume for simplicity that a ski area, S_F, has two single-chair fixed-grip chairlifts each with r seats that make a complete cycle every t minutes, and that each skier skis down the hill in t/2 minutes.[10] In steady state if the number of skiers, n, is greater than 2r, there will be r/2 skiers on each chairlift, r skiers on the slope and n/2 - r skiers queuing at each chairlift. Expected time per complete skier-cycle equals t + (n/2 - r)(t/r) when $n \geq 2r$ and t for $n < 2r$.

Now consider a ski area, S_D, with one detachable chairlift of identical capacity to the aggregate capacity of the two fixed-grip chairlifts (that is, one chairlift with r seats that completes a cycle in time t/2). If n equals 2r at both ski areas, a skier at ski area S_D takes only t/4 minutes to go up the hill but waits t/4 minutes in the lift line resulting in the same total time per cycle as at ski area S_F. Thus, when there are 2r or more skiers, the only benefit from the faster chairlift comes at the end of the last run. Skiers at ski area S_D finish their total runs t/4 minutes earlier.

Although B-R assume that ski areas operate at full capacity, the ski industry's average capacity utilization rate has been consistently below 50 percent per season. In our example, if there are fewer than 2r skiers at ski area S_F, skiers still need t minutes to make one complete cycle even though there are empty seats. However, at ski area S_D total time is $3t/4 + (n - 3r/2)(t/2r)$ for $n > 3r/2$ and $3t/4$ for $n \leq 3r/2$. When $3r/2 < n < 2r$ there are lift lines at ski area S_D and no lift lines at ski area S_F, but total time per cycle is less at ski area S_D. As a result, while the benefit to avid skiers of replacing fixed-grip chairlifts with detachable chairlifts of equivalent capacity can occur even on weekends and holidays, it will be greatest during the off-peak time period, such as non-holiday weekdays. As in the B-R model, ski areas specializing in avid skiers charge higher prices, because they offer these skiers more runs per day. As additional ski areas adopt detachable chairlifts to attract skiers willing to pay higher prices for these chairlifts' special features and the additional runs per day, late adopters must share this sub-market with those that have already adopted. With a continuum of skier types the adopting ski areas would have to lower their prices in order to attract relatively less avid skiers as the number of adopters increases.

IV. The Effect of Detachable Chairlifts on Lift-ticket Price

In this section we test the model's implication for the effect of a detachable chairlift on lift ticket prices. The absence of data on skier visits to specific ski areas precludes estimation of the determinants of both ticket prices and skier visits. Instead, we estimated OLS price regressions for the last season of our sample period, 1996-1997, as a function of whether or not the ski area had a detachable chairlift plus a set of control variables likely to be correlated with lift ticket prices: vertical drop, location on U.S. Forest land, the number of competitors within a 125 mile drive of the ski area, the population within 125 miles of the ski area, and a set of regional dichotomous variables.[11] We define the local alternatives to a ski area as all other ski areas within 125 miles of the ski area. According to Perdue (1996), 125 miles is the approximate limit in driving distance for a single day of skiing.

Our sample includes 344 U.S. ski areas for which we have complete data. Data on lift capacity, lift ticket prices, vertical drop and types of ski lifts come from annual editions of the ***White Book of Ski Areas***.[12] The National Ski Area Association (NSAA) provided information on whether or not the ski area is located on land operated by the U.S. Forest Service. The Geographic Information System provided demographic data from the U.S. Census for the years 1980 and 1990. The number of ski areas within 125 miles of driving distance was determined using the on-line version of MapBlast.[13] We divided the country into regions (West, Rocky Mountains, North Central, South, and Northeast) and included dichotomous variables for four of the regions in the price regressions with Northeast as the excluded group.[14]

Table 1 presents results for both off-peak (non-holiday weekdays) and on-peak periods (weekends and holidays). The mean lift ticket price was $29.97 on weekends and holidays and $25.73 on non-holiday weekdays. Ski areas with larger vertical drops, a proxy for the amenities and quality of the ski area, charge higher lift ticket prices ($6.78 more per 1,000 vertical feet on non-holiday weekdays and $7.19 more on weekends and holidays). The mean value of vertical drop is 1,156 feet. The coefficient for location on U.S. Forest land is not statistically significant. The coefficients for the population within 125 miles and the number of competitors are small positive numbers and statistically significant in all cases. While there was no regional effect among the Northeastern, North Central and Southern ski areas on weekends and holidays, the ski areas in the Rockies and the West had lower prices relative to these groups. This later result is not surprising given the peak-load nature of skiing in the Eastern half of the country.

