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Metrics at 8,000 Meters: Determinants of Summit Success in the Himalayas

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Determinants of Summit Success in the Himalayas

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Abstract

This paper examines the determinants of success for individuals summiting 8,000m Himalayan peaks from 1995 to 2019. Using binary logistic regressions, this paper presents evidence that a climber's citizenship is a highly significant determinant of success. Chinese citizens are clear outliers with 192% more odds of success than an American. The success rates related to season, gender, and year all conform with existing research, justifying the robustness of the citizenship trends. Despite controlling for per capita income, the results assert that wealth may not be an important determinant of success and provokes interesting questions as to what factors may influence citizenship success trends.

Table of Contents

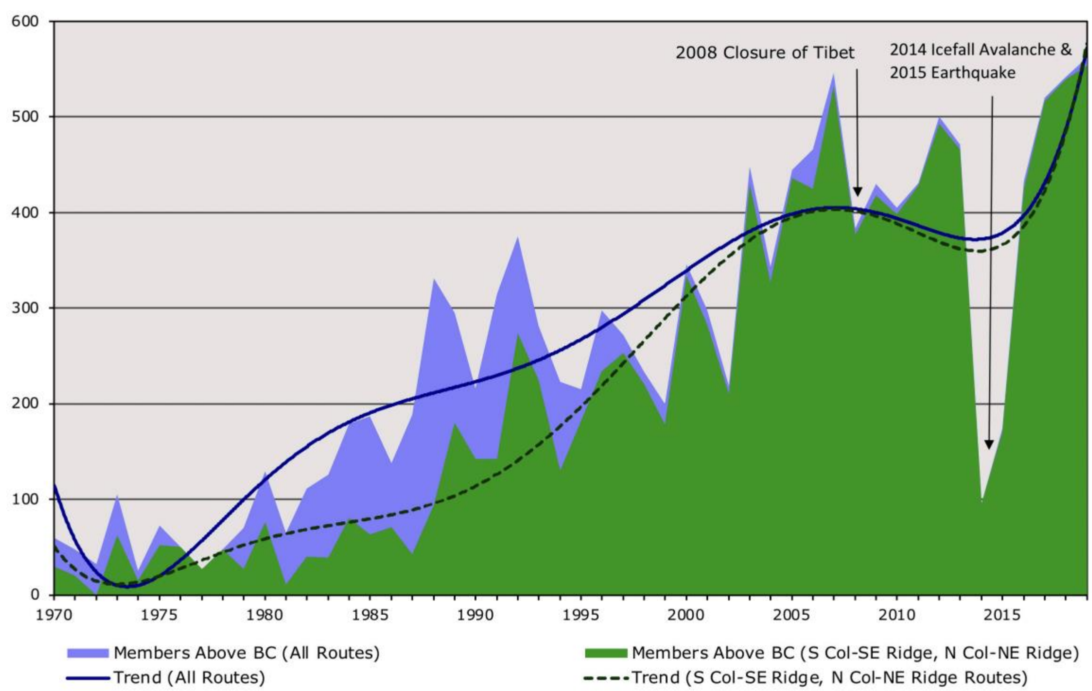
I. Introduction

The history of expeditionary climbing in Nepal is generally analyzed in four stages: the exploratory period (1900-1949), the expeditionary period (1950-1969), the transitional period (1970-1989), and the commercial period (1990-present). A small number of expeditions explored the Himalayan mountains in the 1920s and 1930s with little summit success. The Himalayan climbing saga was ignited in 1953 when Sherpa Tensing Norgay and Sir Edmund Hillary became the first people to successfully summit Everest. The expedition's success captivated the world, familiarizing the Himalayas and their climbing opportunities to people around the globe.

Although alpine clubs and scientists were enamored, restrictions placed on foreign climbers by the Nepalese and Tibetan governments slowed the growth of the Himalayan climbing industry. Following the first successful summit, international relations proved to be the biggest obstacle to prospective Everest expeditions. The Chinese government officially closed the Tibetan routes of Everest from 1950 to 1980 and Nepal didn't formally allow foreigners to climb unless accompanied by scientific teams until 1985 (Bogage 2019). The transitional period began as foreign relations improved and expeditions grew in number. During this period before 1990, the vast majority of expeditions attempting to summit Himalayan mountains were formed and funded by governments, scientists, or experienced climbers joining forces on their own accord (Savage, Torgler 2013). As the popularity of Himalayan climbing grew, the composition of expeditions changed dramatically.

