Climate Zone Crucial for Efficiency of Ski Lift Operators

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Climate Zone Crucial for Efficiency of Ski Lift Operators

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Abstract:

This paper investigates the efficiency of ski lift companies across different climate zones in a group of countries based on establishment data. By a joint estimation of the stochastic frontier production and efficiency equations, the results indicate that ski areas in subarctic climate zones are far more efficient than their counterparts in warmer zones. Presence of a large local market and elevation of the ski area are factors not relevant for efficiency. Output of ski lift operators (companies) increases with the length of ski runs, number of ski lifts, share of slopes covered by snowmaking facilities and availability of fast lifts. Productivity is also significantly higher for ski lift companies owned by a large conglomerate.

Keywords: technical efficiency, stochastic frontier production function, ski lift companies, climate zones, ownership.

JEL classification: D24, D21, C2, R4

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1. Introduction

Cable cars and ski lifts form an important part of the infrastructure at mountain destinations. Just like within other narrowly defined transportation industries (Kerstens, 1996; Karlaftis & Tsamboulas, 2012), ski lift operators (companies) exhibit a wide degree of variation in technical efficiency (Botti, Goncalves, & Peypoch, 2012; Brida, Deidda & Pulina, 2014; Goncalves, 2013, Goncalves, Robinot & Michael, 2016). Several studies emphasise the role of location and elevation for performance of ski lift companies. Others predict that climate change will have negative consequences, particularly for certain ski areas at low elevation (Abegg, Agrawala, Crick, & De Montfalcon, 2007; Dawson & Scott, 2013). Beyond the European Alps, productivity of ski areas could be related not just to altitude, but also to other factors that affect the availability of snow, such as latitude or climate zone. Despite this, the role of latitude in determining performance of ski areas is largely neglected. In fact, the climate zone (or latitude) might be even more important than elevation in explaining productivity and efficiency of ski lift operators in certain areas, such as in the Nordic countries. In these countries weather conditions vary between warm summer humid continental or oceanic climate in the south and coastal areas, and a subarctic climate in the North and inner regions.

Findings of the TOPDAD project reveal that both latitude and elevation are crucial parameters when studying the impact of global warming on winter tourism demand in ski destinations. These results suggest that subarctic ski destinations (West and North Dalarna, Jämtland and Hedmark) as well as Finnish Lapland are expected to attain more winter tourists due to global warming (TOPDAD 2016; Prettenthaler, & Kortschak, 2015). However, climate change may also be a serious threat for the operations of ski lift companies in the Northern latitudes (Moen & Fredman, 2007). According to climate change scenarios, the average annual temperature change for the Nordic countries clearly exceeds that for other European countries (ACIA, 2004).

In this study the aim is to investigate whether factors other than altitude, such as climate zone and local market, drive the efficiency of ski lift operators. The approach includes estimation of the frontier production function both separately and jointly with the technical inefficiency (Kumbhakar, Ghosh & McGuckin, 1991). Focus is put on the winter seasons 2013/2014 and 2014/2015. These winters were snow-poor in the South of Scandinavia and South of Finland, with higher than average temperatures but with average snowfall in the subarctic climate zone. Data are based on a representative sample of ski lift operators in the Nordic countries, covering 60 to 85 per cent of the markets.

The study adds to the growing literature on productivity and efficiency determinants of ski lift companies and the main contribution is the inclusion of climate zones and detailed establishment data across countries. With the exception of Falk (2009), studies based on internationally comparable ski lift company information are rare. To the best of the author's knowledge, this is the first attempt to provide empirical evidence on this relevant topic. The study also contributes to the growing literature on the performance and efficiency of tourism enterprises related to climate change. Stagnation of demand for downhill skiing as experienced in the European Alps (Vanat, 2016) has been observed in the Nordic countries, too (see Graph 2 in the Appendix). After several successful winters, the number of visits to the Nordic ski area (except Iceland) slowed to a growth rate of 1.7 per cent per year on average between the seasons 2006/2007 and 2014/2015 (based on skier visits to the 80 largest ski lift operators).

The study is organised as follows. Section 2 introduces the conceptual background, and section 3 the empirical model. Section 4 presents the data and descriptive statistics while section 5 exhibits the empirical results, and section 6 concludes.

2. Conceptual background

Many studies emphasise the influence of external factors on the performance of ski lift companies, such as elevation. In particular, low-lying ski areas have been considerably more affected by warm winter seasons in the past than their counterparts at higher elevations (Tuppen, 2000; Hamilton, Rohall, Hayward & Keim, 2003; Unbehaun, Pröbstl & Haider, 2008; Dawson, Scott & McBoyle, 2009; Pickering, 2011; Steiger, 2011; Gonseth, 2013). Pickering (2011) finds that poor snow coverage in Australia leads to a decline in visitors by more than 50 per cent for the three lowest-altitude ski areas as compared to the average. Lower-elevation areas in the Austrian province of Tyrol also experienced large reductions in skier visits and lift transports during snow poor winter periods (Steiger, 2011). For New Hampshire, Hamilton et al. (2003) find that many low-elevation ski areas in the southern parts of the state have been abandoned in favour of areas up north at higher elevations. Further, there are indications that not only low-elevation, but also low-latitude ski areas are affected by global warming (Bark, Colby & Dominguez, 2010). Hendrikx et al. (2013) find that climate change leads to reduced snow coverage at lower elevations as well as at lower latitude ski areas, although in the latter case to a lesser extent. Based on regional data for European countries, Damm et al. (2016) show that the snow sensitivity of overnight stays is less pronounced at higher latitudes.

This study focuses on ski lift operators in the Nordic countries. These operators have several characteristics in common: They are relatively small, located at low elevations and with a high share of domestic visitors (see Haanpää, Juhola & Landauer, 2015 for Finland). In the Southern regions, day-trippers represent a significant share. According to the Köppen classification, Nordic countries have three distinctive climate zones: (i) subarctic climate (Dfc), (ii) warm summer humid continental (Dfb) and (iii) oceanic climate (Cfb). Climate refers to the long-term average of weather at a given location (Scott & Jones, 2007).