While we generally expect that prices will be lower when there are more competitors, the number of ski areas in the country has decreased by approximately one-third since the 1970s. The positive correlation between number of competitors and ticket prices suggests that the number of competitors is a proxy for the demand in the local market. Local markets with a larger number of ski areas have large enough demand to keep smaller ski areas from exiting the market.

Ski areas with faster chairlifts charge higher lift ticket prices both on weekends and holidays and on non-holiday weekdays. However, on non-holiday weekdays, there is an even higher price premium for ski areas with faster chairlifts ($7.25 versus $5.81). Given the lower mean lift-ticket price on week-days, the price premium as a percentage of the price is even higher in percentage terms (28.18 percent versus 19.39 percent). While some of the price premium during both time periods is certainly due to the other special features of these chairlifts mentioned earlier, we contend that the greater effect on lift ticket prices on non-holiday weekdays supports our hypothesis that the faster chairlifts allow ski areas to further differentiate their service to the relatively more avid skiers both on non-holiday weekdays and on weekends and holidays with the greatest impact occurring on non-holiday weekdays.[15]

V. The Diffusion Process

In this section we discuss the estimation procedure, the variables used in the estimation of the diffusion model, and the main results supporting the hypothesis that the incentive to adopt the detachable chairlift decreases as more local competitors adopt. In the next section we analyze the sensitivity of our results to the data used in the estimations.

A. Estimation Procedure

The generally accepted procedure in the economics literature is the estimation of what are normally called parametric duration or log-linear survival models to determine the effect of exogenous variables on the time until a firm adopts the new technology.[16] Earlier work (H-M and L-L-M) used a negative exponential distribution for the hazard function, which constrains the hazard function to be memory-less. More recently, K-S tested the time dependence of the baseline hazard by assuming a Weibull distribution of adoption time, which includes the exponential distribution as a special case. We follow K-S by estimating the duration model using the Weibull distribution.[17]

B. Data

We estimated the duration model using annual data for the same 344 ski areas from the 1980-1981 to 1996-1997 ski seasons for the following exogenous variables: whether or not the ski area started business after 1970, whether or not the ski area is on U.S. Forest Land, vertical drop, the number of potentially skiable acres, the number of competitors within 125 miles of the ski area, and number of adopters within 125 miles of the ski area at time t-1.

Age of the ski area: Given that new ski areas have generally added chairlifts in stages over time, we conjecture that the newest ski areas would be more likely to add chairlifts of any type in a given year. Ideally, we would know the acquisition dates of each of the ski area=s chairlifts, but this information is not available in any systematic manner. We use a dichotomous variable indicating whether or not the ski area started business after 1970. We also re-estimated the model using the actual establishment date. The median initial date of operation is 1958.

U.S. Forest Land: Ski areas on National Forest land generally have lower costs, because the rental prices for use of the land have not reflected market prices. On the other hand, they face parking and hotel space constraints that other ski areas do not face, because of their remote locations and restrictions imposed by the U.S. Forest Service. Specializing in a smaller number of avid skiers may result in less congestion of these related facilities and provide them an additional incentive to adopt the detachable chairlift. We use a dichotomous variable to control for the 32.8 percent of ski areas located on land operated by the U.S. Forest Service.

*Size of the Firm and Growth of Demand (Vertical Drop)***:** We use vertical drop as our control for both the size of the firm and the expected increase in demand during this time period.[18] Ski areas with higher vertical drops may have an incentive to adopt the detachable chairlift due to scale economies.[19] Although the number of skier days has remained relatively constant in the U.S. throughout this time period, skiers are skiing more during extended vacation periods at ski resorts with larger vertical drops. These are also the ski areas most likely to be competing with the largest ski areas in the U.S. and the rest of the world for the avid skier.