In their analysis, Savage and Torgler (2013) explain that many "credit or blame" Dick Bass for beginning the "explosion" of commercialization in the 1990s. In 1986, Dick Bass completed the Seven Summits challenge by climbing the highest mountains on each continent: Mt. Everest, Aconcagua, Denali, Kilimanjaro, Mt. Elbrus, Mt. Vinson, Mt. Kosciuszko. Importantly, Bass was a relatively inexperienced climber. Reflecting on his Seven Summit journey in an interview with Forbes, Bass explained that members of his expedition were "honest enough to know what we were. And we weren't experienced climbers. We had a dream and were really rank amateurs, when you get down to it" (Clash 2015). Bass' awe-inspiring accomplishment demonstrated a notion that became a pillar in Nepal's fast-growing climbing industry: sufficient funds - not years of climbing experience - are the key to climbing the highest peaks in the world. In their study, Savage and Torgler (2013) explain that an expedition is characterized as commercial when it is organized for profit and can consist of "a mix of individuals with a range of climbing experience and training (from little to none) with only the expedition leaders and Sherpas having any true mountaineering experience". Many credit the shift towards commercial expeditions as being responsible for a massive explosion in activity. This explosion is exemplified in Figure 1, which shows climbing activity for members above base camp on Everest from 1970 to 2019.

Figure 1: Climbing Activity for Everest (1970-2019)



Source: Salisbury, Hawley, and Bierling 2021

This growing number of climbers - a large proportion of which have relatively small high-altitude mountaineering experience - has perpetuated a conventionally accepted perception that the sport's integrity has declined. To sum this up succinctly, Savage and Torgler (2013) explain that "the idea that the commercial operations that are to blame for the current state of climbing has been well supported in not only the popular press but also by many famous and respected climbers". Since 1995, famous climbers have published a substantial amount of anecdotal evidence citing the dangers of commercialization. Hillary himself blames commercialization as being "responsible for the degradation of pro-social norms and behaviors" (Savage et al 2013). A distinguished book, *Dark Summit: The Extraordinary True Story of Everest's Most Controversial Season* (2008), criticizes "commercial cowboys and an abundance of antisocial behaviors" as being responsible for mountaineering deaths in 2006 (Savage et al 2013). To combat inexperience, the Nepalese government proposed amendments to Everest permit requirements in 2019 demanding that climbers submit proof of successfully summiting another 6,500-meter peak and requiring tourism companies "to have at least three years' experience organizing high-altitude expeditions before they can lead climbers on Everest" (Sharma and Schultz, 2019). The new rules were set to be enacted for the 2021 spring season but "despite international scrutiny and intense pressure from climbing groups to tighten operations on Everest, officials say the rules need further review before they can be put in place" (Schultz and Sharma, 2021). In the past two years, no concrete action has been taken to enact these restrictions. After corresponding with the program director of a popular guiding company that is familiar with the 2023 Everest permitting process, it is clear that these amendment efforts have been dissolved.

The introduction of a competing social institution - commercial expeditions - has resulted in a "weakening of the prosocial behaviors in the more 'traditional climbers' in the modern period, creating by a crowding out effect, which may have led to the break down in prosocial behavior and rise of antisocial behavior" (Savage et al 2013). Despite this and a mountain of anecdotal evidence, researchers have uncovered that the picture is not nearly as bleak; commercialization's negative effects might be contained in social behaviors rather than determinants of life and death. Research has shown that "after controlling for use of standard route, peak, age, season, sex, summit success, and year of expedition, increased Himalayan experience was not associated with a change in the odds of death" (Westhoff, Koepsell, and Littell 2012). Further, "participation in a commercial climb was associated with 37% lower odds of death relative to a traditional venture, although not significantly" (Westhoff, et al. 2012). Given the ongoing wave of escalating commercialization, these findings represented a breakthrough in mountaineering knowledge.

That said, in the ten years since the study was conducted there has been a substantial increase in commercial activity. The original intent of this paper was to include data from 2012 - 2022 and present updated conclusions. After corresponding with Richard Salisbury, the Technical Director of the Himalayan Database, it was clear that contemporary expeditions are no longer able to fit into the binary categories of commercial or traditional. In his words, "there is no clear and reliable way to determine this value since there is a broad spectrum of expeditions that fit between the two categories". That said, to extract valuable insights regarding risks associated with climbing, other biographical characteristics must be considered in addition to prior experience.