The Nordic countries are also characterised by a significant geographical length (see Graph 4 in the Appendix). In Sweden, for instance, the geographical distance between the most southern (e.g. Vallåsen) and the most northern ski areas (Riksgränsen) exceeds 1,000 km. The distance between Finnish ski areas is almost similar. While the larger ski areas are located in reasonably snow secure subarctic climate zones (see Graph 4 in appendix for an illustration of Köppen climate types), several small- and medium-sized ski lift operators are found in the warmer climate zone. Recent studies suggests that climate change is a concern for winter tourism even in high latitudes (see Brouder & Lundmark, 2011 for Northern parts of Sweden; Tervo-Kankare, Hall & Saarinen, 2013 for Finnish Lapland, Tervo, 2008 and Haanpää, Juhola & Landauer, 2015 for Finland; Nicholls & Amelung, 2015 for the Nordic countries in general; and see Kaján & Saarinen, 2013 for a survey). In this context, ski lift operator efficiency is measured by the ratio of the observed to the maximum feasible output, conditional on observed quantity and quality of inputs (lifts, length of runs, quality of lifts and snowmaking). It can be expected that ski areas in the warmer climate zones have a shorter and more snow-vulnerable season than their counterparts in the colder zone. Further, ski areas in the warmer climate zones have a disadvantage in the production of snow because of the lower number of days with optimal conditions for this activity. The same argument has been used for low elevations ski areas in the European Alps; such warmer conditions may affect the possibility to run efficient operations (Steiger & Mayer, 2008; Steiger & Stötter, 2013).

For the purpose of the study, the Nordic countries are grouped into two climate zones: subarctic, which is characterised by a long snow season (Veijalainen et al., 2010), and oceanic and warm summer humid continental, which is characterised by a shorter snow season. Damm et al. (2016) calculate ski season length for European mountain areas. The authors find that in the Nordic countries, the majority of regions have an average length of ski season of 100 or more days (measured as a minimum snow depth of 30 cm or more).

3. Empirical model

Output of ski lift companies is mainly determined by the factors of land (length or number of slopes) and number of ski lifts or lift capacity (Echelberger & Shafer, 1970; Goncalves, 2013; Mulligan & Llineares, 2003). Traditional input factors are number of employees and capital stock (Brida et al., 2014). A measure of the labour input is not included in the production function. The main reason behind this is that information on employment is only available for a small number of ski operators. Labour input can be neglected because the ski industry is capital intensive with a low share of labour costs in total output. This is confirmed by Skistar (2015), (the largest operator in the Nordic countries with six separate establishments in Sweden and Norway), who reports the share of labour costs to 25 per cent. Another aspect is quality factors. Quality of lifts is generally measured as the presence of fast or more comfortable lifts or their share in overall lift capacity (Falk, 2009). Chairlifts and modern gondola ropeways can approximate fast lifts. Surface lifts and t-bar lifts belong to the group of less comfortable lifts.

Proper snow supply is an essential factor for skiing (Steiger & Mayer, 2008). Snowmaking facilities can compensate for the lack of natural snow. Previous studies for the European Alps suggest that the sensitivity of skier visits to natural snow can be partly balanced by the level of snowmaking investments (Damm, Köberl & Prettenthaler, 2014; Gonseth, 2013; Steiger & Stötter, 2013). The snowmaking capacity can be measured by the percentage of ski runs or ski-able terrain equipped with snowmaking facilities. Snowmaking is widespread among ski lift companies in the Nordic countries with a 50 per cent share of ski runs covered by these facilities on average based on the sample. Alternatively, the planned duration of the ski season may be used as an indicator of snow coverage based on the assumption that a long season implicitly reflects good snow coverage. Average slope height is another measure of snow conditions because snow lasts longer at high altitudes. However, due to the differences in latitude between ski areas in North Scandinavia or Lapland and the southern areas, altitude cannot be employed as a sole measure of snow conditions.

Another aspect of importance for ski lift operators is ownership. Changes of ownership may have a direct effect on output and productivity. Therefore ownership is included in the production function rather than in the inefficiency equation. There are several reasons why large ski conglomerates often have a higher level of output given their inputs than small or independent operators. One reason is that they have better access to financial and marketing resources. Publicly traded companies, for instance, may have easier access to equity markets. Flagestad and Hope (2001) suggest that larger groups also have lower transaction costs in the form of savings in marketing, information, reservations, etc., making them more efficient. This can be referred to as the "corporate model" (Flagestad & Hope, 2001). However, ownership concentration is less predominant in Nordic countries, with the exception of Skistar. Instead there are many independent ski operators, often co-owned by private and public interests. Flagstad and Hope (2001) call this model the “community model”. Proximity to larger agglomerations may also affect output or efficiency of ski lift companies (Mulligan & Llineares, 2003). Using data for ski lift companies in the US, the authors show that a large local market is an advantage, since output is expected to decrease with the distance of the ski area from where skiers live or stay. In order to account for proximity to population centres, the presence of a town with 25,000 inhabitants within travel time of one hour is used.

Efficiency of firms is commonly estimated in either a single frontier production function framework (Amsler, Lee & Schmidt, 2009) or jointly with technical inefficiency (Kumbhakar et al., 1991). In this study both approaches are employed. Econometrically, the joint approach estimates inefficiency, instead of efficiency. Nevertheless, the variables of importance are the same and the results can also be interpreted as efficiencies. Drivers of technical efficiency may be estimated in either a parametric or non-parametric model (see Assaf & Josiassen, 2016; Murillo-Zamorano, 2004 for surveys). The parametric approach is preferred here since it is less sensitive to outliers (Assaf & Josiassen, 2016). This is particularly crucial when some of the variables are based on rough measures, like snowmaking capacity. Kumbhakar et al. (1991) propose a joint estimation of the frontier and the inefficiency model for cross-sectional data where the inefficiency term is assumed to follow a truncated normal distribution. Wang (2002) suggests a specification where external factors affect both the mean and the variance of the inefficiency. In this study, the external factors are related to the mean of inefficiency. Preferable determinants are external factors which are not under the control of the firm. These factors may not affect production directly. The joint stochastic frontier production and inefficiency model can be described as follows:

$$lnY_i = \sum_{j=1}^{J} \alpha_j X_{ij} + \sum_{j=1}^{K} \beta_j Z_{1ij} + v_i - u_i \quad (1)$$

$$\mu_i = \delta_{0,i} + \sum_{n-1}^{N} \delta_{n,i} Z_{2ni} \quad (2)$$

$u_i \sim N^+(0,\sigma_u^2)$ and $v_i \sim iidN(0,\sigma_v^2)$.