Potentially Skiable Acres: While ski areas have some flexibility in increasing their lift capacity and skiable acres at the beginning of the ski season, they will eventually face a binding limit on skiable terrain. At higher lift capacity to potentially skiable acre ratios, skiers face a relatively greater degree of congestion that limits the number of ski runs. Since lift capacity in any given year is endogenous, we do not include lift capacity in the estimation. We hypothesize that ski areas with more potentially skiable acres will be more likely to add a chairlift regardless of its speed. Since there is no direct exogenous measure of potentially skiable acres available, we use actual skiable acres in the year 2000 as our proxy for this variable and terminate the sample period at the end of the 1996-1997 ski season. Data on skiable acres for the year 2000 ski season came from ***Ski Area Management*** magazine research data base available on-line.[20]

Number of competitors in the local market: Due to a lack of data on skier visits and skier types at specific ski areas, we are unable to determine the number of skiers or the distribution of skier types per local market. According to the pricing regressions reported in Section IV, however, ski areas with a larger number of competitors charge higher lift ticket prices, ceteris paribus, likely due to higher demand per ski area. Since ski areas catering to avid skiers in the B-R model charge higher prices even in the absence of faster chairlifts, the higher prices could also indicate a higher concentration of relatively avid skiers in these local markets. As a result, we hypothesize that an increased number of competitors, ceteris paribus, provides a greater incentive for any one ski area to adopt the faster chairlift in order to differentiate its service relative to that of its competitors. We define this variable as the number of ski areas located within 125 miles of driving distance from the ski area. This number ranges from 0 to 48. As a test of the sensitivity of this assumption, we also estimated the model with local competitors defined as all ski areas within 50 miles of the ski area.[21] In this case the number of potential competitors ranges from 0 to 21.

Number of adopters in the local market at time t-1: We define the number of adopters as all ski areas within 125 miles of the ski area that had installed at least one high-speed detachable chairlift by the end of the previous ski season. This number ranges from 0 to 14. We also estimated the model using 50 miles in place of 125 miles. In this case the number ranges from 0 to 8.

C. Estimation Results

Table 2 presents the results. Ski areas with larger vertical drops adopter sooner. These results are consistent with those generally found in the literature that larger firms and firms facing increased demand over time are likely to adopt innovations sooner. Ski areas that began operation after 1970 adopted earlier. We also estimated the model using the actual year of initial operation with the same result. This result is consistent with the generally held view in the industry that younger ski areas approach their ideal lift capacity configuration in stages over time. Ski areas located on National Forest land also adopted the faster chairlift technology earlier. We hypothesized two reasons for this result: lower land rental costs and constraints that limit the number of skiers, such as congestion on access roads, remote locations, and limits on available parking and hotel facilities. Ski areas with more potentially skiable acres adopted sooner. We argued that the number of potentially skiable acres is an indirect measure of potential congestion on the slopes. Ski areas with more local competitors were also more likely to adopt sooner. We hypothesized that with a larger number of ski areas there is an increased incentive for any one ski area to differentiate the quality of its service by adopting.

Our main result, however, concerns the effect that the adoption decisions of local competitors have on the propensity of a ski area to adopt the innovation. Contrary to findings for other innovations in the literature, the propensity to adopt decreases as the number of prior adopters increases. This is so even given that at least some of the ski areas in our sample compete with ski areas outside of their immediate geographical area. On the other hand, the estimated value of ñ is 3.75 and is statistically significantly different from 1. As a result, the hazard function exhibits the property of positive duration dependence generally found in the literature. K-S argued that by allowing the hazard rate to vary over time, one provides a better test of the effect of prior adoptions by competitors than that of earlier studies that had restricted the distribution of the hazard function. While they also found positive duration dependence for some of the industries in their sample, there was an absence of a deterrent effect of prior adoptions on a firm=s adoption rate. K-S justify this finding by making an analogy to the spread of epidemics based on A(i) the learning processes involved in the use of new technology and its transmission through human contact, with the >infection= being information; (ii) pressure of social emulation and competition; or (iii) reductions in uncertainty resulting from extensions of use@ (p. 509).