II. Literature Review

A small number of studies have laid the groundwork for high-altitude climbing knowledge. A 2020 paper published in the Public Library of Science offered an exhaustive report detailing how gender and age affect death and success rates for Himalayan climbers from 1950 - 2022. This paper uncovered valuable trends such as that "the overall probabilities of success and of complete success in 2006–2019 are essentially double those estimated for 1990– 2005" (Huey, Carroll, Salisbury, and Wang 2020). As for gender, "women are a small but increasing proportion of Everest mountaineers, and women and men have very similar success and death rates in spring on commercial routes" (Huey, et al. 2020). As for age, the 2020 study supports a previous finding that age 60 represents an important threshold and those above 60 have significantly higher death rates (Huey, et al. 2020). That said, researchers did find that "adverse effects of old age are now postponed by about 15 years", so "a generic 60-year-old climber in the recent sample [2005-2019] has roughly the same death probability as a generic 48.5-year-old in the early sample [1990-2005]" (Huey, et al. 2020).

The Himalayan mountains are extreme environments especially equipped to test the limits of human survival. For this reason, much of the academic research done using Himalayan climbing data explores the human's biological capacity to survive at high altitudes with and without supplemental oxygen. Other published reports include statistical analyses of data targeted to help climbers plan safe and successful expeditions. Beyond the characteristics of age and gender, regression analysis is limited.

A 2021 statistical analysis of Himalayan climbing data uncovered interesting citizenship trends. In their analysis of Japanese vs. non-Japanese ascents rates for all Himalayan peaks, researchers found that "beginning at age 50 the Japanese have substantially higher ascent rates than other nationalities; in fact, the elder Japanese have higher ascent rates than their younger compatriots" (Salisbury, Hawley, and Bierling 2021). "Fatalities in High-Altitude Mountaineering: A Review of Quantitative Risk Estimates" (Weinbruch 2013) compiles all existing research up until 2013 related to climbing risk. This publication does not contain an analysis of how a climber's citizenship might affect their chances of success, death, or injury.

This paper examines determinants of success for climbing expeditions summiting 8,000-meter peaks in the Himalayas from 1995 up until 2019. Specifically, it analyzes to what degree peak choice, season, year, and citizenship affect an individual's chances of summiting. Using binary logistic regressions, this paper shows evidence that a climber's citizenship is a highly significant determinant of success. The results detect interesting groupings of citizenships that underperform and overperform compared to Americans. Chinese citizens are clear outliers with 192% more odds of success than an American. The success rates related to season, gender, and year all conform with existing research, justifying the robustness of the citizenship trends. From here, this research will further question the magnitudes of financial and social motives behind Himalayan climbing and how a citizenship's success rate relates to their country's GDP. Despite controlling for per capita income, the results assert that wealth may not be an important determinant of success and provokes interesting questions as to what factors may influence citizenship success trends.

III. Data

Data Source

The data analyzed in this paper is extracted from a database created and managed by a non-profit organization called The Himalayan Database. The database contains truly comprehensive records of every expedition attempted on significant Himalaya mountaineering peaks. As described on the website, "each expedition record contains detailed information including dates, routes, camps, use of supplemental oxygen, successes, deaths and accidents” as well as “biographical information for all members listed on the permit as well as for hired members (e.g., Sherpas) for which there are significant events such as a summit success, death, accident or rescue” (Hawley, Salisbury 2022). The records include expeditions from 1905 up until Spring 2022 and are supplemented by “information gathered from books, alpine journals, magazines, and correspondence with Himalayan climbers” to complete the exhaustive historical records (Salisbury, et al. 2021). The database contains 471 peak records, 10,800+ expedition records, 81,900+ member records, and 15,200+ literature records.

The database consists of digitized expedition archives records collected primarily by Elizabeth Hawley. Starting in 1963, Elizabeth Hawley and her staff met with almost every single climbing team before and after their expedition in the Nepal Himalayas (Westhoff, et al. 2012). Adrian Burgess, a famous mountaineer, remembers Hawley as “the dragon lady who interviewed you and asked what you were going to climb, and she probably knew more about it than you did” (O’Neil 2010). In an interview with Rock and Ice, Reinhold Messner - one of the world’s most famous climbers - said “I respect her very much … She's a quite cynical person. Very intense, cultured, very strong lady” (O’Neil 2010). He added “without Miss. Hawley we would not have the history we have … she knows more about the Himalaya than anyone else” (O’Neil 2010). On the verge of her 86th birthday, she told Rock and Ice journalist Devon O’Neil (2013) “I started meeting expeditions, all the expeditions that came here, and I’ve been meeting all the expeditions that came here ever since”. After six decades of living in Kathmandu as the “undisputed authority on mountaineering”, Hawley passed away in 2018 at 94 years old (Choegyal 2018). Since her passing, Billi Bierling now leads a team of seven responsible for collecting and updating the database bi-annually.