Subcript *i* refers to the ski lift operator, *ln* represents the natural logarithm, *Y* represents output measured as number of skier visits, and the *X* is a vector of input variables including land (length of slopes) and equipment (number of ski lifts). Quality of lifts and snowmaking capacity are denoted by Z_{1ij}. The α_j and β_j are the parameters to be estimated, and the variable v_i is a part of the error term, assumed to be independently and identically distributed with $N(0,\sigma_v^2)$ and independent of u_i. The remaining part of the error term, u_i, is a non-negative random variable capturing technical inefficiency, which is assumed to be independently and identically distributed, but truncated at zero with mean μ_i and variance σ_u^2. Maximum likelihood estimation provides the parameter estimates and the variance parameters σ_u^2, σ_v^2 and $\lambda = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$. Treated separately, technical efficiency is defined as the ratio of observed output to the corresponding frontier output, and is calculated as follows:

$$TE_i = exp(-u_i). \quad (3)$$

Technical efficiency takes on value between 0 and 1 (or multiplied by 100) with 1 representing the technically most efficient firm and 0 its opposite. The efficiency level for different groups of ski lift operators may be compared by elevation, climate zone, and proximity to urban agglomerations. Given data availability and in accordance with findings in the literature, the stochastic Cobb-Douglas type production function is specified as follows:

$$\begin{aligned} \ln Y_i = \alpha + \beta_1 \ln KM_i + \beta_2 \ln NOLIFTS_i + \beta_3 QUALITYLIFTS_i + \beta_4 SNOWMAKING_i \\ + \beta_5 OWNERSHIP_i + v_i - u_i \end{aligned}. \quad (4)$$

with the set of variables listed below.

Y:	Dependent variable, number of skier visits (i.e. one day or part of a day of skiing for one skier) in the 2013/2014 and 2014/2015 winter season,
KM:	Total length of slopes in kilometres,
NOLIFTS:	Number of ski lifts (t-bar and surface lifts, chairlifts, gondola ropeways),
QUALITYLIFTS:	Dummy variable for presence of fast lifts (e.g. chairlifts, modern gondola ropeways),
SNOWMAKING:	Proportion of ski runs covered by snowmaking facilities and
OWNERSHIP:	Dummy variable for ski lift companies owned by a larger group (“SKISTAR”).

As suggested by Kumbhakar et al. (1991) and Battese and Coelli (1995), it is assumed that the parameter μ is a function of various exogenous factors. In this case, the inefficiency equation includes location and climate specific factors:

$$\mu_i = \delta_0 + \beta_1 CLIMATEZONE_i + \beta_2 LOCALMARKET_i + \sum_{j=1}^{J} \delta_{co,j} COUNTRY_{ij} + e_i \quad (5)$$

These climate and location specific factors include the following elements:

CLIMATEZONE: Dummy variable equal to one if the ski area is located in one of the two warmer climate zones (warm summer humid continental or oceanic climate) with the subarctic climate zone used as the benchmark,

LOCALMARKET: Dummy variable measuring the proximity to a town with a population of at least 25,000 inhabitants within a distance of 50 kilometres or with a travel time of one-hour and

COUNTRY: Country dummy variables with Sweden as the reference category.

The two-equation model can be estimated jointly by Maximum Likelihood with heteroscedasticity consistent standard errors. The inefficiency coefficient can be transformed into marginal effects by a method proposed by Wang (2002). In addition, the stochastic frontier model will be estimated excluding the inefficiency determinants.

4. Data sources and descriptive statistics

There are about 500 ski lift operators in the three Nordic countries of Finland, Norway and Sweden (see Graph 5 for the location of ski areas). This study employs detailed data on a large amount of these, covering 84 per cent of the market in Finland, 80 per cent in Sweden and 60 per cent in Norway. The data originate from several sources. Information on output measured as skier visits, the highest lift station, number of lifts (and type), length of total ski runs, longest ski-run, number of terrain parks and snowmaking coverage are provided by the national associations of ski lift companies ALF, 2015; SHKY, 2015; SLAO, various issues). In a few cases, information on the number of skier visits is based on ski lift revenues and the average lift ticket price (Elkedalen, Gaustablikk, Gautefall, Rauland and Vassfjellet) or are directly obtained from the ski lift company (i.e. Oppdal and Roldal). In cases of incomplete data from the ski lift associations, information has been obtained directly from the establishment in question or from its website. Ownership information is drawn from the annual reports of the SKISTAR company (Skistar, 2015).

Each ski area is assigned to a Köppen climate zone (see Graph 4 in Appendix). One fourth of the ski lift operators in the sample are active in the warmer climate zone (see Table 3 in Appendix). Sweden is the country with the largest number of ski lift companies in this zone. Google Maps is used to calculate the travel distance between the ski area and the nearest town as well as that to the capital city for each country. A large local market is defined as a town with 25,000 inhabitants or more within a distance of 50 kilometres or travel time of one hour from the ski area.

Table 1: Descriptive statistics

	Mean	Std. dev	Min	Max
Number of skier visits (mean 2013-2014, 2014-2015), 1000s	152	192	15	967
Length of ski runs, km	20	18	2	101
Longest ski run, metres	2165	1393	450	7000
Share of snowmaking capacity, %	0.51	0.37	0.00	1.00
Number of ski lifts	11	9	2	48
Elevation of highest lift station, metres	658	370	92	1450
Maximum vertical drop, metres	321	210	55	1008
Number of terrain parks	2	1	0	7
Distance to the capital city, km	459	308	1	1360
Distance to the nearest town with population >=25k, km	120	106	1	710
Dummy variables:	percentages			
Ski lift operators owned by Skistar	0.08			
Location in warm summer humid continental, oceanic climate zones	0.25			
Large Local market	0.40			
Fast lift	0.65			

Source: See text and reference list.