We believe that positive duration dependence for the ski industry is due to a different reason. When the detachable chairlift was introduced in 1981, there were several articles about the new technology in the trade literature, and the technology had already been in use at European ski areas. As a result, it is unlikely that a lack of information alone, at least among ski areas, could explain the positive duration dependence reported here. There is evidence to suggest that changes in skier opportunity costs of time during the 1980s and 1990s encouraged ski areas to increase overall capacity in order to shorten lift lines and increase the potential number of runs per skier per day. For example, although the number of skier days at U.S. ski areas has remained relatively constant at approximately 50 million per year between 1980 and 1997, overall lift capacity in the industry has increased by approximately 70 percent. Lift ticket prices increased by 154.69 percent on non-holiday weekdays and 148.86 percent on holidays and weekends during this time period, while the CPI increased by only 78.4 percent.

Willingness of skiers to pay even higher lift ticket prices, ceteris paribus, at ski areas with detachable chairlifts, especially during off-peak time periods, suggests that increases in the opportunity costs over time have resulted in an increased demand for more runs per day. While only 5 percent of the U.S. population goes skiing at least once each year, skiers are among the wealthiest Americans. In 1996 average skier household income was more than $80,000 with the share of skier households with income under $50,000 only 27 percent (Cravatta, 1997). By comparison, median U.S. household income was only $35,000 in 1996. Since 1980, the biggest increases in income were received by the upper fifth of the income distribution.[22] Given no change in skier days per year, the increase in overall capacity has increased the potential number of runs per skier-day for all skiers. Since a detachable chairlift can result in even more runs per day with the same capacity as that of the older technology, the empirical results are consistent with the overall increased demand for more runs per day in the industry as a whole.

VI. Sensitivity Analysis

In light of the heterogeneity of the U.S. ski industry, we estimated the diffusion model to test the sensitivity of the results to the data being used. We looked at regional differences, simultaneous adoptions, entrants, and size of the ski area. Table 3 summarizes the main results for the number of prior adopters and competitors.

A. Regional Differences

Avid skiers are not likely to spread themselves uniformly across all regions of the country. For example, ski areas in the Rockies rely less on local skiers and attract large numbers of skiers from other regions of the country and the world. As a result, they are likely to attract a proportionally higher number of avid skiers. The 130 Western and Rocky Mountain ski areas differ in other ways. 27 of the 72 ski areas in the Rocky Mountain states and 17 of the 58 Western ski areas had adopted by 1997, compared to only 21 of the 115 Eastern ski areas and 3 of the 87 ski areas in the North Central region. In addition, the distances between clusters of Western and Rocky Mountain ski areas are more pronounced. When the market area includes all ski areas within 125 miles of one another, there is little overlap of local markets.[23] This is not the case elsewhere. For example, all ski areas in New Hampshire share the same competitors within New Hampshire, yet those located in the Northeastern part of the state have competitors in Maine within 125 miles, while those in the Southwestern part have local competitors in Vermont and Massachusetts. Despite these differences, Table 3 shows that the coefficients for the number of local competitors and number of local adopters variables are statistically significant with the predicted signs for the Eastern, Western and Rocky Mountain regions.

B. Simultaneous Adoptions

One potential problem in the estimation of diffusion models is the case of simultaneous adoptions. We assumed that adoptions are made without knowledge of the intentions of one=s competitors, which is also H-M's and L-L-M's maintained assumption. By contrast, K-S assumed that firms knew whether or not their competitors would also adopt at time t and t + 1. This approach, however, amounts to assuming perfect foresight and ignores the strategic interaction among competitors. K-S justify this approach by stating that while it "does not fully reflect the strategic nature of some of the recent [theoretical] contributions, ... , the theoretical literature gives no indication of what might be a more adequate empirical approach" (p. 507).

Simultaneous adoptions are a potential problem given that 28 of the 68 ski areas adopted in the same year as at least one other local competitor. Given that some of the ski areas may have known of the binding intention by local competitors to adopt, we estimated the model based on the extreme assumption that every ski area knew whether or not its competitors were going to install a detachable chairlift prior to making its own decision. As shown in Table 3, the coefficient for prior adopters remains positive and statistically significant for the Eastern ski areas at the five percent level and for the entire sample at the ten percent level.