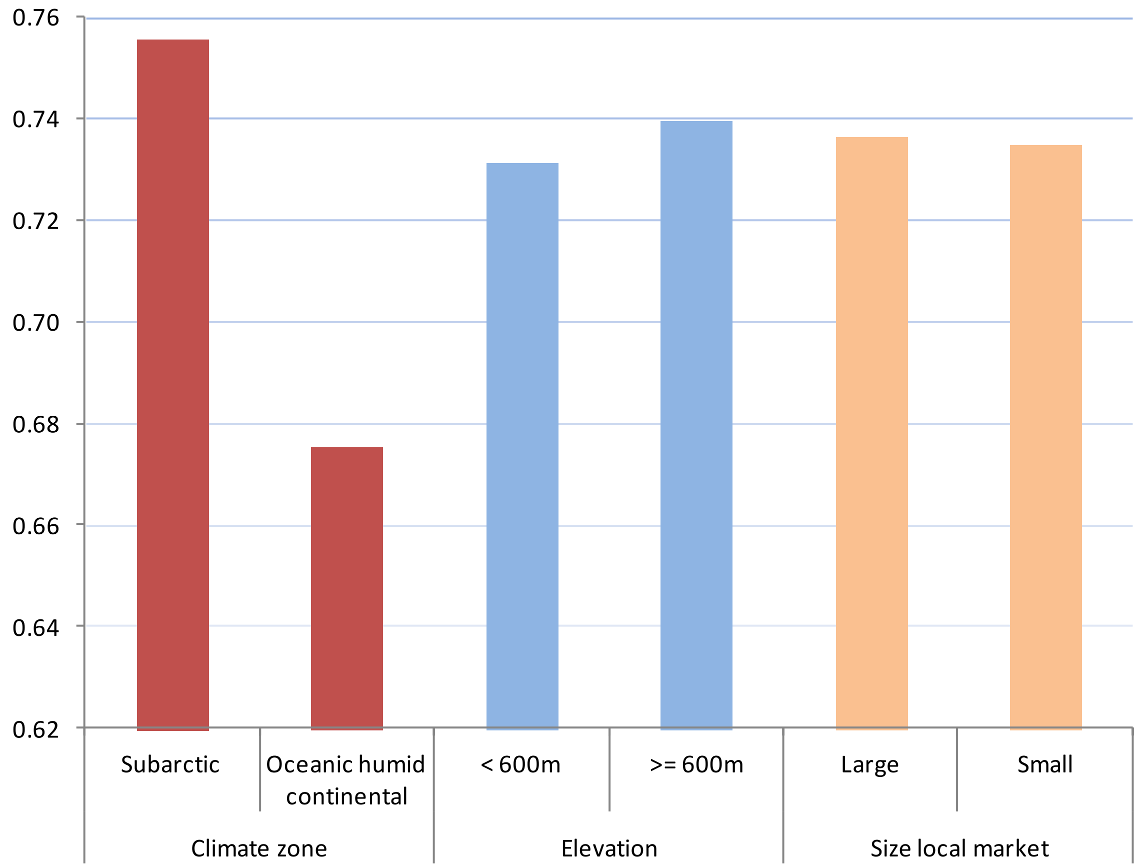
The ski areas studied show considerable heterogeneity in terms of size, quality characteristics and distance to the nearest agglomeration (Table 1). Out of the 83 ski lift operators investigated, six are owned by Skistar. The mean length of ski slopes per operator is approximately 20 kilometres (ranging between 2 and 101 km), the number of ski lifts is 11 and the highest lift station is located at 660 metres above sea level on average. The highest elevation is 1,450 metres – much lower than in the European Alps. The vertical drop is relatively small with an average of 320 metres, and the share of slopes covered by snowmaking is 50 per cent on average. This is lower than in Austria (for North Tyrol 75 per cent Steiger, 2011) but higher than in France where between 18 and 34 per cent of the slopes are prepared with fabricated snow (Spandre et al., 2016). A majority of the ski areas offer a snow or terrain park. The travel distance from the ski areas to the capital city in each Nordic country is on average 460 kilometres. Two out of five ski lift operators are located close to a town with at least 25,000 inhabitants.

5. Estimation results

Estimation results show that ski operators in subarctic climates are markedly more efficient than those in milder climate zones (Graph1, Table 2, Table 4 in the Appendix), independent of model (separate technical efficiency or joint technical inefficiency). Elevation and local market are not important for efficiency. A first impression of the technical efficiency distribution for the ski lift operators is given by the scores based on the single equation stochastic production function with truncated normal distribution of the inefficiency term. This distribution is highly skewed across the two different climate zones (Graph 3 in the Appendix). Ski lift companies in the warmer climate zones are overrepresented in the low efficiency range whereas the majority of ski lift companies in the colder climate zone are close to the production frontier.

On average, the efficiency level of ski lift companies operating in the subarctic zone is 76 per cent, which is eight percentage points higher than for those in the warmer climate zone (Graph 1 and Table 4 in the Appendix). Efficiency of ski operators nearby large cities does not deviate from that of those in rural areas. Likewise, the efficiency level of ski lift companies with a maximum elevation of 600 metres arrives at the same level as for those located at higher elevations (between 600 and 1450 metres). Thus, as opposed to elevation and size of the local market, climate zone is a clearly discriminating factor for technical efficiency. The technical efficiency index can also be used to benchmark the ski lift companies against each other (Botti, Goncalves, & Peypoch, 2012). Tjiamstanbackarna, Hemsedal, Myrkdalen, Vuokatti and Trysil are the most efficient ski lift companies in the sample (Table 5). The Sälen ski resorts Lindvallen/Högfjället, Tandådalen/Hundfjället (including Sälenfjällen) are in the Top 20 group while Levi and Åre are in the upper middle part (Top 30).

Graph 1: Technical efficiency for different types of ski areas



Note: Technical efficiency level is calculated based on the stochastic frontier function under the truncated normal distribution and excluding the inefficiency equation (see Table 4). The technical efficiency score is one for a technical efficient ski lift operator and zero for an inefficient firm.

Simultaneous estimations give some deeper insights into the drivers of efficiency of ski lifts operators. However, in this model *inefficiency* is estimated based on two separate specifications: i) including climate zone, local market and elevation and ii) encompassing only climate zone because the two latter variables do not reach significance at conventional levels (Table 2).

All coefficients of the input factors in the frontier production function part of the estimations render expected positive signs and are significant at the five per cent level, thus following the pattern of the technical efficiency estimation (Table 4 in the Appendix). Since the length of ski runs and number of ski lifts are measured as the natural logarithm coefficients, they can be interpreted as elasticities. The elasticity of output with respect to the length of ski runs is 0.20. Total number of lifts is more important, as indicated by an output elasticity of 0.67. The magnitude of the semi-elasticity of the share of ski runs covered by snowmaking facilities is about 0.55. This means that an increase in snowmaking capacity by 10 percentage points is associated with a 5.5 per cent higher number of skier visits, thus considerably higher than for a sample of ski lift companies in Austria, Switzerland and France, which amounts to about 0.10 (Falk, 2009).

In order to obtain an indication of the magnitude of the continuous variables, a one standard deviation increase in the share of each variable can be calculated. An increase in the share of ski runs covered by snowmaking by one standard deviation is associated with a 20 per cent higher output. Corresponding increases in the length of ski runs and in the number of ski lifts are related to increases of 20 and 55 per cent, respectively. The interpretation of this is that snowmaking coverage is an important input factor that cannot be neglected. Overall the findings indicate that the number of ski lifts is the more important factor in determining output than snowmaking coverage and length of slopes. This is not surprising as the number of lifts is a proxy of total lift capacity. Thus, a lack of transportation facilities is a main limitation for long term increases in production.