While the coefficients for the number of prior adopters are still positive for the Rocky Mountain and Western regions, they are no longer statistically significant. One possible interpretation is that these ski areas are less concerned about the adoption decisions of their local competitors and are only concerned about the national and international market. However, even if some of the ski areas knew in advance of binding commitments by competitors to add a faster ski lift, not all of the ski areas could have had this information. Even assuming that everyone knew everyone else's intentions, there is still no support for the alternative hypothesis of an epidemic effect due to the adoption decisions of one's most immediate competitors.

C. Entrants

While a large number of small ski areas left the industry between 1980 and 1997, 26 ski areas entered the industry. Six of these ski areas eventually installed a detachable chairlift. While duration models control for right-hand censoring associated with non-adopters being in the sample at the end of the sample period, there is no direct method for controlling for left-hand censoring. We reported results including these 26 ski areas in Table 2, because all of the exogenous variables are either site specific (vertical drop, location on National Forest land, and potentially skiable acres) or competitor specific (number of competitors and number of prior adopters). None of the entrants rented U.S. Forest land. Given that someone could have used these lands as ski areas at any point during this time period, the decision to add a detachable chairlift is essentially the same as that faced by an existing ski area. We also estimated the model without these 26 ski areas with no significant change in the estimated coefficients.

D. Size of the Ski Areas

No ski area with a vertical drop below 500 feet or fewer than 75 skiable acres installed a detachable chairlift during this time period. As a further test, we estimated the model excluding the 122 ski areas with less than 500 vertical feet and 75 skiable acres with essentially identical results for the number of prior adopters and local competitors.

VII. Entry Deterrence

Given the large increase in industry capacity during the sample period, one might argue that our results provide support for strategic models of entry deterrence. Empirical support for these models, however, is rare and inconclusive. For example, Lieberman (1987) notes that even though his work has shown evidence of significant excess capacity in some industries, Aexcess capacity entry barriers identified in theory are not very common in practice. While firms in the sample held significant excess capacity, most was maintained to accommodate demand variability and investment lumpiness... These findings do not imply that excess capacity cannot deter entry, but rather that its use is both rare and unlikely to be completely effective@ (p. 624). More recently, Mason and Phillips (M-P) (2000) argue that Ait is evident that existing industry studies do not provide clear evidence that dominant firms strategically preempt rivals or keep new firms from entering the market. In all these field studies, determining the motives of producers and the causes of changes in a market=s structure are main difficulties@ (p.109).

Our empirical results are also unlikely to support these theoretical models for several reasons. While the theoretical models on entry deterrence focus on the threat of greater production of a manufactured good and the undercutting of a competitor=s price, excess capacity in a service industry, such as skiing, is not necessarily idle capacity since empty seats can affect waiting time directly. As mentioned earlier, in the B-R model a skiing industry organized as one large firm is no different than one consisting of several smaller homogeneous firms each with one ski lift. Given that skiers self-select areas based on their preferences for ski runs, their model implies that both revenues per unit of lift capacity and lift lines will equilibrate at each ski area after the expansion in capacity. The incentive for a ski area to increase capacity comes from an exogenous increase in skiers= demand for shorter lift lines or an increase in the number of skiers. As a result, ski areas can increase ticket prices even when there is Aexcess capacity@.

The B-R model implies that an increase in demand for ski runs results in identical percentage increases in capacity across homogeneous ski areas. We have argued earlier that the large increase in capacity in this industry is largely a response to increases in skier incomes and preferences for more runs per day. Even though ski areas in the U.S. are not homogeneous, 75 percent of the ski areas in our sample increased capacity between 1980 and 1996. We follow Morey (1984) in defining lift capacity as Vertical Transport Feet per Hour (VTFH), which is the number of persons who can be transported 1,000 vertical feet per hour.[24] While only 68 of 344 ski areas installed at least one detachable chairlift with an average net increase in VTFH of 3,538 per ski area, there were 619 instances when a ski area without a detachable chair lift increased capacity by an average 2,521 VTFH using other lift technology. While the increase in VTFH was larger when a detachable chairlift was installed for the first time, the ***percentage change*** in VTFH per ski area was essentially identical regardless of type of lift installed. For example, in years when adding chairlifts increased capacity, the additional capacity averaged 21.74 percent of the ski area's capacity for those ski areas not using detachable chairlifts and only 19.02 percent for those installing a detachable chairlift for the first time. These changes in capacity were lumpy in the sense that the typical ski area added capacity approximately once every six years.[25]

As both Lieberman and M-P indicate, it is difficult to discern a firm=s motives for adding capacity simply from the data. While this research does not attempt a complete analysis of capacity expansion in this industry, primarily due to a lack of data on skier visits, our data suggest that adoption of detachable chairlifts was not likely due to strategic reasons implied by the entry barrier literature. Instead, it appears that ski areas that adopted the faster lifts were preempting other ski areas likely to cater to avid skiers, where in M-P=s words Apreemption is taken to mean expansion to take advantage of new opportunities@ (p. 108).

VIII. Conclusion

In this article we have considered the diffusion process for an innovation in service time. We make a distinction in the modeling of lift capacity that goes beyond defining capacity as the number of skiers that can be transported during a given time period. By doing so, we show that the main effect of using faster chairlifts in place of slower chairlifts occurs when the full capacity of the ski area is not being used. The faster chairlift allows avid skiers to ski more times per day or to complete a desired number of runs in a shorter time period. Given the limited number of avid skiers and the significantly higher cost per unit of capacity relative to the alternative technology, not all local ski areas will compete for these skiers by installing the faster chairlifts. As a result, we have hypothesized that adoptions by ski areas decrease the propensity of other local ski areas to adopt. Our empirical results support this hypothesis.

Innovations in service quality, in particular speed of service, are likely to play a more significant role in future years given the increased importance of the service sector and individuals' opportunity cost of time. Accounting for innovations in service quality should go beyond overly simplified characterizations of capacity to account for not only the number of people who receive service per given time period but also speed and cost of service. To the extent that innovations provide opportunities for differentiating a service according to service speed or other measures of service quality, we should not be surprised to see further evidence of the kind reported here.

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TABLE 1

THE EFFECT OF DETACHABLE CHAIRLIFTS ON LIFT-TICKET PRICES
FOR THE 1996-1997 SKI SEASON[1]

Variable	Mean Values	Non-holiday Weekdays[2]	Holidays and Weekends[3]
Constant		12.324* (1.395)	18.036* (1.325)
Vertical Drop (thousands of feet)	1.156	6.782* (0.672)	7.189* (0.639)
Western Region[4]	0.166	0.379 (1.491)	-3.536* (1.417)
Rocky Mountain Region[4]	0.212	0.725 (1.489)	-4.232* (1.415)
North Central Region[4]	0.224	2.011** (1.214)	0.904 (1.154)
Southern Region[4]	0.064	4.566* (1.668)	6.717* (1.585)
Number of Local Competitors within 125 miles	14.547	0.090* (0.040)	0.092* (0.038)
Located on U.S. Forest Land[4]	0.328	1.600 (1.124)	1.493 (1.068)
Population within 125 miles in 1990 (millions)	7.089	0.188* (0.055)	0.211* (0.052)
Detachable Chair Lift[4]	0.198	7.245* (1.108)	5.810* (1.053)
Adjusted R^2		0.623	0.604

*Significant at the 5 percent confidence level ** Significant at the 5 percent confidence level
Observations = 344 [1]Standard errors in parentheses [2]Mean lift ticket price of $25.73
[3]Mean lift ticket price of $29.97 [4]Yes equals 1

TABLE 2

ESTIMATION RESULTS OF LOG-LINEAR SURVIVAL MODEL
(WEIBULL DISTRIBUTION)[1]

Variable	Mean Values	Coefficient (standard error)
Constant		4.142* (0.152)
Vertical Drop (thousands of feet)	1.148	-0.351* (0.053)
Potentially Skiable Acres (thousands of acres)	0.488	-0.077* (0.035)
Established after 1970[2]	0.203	-0.252* (0.076)
Located on U.S. Forest Land[2]	0.328	-0.188* (0.094)
Number of Previous Adopters	2.474	0.041* (0.017)
Number of Competitors	14.511	-0.016* (0.004)
ñ		3.34486
Number of observations		344
Log likelihood function		-294.32