The dummy variable measuring fast lifts (chairlifts or gondolas) is significant at the five per cent level with a coefficient of 0.24. This indicates that ski lift operators with fast lifts have 27 per cent higher output given firm characteristics. The discrepancy between these two values depends on the measurement of the variables included. When the dependent variable is measured in logarithms, the marginal effect of a dummy variable has to be calculated as (exp(α) – 1) multiplied by 100. There is also a significant and positive coefficient for ski operators belonging to the Skistar group. This implies that large enterprise groups have advantages compared with independent operators. On average ski areas belonging to Skistar have a 70 per cent higher output given their characteristics and inputs.

Table 2: Factors affecting the output and inefficiency of ski lift companies

	(i)			(ii)		
	Coeff.		t	Coeff.		t
Production function:						
ln length of slopes, km	0.196	**	2.41	0.216	**	2.47
Share of snowmaking capacity, %	0.547	***	3.41	0.533	***	3.38
ln number of ski lifts	0.670	***	4.42	0.669	***	4.25
Dummy variable fast lift	0.236	**	2.00	0.250	**	2.00
Dummy variable affiliation Skistar	0.685	***	3.57	0.671	***	3.70
Dummy variable Norway	-0.105		-0.45	-0.072		-0.44
Constant	2.492	***	5.93	2.404	***	7.51
Inefficiency equation:						
Dummy variable oceanic humid continental climate	0.854	**	1.97	1.098	***	2.72
Dummy variable Norway	-2.329		-1.08	-2.440		-1.05
Dummy variable max elevation 600 metres or below				-0.129		-0.31
Dummy variable size local market				-0.173		-0.47
Constant	0.077		0.11			
λ	0.694	***	12.25	0.704	***	15.83
σ_u^2	0.534	***	3.09	0.572	***	4.31
σ_v^2	0.236	***	6.19	0.240	***	5.58
# observations	83			83		
Log likelihood	-37.67			-37.45		
Marginal effect dummy variable oceanic or humid continental climate	0.333			0.360		
LR test: inefficiency component=0 (p-value)	0.031					
Pseudo R^2	0.77			0.77		

Notes: Asterisks ***, ** and * denote significance at the 1, 5 and 10 per cent level, respectively. The dependent variable is the logarithm of the number of skier days (mean 2013/2014 to 2014/2015). Estimation method is maximum likelihood with robust standard errors and where the distribution of the inefficiency term is assumed to be truncated normal. Estimates are based on the SFCROSS command in STATA 14. Specification (ii) does not contain an intercept in the inefficiency model. The Likelihood ratio tests indicate that the null hypothesis – assuming the technical inefficiency effects are not present – is rejected at the one per cent level based on the critical values provided by Kodde and Palm (1986). The estimate of the variance parameter λ is 0.70 and highly significant, implying that 70 per cent of the variation in output (given the input factors) is due to inefficiency, and 30 per cent is due to random factors.

The country dummy variable for Norway is not significant. This indicates that there are no apparent differences in the efficiency level across countries. Still, country effects have to be interpreted with care since the sample of Norwegian ski companies does not include small- or medium-sized operators.

The final part of the empirical section encompasses the multivariate analysis of the inefficiency scores (Table 2, lower panel). These results show that the inefficiency level of ski lift companies depends significantly on the climate zone when controlling for elevation of the ski area and the local market indicator. In particular, the coefficient of the dummy variable measuring the location in oceanic or humid continental climate is positive and significant at the five per cent level. Thus, a positive coefficient implies that the change in the external factor in question is associated with a surge in technical inefficiency (or reduced technical efficiency). Since the magnitude of the dummy variable cannot be directly investigated, marginal effects are provided (Wang, 2002). On average, the marginal effects show that the level of inefficiency of ski lift companies operating in the warmer oceanic or humid continental climate zone is 30 per cent higher than for those located in a subarctic climate (or equal to a 12 percentage points difference). Further, the local market variable – which is measured as ski areas that have a town of a certain size close by (25,000 or more population and travel time of one hour or less) – and the low elevation dummy variable are no longer significant when estimations are made simultaneously. Overall, the results of the single stochastic frontier equation are consistent with those of the simultaneous model; however, the latter approach should be preferred because it is more general than the former in that it takes into account several inefficiency determinants simultaneously.

Several robustness checks have been conducted. First, the stochastic frontier production model is specified as a translog production function. This change of specification does not affect the efficiency scores nor are the sign and significance of the inefficiency determinants influenced. There are also experiments undertaken with additional variables with presumptive effect on the production or the inefficiency level of ski lift companies. These variables include the number of terrain parks (measured as a set of dummy variables), presence of a neighbouring ski area, travel distance to the nearest international airport (alternatively, presence of an airport within one hour of travel), and the vertical drop of the ski areas. However, unreported results show that none of these variables are significant at conventional levels. Further, Norwegian ski operators are excluded in one specification because in this sample large ski lift companies are overrepresented. Again climate zone is significant with a similar magnitude (coefficient of 0.95 and a t-value of 2.18), indicating that the main variable is not sensitive to the inclusion or exclusion of Norway. Second, a quadratic specification and interaction effects have been tested, although the efficiency scores are not sensitive to variations in the specification of the production function. Third, the stochastic frontier production function is estimated with panel data using a random effects specification covering up to three winter seasons. Still, the technical efficiency scores are similar to the cross-section results. This is no surprise since the characteristics of the ski lift operators and ski areas do not vary over time.

6. Conclusions

This paper has analysed the efficiency of ski lift companies in three Nordic countries with a special emphasis on the importance of climate zone. The empirical methodology consists of a stochastic frontier production function and an inefficiency equation estimated jointly by maximum likelihood. The novel result is that ski lift companies operating in the warmer oceanic humid continental climate zones are significantly less efficient than those located in the subarctic zones. It is noteworthy that the difference in the level of inefficiency of these two groups is quite large with about 30 per cent which is equal to 12 percentage points. Presence of a large local market and location at low elevations are not relevant.

Results for the stochastic production frontier model show that output can be explained by length of ski runs, number of ski lifts, presence of fast lifts, snowmaking capacity and large ski conglomerates (Skistar). The most important production factor is the number of ski lifts.

There are several policy conclusions that can be drawn from this analysis. An important implication of the findings is that many ski-lift operators in low-latitude areas do not realise their full productivity potential. A possible explanation is that these companies do not have the required climate conditions to produce snow when it is needed for instance in the early season, or when there are higher than average temperatures or poor snow coverage in the warmer climate zone. The higher level of inefficiency of some ski lift companies is a serious threat to operations and will most likely lead to an increase in company debts and possible future closures. In contrast, ski areas at higher latitudes are already operating close to their maximum efficiency level and thus have better growth prospects. This in turn could lead to a rise in concentration, with a small number of large ski-lift companies at higher latitudes dominating the ski industry, as already observed in the European Alps and in North America (Müller & Weber, 2008; Hamilton et al., 2003).

This research is subject to several limitations, including the fact that very small ski-lift operators (those with one or two ski lifts) are not included in the empirical analysis, and that Norwegian operators are underrepresented due to data limitations or accessibility. In addition, analysis only focuses on observable factors such as input factors, climate zone (latitude) and location, while several other aspects may also be of importance. These include management skills, grooming of slopes and availability of nearby hotel beds. It would be interesting to see these additional variables addressed in future research on possible determinants of efficiency among ski lift operators.

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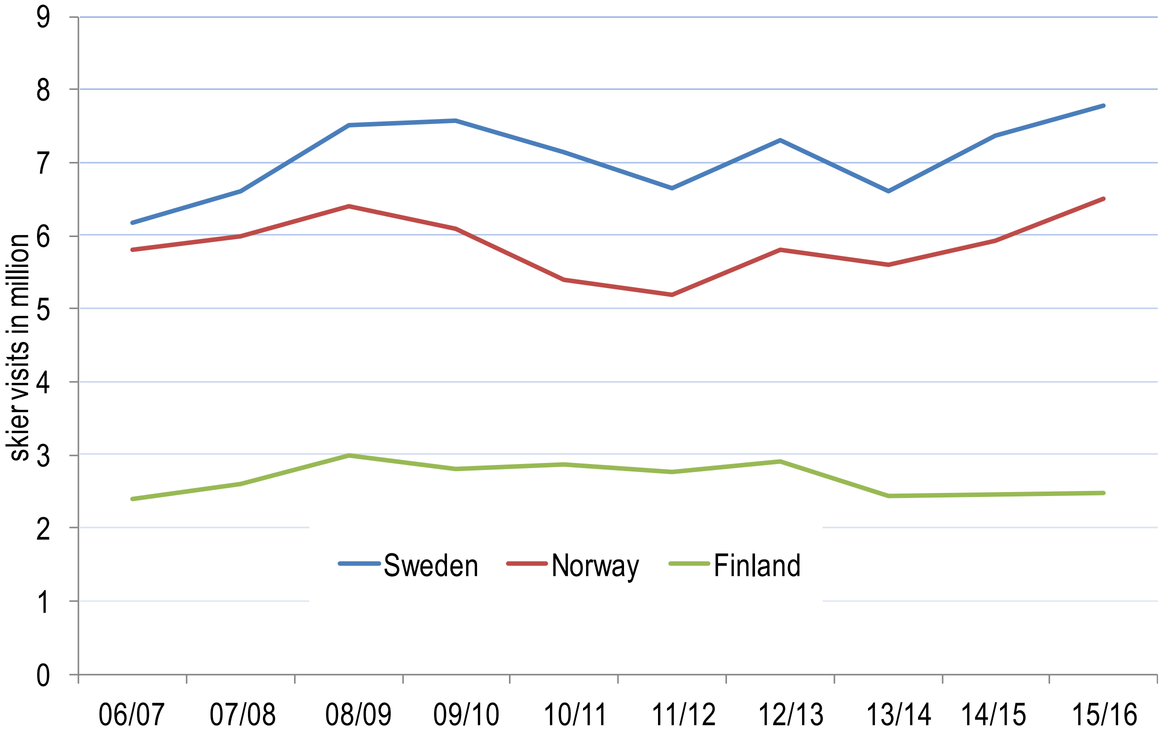
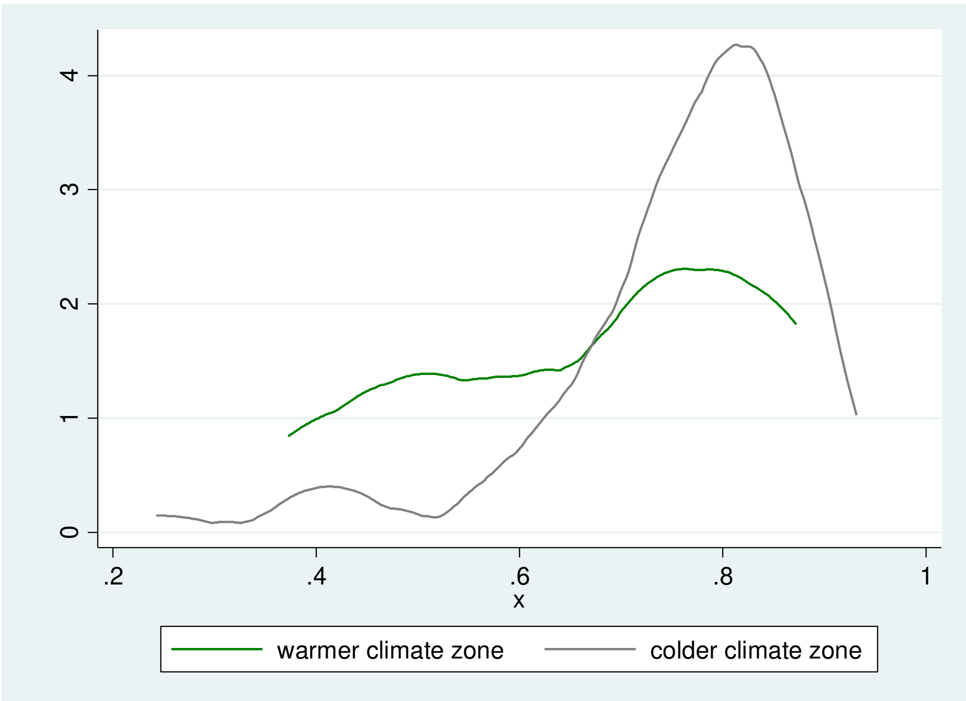
Appendix