* Significant at the 5 percent confidence level
[1]Dependent variable is the time of duration [2]Yes equals 1

TABLE 3

EFFECTS OF PRIOR ADOPTIONS AND NUMBER OF COMPETITORS
FOR VARIOUS SUB-SAMPLES
(WEIBULL DISTRIBUTION)

Sub-sample	Number of Prior Adopters	Number of Local Competitors	Number of Observations	Log Likelihood Function	ñ
Full Sample	0.041* (0.017)	-0.016* (0.004)	344	-294.83	3.31855
Eastern Region	0.049* (0.021)	-0.009* (0.004)	115	-89.63	6.02184
Western Region	0.080* (0.039)	-0.027** (0.014)	58	-68.08	4.34342
Rocky Mountains	0.078* (0.029)	-0.044* (0.011)	72	-98.94	3.22323
Perfect Foresight Full Sample	0.030** (0.017)	-0.016* (0.004)	344	-294.21	3.24413
Perfect Foresight Eastern Region	0.050* (0.017)	-0.009* (0.004)	115	-89.63	6.02184
Perfect Foresight Western Region	0.053 (0.050)	-0.025 (0.018)	58	-69.07	3.96021
Perfect Foresight Rocky Mountains	0.033 (0.054)	-0.030 (0.021)	72	-101.18	2.60472
Full Sample Minus New Entrants	0.044* (0.017)	-0.016* (0.004)	323	-280.65	3.40785
Full Sample Minus Ski Areas with less than 75 Skiable Acres and/or less than 500 Vert. Feet	0.041* (0.016)	-0.014* (0.004)	222	-286.79	3.31530

* Significant at the 5 percent confidence level **Significant at the 10 percent level

[1] Examples include Levin, Levin, and Meisel (L-L-M) (1992) for the diffusion of optical scanners, Hannan and McDowell (H-M) (1987) for the diffusion of ATMs, and Karshenas and Stoneman (K-S) (1993) for computer-controlled machine tools.

[2] For example, L-L-M find that the percentage change in per capita personal income over the previous three years is positively correlated with the propensity to adopt, while H-M find that the yearly growth in deposits and the growth in deposits in the three previous years is correlated with a greater propensity to adopt. K-S divided its sample of firms into two sectors (electrical and non-electrical) and found that the sector with the higher relative growth rate had a greater propensity to adopt computer controlled machine tools in the UK.

[3] For example, Reinganum (1981) argues that cost reductions in concentrated industries producing a homogeneous good result in higher profits for the adopting firm, which suggests that diffusion is likely to be faster in concentrated industries. On the other hand, QuirmbachFs (1986) model has firms in concentrated industries colluding in order to slow down the diffusion rate.

[4] L-L-M defined the local market for scanners as the city in which the stores were located, while H-M defined their local market for ATMs as the SMSA where the bank was located.

[5] A related literature links research and development costs to the timing of innovations by firms in industries with heterogeneous product quality. Sutton (1998) has a model and extensive survey of the literature attributing differences in market structure to differences in R and D expenditures. Hoppe and Lehmann-Grube (2001) consider the related issue of second-mover advantages from delaying the introduction of an innovation in product quality when R and D expenditures are high and product quality improves continuously over time.

[6]This information was provided in a private communication by Mr. Randy Woolwine, Marketing Director for Dopplemayer-USA, one of the major suppliers of detachable chairlifts.

[7] The nominal price of a detachable chairlift has remained essentially unchanged at approximately $2.2 million per mile since 1981, while the current cost for the slower fixed grip chairlift of equivalent capacity (in terms of passengers transported per hour) is approximately $1.4 million per mile. In recent years the nominal price of the fixed grip chairlift has increased somewhat.

[8] Although Aavid@ skiers are assumed to be willing to pay more to ski more runs, one could assume, instead, that they are interested in minimizing the amount of time needed to complete any given number of runs.

[9] We make this distinction to emphasize that the usual definition for capacity, such as the maximum output per unit of time, is not sufficient for explaining the differences among service firms that process the same number of customers per time period but at different speeds per service unit. See Mulligan

(1983, 1986) for examples of this approach.

[10]This assumption is made for expositional purposes. Letting the skiing time differ from the time needed to go up the hill or making skiing time stochastic does not affect our analysis.