Graph 2: Evolution of skier visits in the Nordic countries



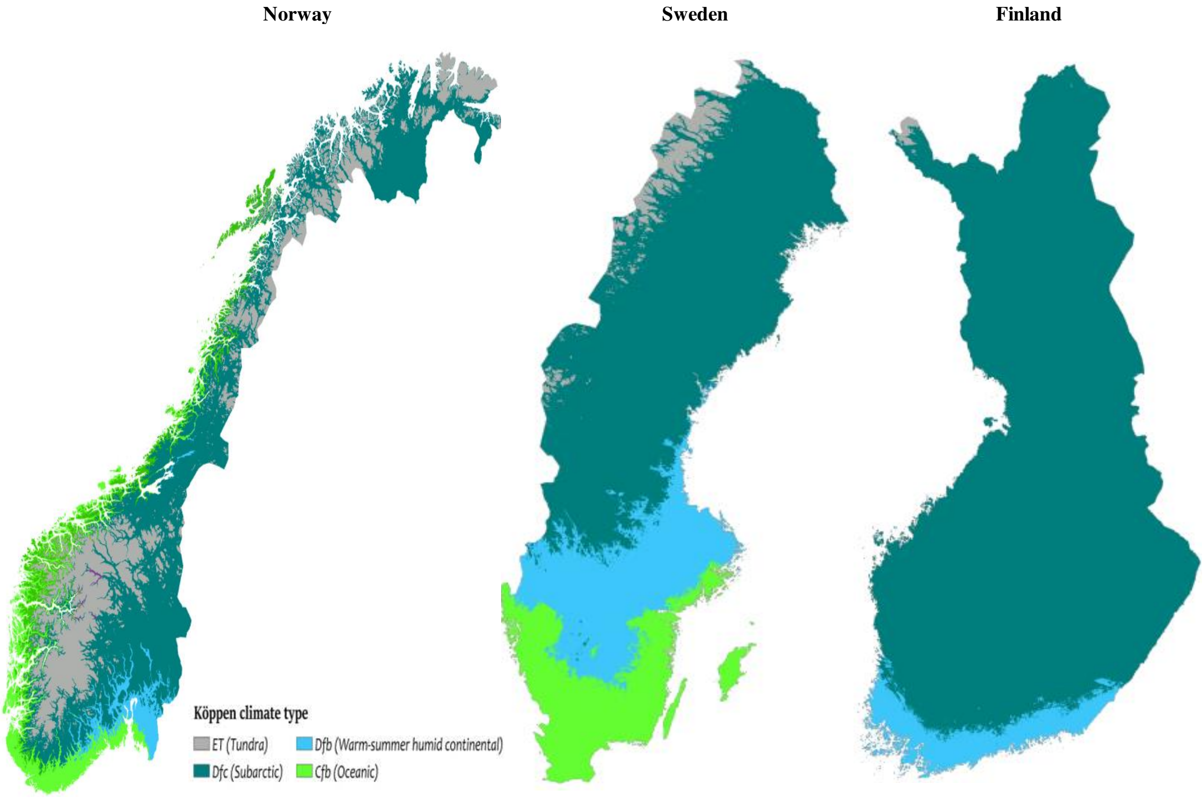
Source: National associations of ski lift companies (SLAO, www.slao.se, ALF, http://alpinanleggene.no; SHKY, The Finnish Ski Area Association).

Graph 3: Distribution of the technical efficiency scores



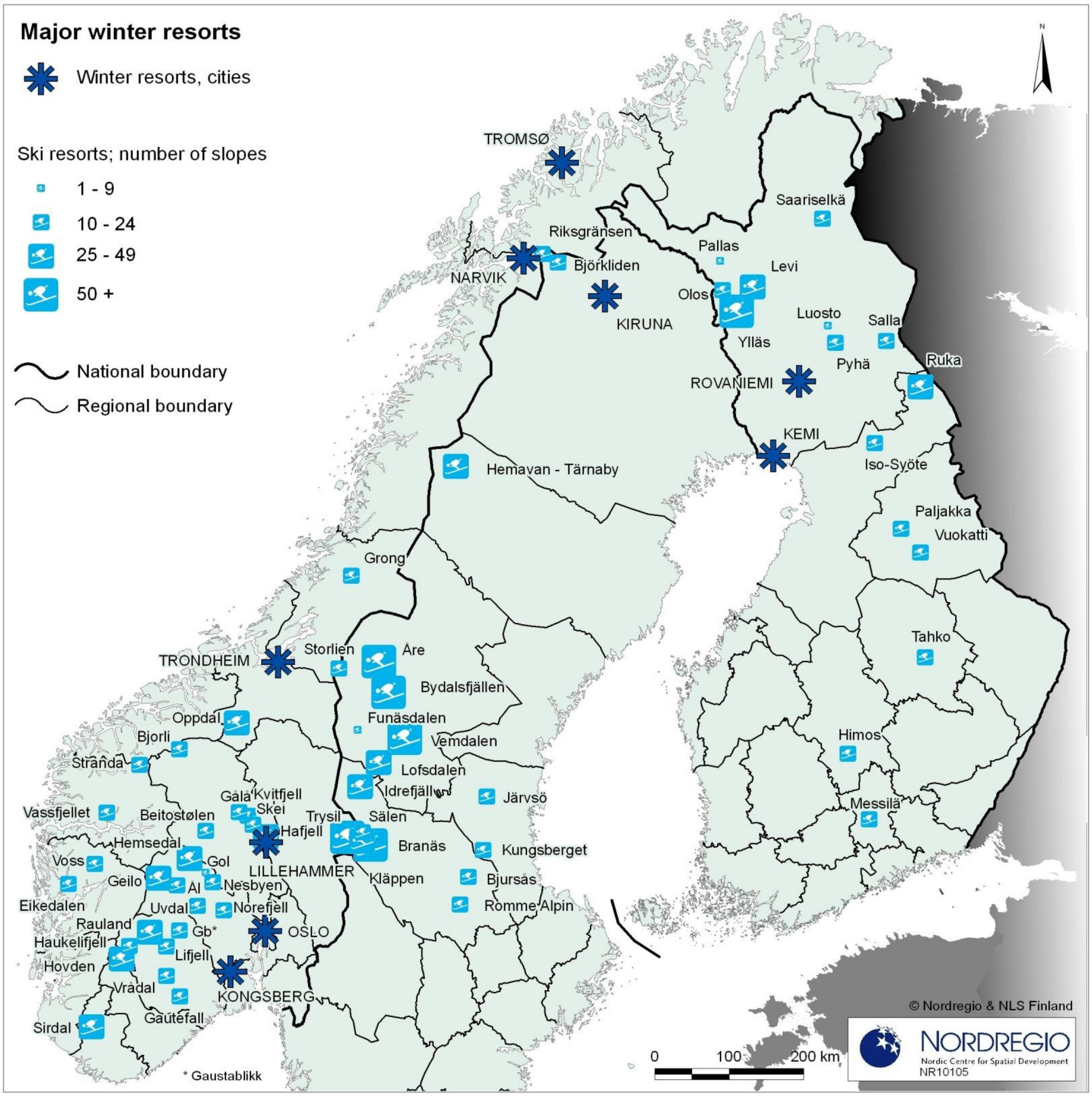
Notes: The graph shows the probability distribution of the technical efficiency scores for two climate zones based on the stochastic frontier function under the truncated normal distribution (without the inefficiency model) (based on Table 4).