[11]While other variables, such as amenities and the number and difficulty of runs, could serve as proxies for quality, vertical drop is highly correlated with them and they are reported on a much less frequent basis. In addition, the ski areas designated as leading destination ski resorts in popular ski magazines all have large vertical drops. While several of the largest ski resorts compete with one another in national and international markets, we adopt Scotchmer=s [1985] characterization of a local market for the ski industry as: Aski resorts are usually concentrated in very few mountainous areas. Conditional on the clientele that travels to the mountains to ski, each ski slope has little market power because there are many ski slopes@ (p. 468).

[12]The ***White Book*** reports at least some data for as many as 412 ski areas for the 1996-1997 ski season. Ski areas reporting no data or only partial data are, however, among the smallest. For example, the National Ski Area Association published survey results at the end of the 1993/4 ski season indicating that while only 298 ski areas in the United States were members of this association, they accounted for approximately 87.4 percent of the national total of skier days during the 1993/94 ski season (Kottke, 1994). Our sample includes these 298 ski areas.

[13] http://www.mapblast.com/myblast/index.mb

[14] West (AK, WA, OR, CA, NV, and AZ), Rockies (CO, NM, ID, MT, UT, and WY), North Central (ND, SD, MN, WI, IA, NB, MO, IL, IN, OH, and MI), South (AL, GA, TN, KY, NC, WV, VA, and MD), and Northeast (NJ, PA, NY, CT, MA, VT, NH, and ME).

[15]We provide more detailed evidence on price changes during the time period with similar conclusions in Mulligan and Llinares (2002).

[16] An alternative is the so-called epidemic model, which assumes that the limit on immediate adoption by all potential adopters is a lack of information about the merits of the innovation. In these models a slow initial diffusion process is assumed to be followed by an epidemic-like effect due to the accelerated flow of information associated with adoptions by other firms. As suggested by Geroski, the epidemic model is of limited use in explaining a diffusion process when the characteristics of the innovation are well known to potential adopters at the time of the initial adoption.

[17] The more general Weibull distribution separates the effects of each of the characteristics from that of an overall change in the distribution of the hazard rate function. If the estimated value of ñ equals 1, the model is equivalent to a constant hazard model (that is, an exponential distribution of the

adoption time assumed by H-M and L-L-M). If ñ is greater than 1, the model indicates the existence of positive duration dependence of adoption time.

[18]Earlier studies have used the number of employees (Colombo and Mosconi and K-S), total assets (H-M) or a direct measure of output (Goel and Rich [1997]) as proxies for firm size.

[19]In a personal correspondence, Mr. Woolwine, indicated that Avery short detachable lifts are still quite expensive compared to fixed grip lifts. Reason: there is a lot of money in the terminals and associated safety systems. The longer the lift, the less the terminal cost is a percentage of the entire lift price@.

[20]The address is http://www.saminfo.com.

[21]Narrowing the size of the market further, however, results in too many ski areas without a local competitor. For example, in 1996 66 percent of ski areas had no competitors located within 25 miles of the ski area, while only 11 percent had no competitors within 50 miles.

[22] For example, in 1980 individuals in the top fifth of household income received 41.1 percent of aggregate income. By 1996 this figure had increased to 46.8 percent without accounting for the effects on wealth of increases in retirement and investment portfolios (U.S. Census Bureau, 1998).

[23]One exception was made for the ski areas located near Denver, Colorado. In this case we defined the market as all ski areas located within 125 miles of Denver.

[24]VTFH equals vertical feet times lift capacity divided by 1,000. Lift capacity as reported by ski areas to the *White Book of Ski Areas* is the number of persons who can be transported to the top of the hill per hour. This definition of capacity, however, does not account for the ski area=s vertical drop when making lift capacity comparisons among different ski areas.

[25] In addition, the 68 ski areas that eventually adopted the new technology added capacity in future years using other technology on 55 occasions with an average percentage increase of 8.83 in aggregate VTFH per ski area during the year of expansion. In 21 cases ski areas followed the addition of a detachable chairlift in a later year with a reduction in aggregate capacity by removing a lift. The average decrease in VTFH in these cases was 4.9 percent.