Graph 4: Definition of the Köppen climate types



Source: Peterson, A. (2016). Retrieved 9 February 2017 from https://commons.wikimedia.org/wiki/File:Sweden_koppen.svg, https://commons.wikimedia.org/wiki/File:Finland_koppen.svg and https://commons.wikimedia.org/wiki/File:Norway_koppen.svg.

Graph 5: Location of ski areas in the Nordic countries



Source: Roto, J. (2009). Major winter resorts in Scandinavia, Nordregio map. Retrieved 10 February 2017 from http://www.nordregio.se/en/Maps/09-Other/Major-winter-resorts-in-Scandinavia.

Table 3: Ski areas located in warmer climate zones

Ski area	Country code
Bjursås Skicenter	SE
Elkedalen	NO
Flottsbro	SE
Gaustablikk	NO
Gautefall	NO
Hammarbybacken	SE
Isaberg	SE
Kongsberg	NO
Leksand/Granberget	SE
Mullsjö Alpin	SE
Norefjell	NO
Oslo Vinterpark (Tryvann)	NO
Rauland	NO
Ski Sunne	SE
Säfsen	SE
Talma	FI
Ulricehamns skicenter	SE
Vihti	FI
Valfjällets Skicenter	SE
Vallåsen	SE

Source: Own classification based on Graph 4 in the Appendix.

Table 4: Estimation results of the stochastic frontier function (without the inefficiency model)

	Truncated normal			Half-normal		
	Coeff.		z	Coeff.		z
ln length of slopes, km	0.333	***	3.79	0.327	***	3.79
Share of snowmaking capacity, %	0.378	**	2.14	0.359	**	2.31
ln number of ski lifts	0.675	***	4.75	0.687	***	4.97
Dummy variable fast lift	0.251	**	2.03	0.247	**	1.97
Dummy variable affiliation Skistar	0.486	***	2.77	0.475	***	2.89
Dummy variable Norway	0.151	*	1.71	0.162	*	1.83
Constant	2.018	***	8.96	2.101	***	9.38
λ	0.790	***		0.654	***	
σ_u^2	1.100		0.93	0.526	***	4.85
σ_v^2	0.292	***	3.96	0.278	***	4.02
R^2	0.82			0.82		
Number of observations	83			83		
<u>Technical efficiency scores:</u>						
Mean	0.73			0.68		
Warmer climate zone	0.68			0.62		
Colder climate zone	0.76			0.70		
<u>Technical inefficiency scores</u>						
Mean	0.33			0.42		
Warmer climate zone	0.42			0.52		
Colder climate zone	0.30			0.38		

Notes: Asterisks ***, ** and * denote significant at the 1, 5 and 10 per cent level, respectively. The dependent variable is the logarithm of number of skier days measured as the mean over the two seasons 2013/2014 and 2014/2015. Estimated by Maximum Likelihood with robust standard errors. Technical efficiency level is calculated based on the stochastic frontier function under the truncated normal distribution and the half normal distribution, and excludes the inefficiency equation. The technical efficiency score is 1 for a technically efficient ski lift company and zero for the technically efficient firm.

Table 5: Technical efficiency level of ski lift companies

	half normal	truncated		half normal	truncated
Tjiamstanbackarna	0.92	0.93	Bygdsiljum	0.68	0.77
Hemsedal	0.87	0.89	Beitostølen	0.68	0.76
Myrkdalen	0.85	0.88	Vallsberget Lindbäckstatium	0.68	0.76
Vuokatti	0.85	0.88	Norefjell	0.67	0.75
Trysil	0.85	0.88	Lofsdalen	0.67	0.75
Flottsbro	0.84	0.88	Ounasvaara	0.66	0.75
Kungsberget	0.84	0.87	Fjätervålen	0.66	0.75
Oslo Vinterpark (Tryvann)	0.84	0.87	Hassela	0.66	0.75
Järvsö	0.83	0.87	Dundret	0.66	0.75
Kåbdalis	0.83	0.87	Hammarbybacken	0.66	0.74
Gautefall	0.80	0.85	Kläppen Ski Resort	0.65	0.74
Messilä	0.80	0.85	Roldal	0.65	0.74
Sappee	0.80	0.85	Hovfjället	0.65	0.74
Idre Fjäll	0.80	0.85	Stöten i Sälen	0.65	0.74
Vassfjellet	0.80	0.85	Skeikampen	0.64	0.73
Lindvallen/Högfjället	0.79	0.84	Geilo	0.64	0.73
Kongsberg	0.79	0.84	Isaberg	0.63	0.73
Leksand/Granberget	0.78	0.84	Storklinten	0.62	0.72
Tandådalen/Hundfjället Sälenfjällen	0.78	0.84	Funäsdalen Berg & Hotell/Funäsdalen	0.59	0.69
Koli	0.78	0.83	Björkliden	0.58	0.68
Hafjell Ski Resort	0.78	0.83	Hemavan Tärnaby	0.58	0.68
Ruka	0.78	0.83	Ylläs	0.58	0.68
Åre	0.78	0.83	Ulricehamns skicenter	0.58	0.67
Vemdalen	0.78	0.83	Himos	0.53	0.62
Romme Alpin	0.78	0.83	Laajavuori	0.52	0.62
Branäs	0.77	0.83	Tänndalen/Hamrafjällets	0.52	0.62
Kasurila	0.77	0.83	Vihti	0.51	0.61
Ramundberget	0.76	0.82	Rauland	0.52	0.61
Tahko	0.76	0.82	Oppdal	0.51	0.61
Levi	0.74	0.81	Ukkohalla-Palkakka	0.51	0.60
Iso-Syöte	0.74	0.81	Bydalsfjällen	0.50	0.59
Säfsen	0.74	0.81	Riksgränsen	0.47	0.56
Saariselkä	0.73	0.80	Gaustablikk	0.46	0.54
Talma	0.73	0.80	Vallåsen	0.44	0.52
Kvitfjell	0.73	0.80	Ski Sunne	0.44	0.51
Valfjällets Skicenter	0.73	0.80	Gesundaberget	0.40	0.47
Hovden	0.73	0.80	Salla	0.40	0.47
Elkedalen	0.73	0.80	Bjursås Skicenter	0.38	0.44
Kittelfjäll	0.72	0.80	Mullsjö Alpin	0.37	0.42
Orsa Grönklitt	0.71	0.79	Storlien Alpin	0.33	0.37
Voss	0.70	0.78	Trillevallen	0.23	0.24
Pyhä	0.69	0.77			

Notes: Based on the single equation stochastic frontier production function displayed in Table 4, which excludes the dummy variable for affiliation Skistar and the dummy variable for Norway.