The records are housed in a database management system called FoxPro Visual. FoxPro is a relational database management system. The system is well-suited to generate reports and analyses for people interested in expedition-specific questions such as: “What is the best time of year to climb” or “What hired-to-member ratio results has the highest success ratio”. That said, FoxPro Visual has limited capabilities to perform large-scale comparative analysis and further development of the program ceased in 2007 (Hope 2022). As a result, the Himalayan Database (HD) team created a special version of the HD that supports Structured Query language (SQL). As described on the website, this version “allows for more complex multi-table searches to be done”, but is “generally beyond the capabilities of most users and requires a background in computer science or advanced data processing to be useful” (Hawley, Salisbury 2022). The data in this paper was extracted using the following SQL command within the Himal SQL Program:

```
SELECT m.expid, m.membid, m.bconly, m.hired, m.msuccess, m.myear,
m.mseason, m.sex, m.citizen, x.peakid, x.host

FROM members m, exped x

WHERE m.expid=x.expid And x.peakid=="EVER" Or x.peakid=="ANN1" Or
x.peakid=="KANG" Or x.peakid=="LHOT" Or x.peakid=="MAKA" Or
x.peakid=="CHOY" Or x.peakid=="DHA1" Or x.peakid=="MANA" And
Between(m.myear,"1995","2019") And Not m.bconly And Not m.hired And Not
x.host=2
```

Exclusions

The HD is unique in its all-encompassing nature: there are 78 variables alone in the table describing each member of an expedition. To extract actionable insights regarding a target variable, the data must be cleaned extensively. Below is a list of notable cleaning actions taken to compile the data used in this analysis:

- To only examine advanced mountaineering attempts, climbs made that didn’t reach base camp or advanced base camp (CBONLY) are excluded.
- To isolate climbers attempting summits from hired personnel (Sherpas, guides, cooks, etc.) hired members (HIRED) are excluded.
- Expeditions using routes originating in China and Tibet may have incomplete information because their permits might not differentiate between hired personnel and members. For that reason, expeditions out of China and Tibet are excluded (HOST).
- The database records successful summits as a success, disputed success, or claimed success. This analysis uses the success variable because it includes disputes but excludes claims. Subject matter expert Richard Salisbury suggested this approach.
- Although the data captures expedition records from 1905 - 2022, this analysis only includes 1995 – 2019.
    - Before 1970: It is not useful to include data points before important innovations in modern mountaineering.
    - 1970 – 1995: While the transitional period is underway and relatively modern mountaineering techniques are used, a large number of individuals are reclassified with new citizenship due to their country's political transformations. Given this study analyzes trends dependent on nationality, the period begins after these reclassifications to ensure robustness.
    - 2019-2022: It is prudent to exclude the interruption caused by the coronavirus pandemic.
- Cleaning the citizenship variable requires multiple steps:
    - A small number of members (0.75%) are listed as having dual citizenship. Only these individuals’ primary citizenship is analyzed in this study.
    - To streamline results, this study primarily analyzes 15 nationalities that compose the largest number of climbers in the period and groups the rest into one category.

IV. Methods

Logistic Regression Model

To estimate summit success probabilities, this analysis will consist of a logistic regression. To gauge the probability of an event occurring, the outcome needs to be bounded between 0 and 1. To do this, "a logit transformation is applied on the odds–that is, the probability of success divided by the probability of failure" (IBM, 2023). In calculating a logistic regression, "the regression coefficient is the estimated increase in the log odds of the outcome per unit increase in the value of the exposure" (Szumilas, 2010). By interpreting the intercept coefficient, we can evaluate the probability of the regression's baseline case. To interpret the success probabilities of the other variables, the coefficients must be converted into an odds ratio.

$$oddsRatio(x_n) = e^{\beta_n}$$

Econometric Test

The first econometric test is aimed at analyzing how season, peak choice, citizenship, and sex affect successful summits. Success is defined by reaching the highest point on a select major peak above 8,000 meters in the Himalayan range (Everest, Annapurna, Kanchenjunga, Lhotse, Makalu, Cho-Oyu, Dhaulagiri, and Manaslu). While members are generally part of an expedition team, this study analyzes each member's success on an individual level. With a binary dependent variable, the first econometric test will compose of a binary logistic regression. The year is included in the regression to capture the fixed effects of year-to-year advances in technical mountaineering technology and a growing knowledge base. The variables fall into four categories: sex, season, peak, and citizenship. Each category contains one excluded value to represent the benchmark case. The benchmark variables were chosen because they represented the largest subset of observations in the dataset. The regression equation is as follows:

$$\begin{aligned} Y_i = \ & \beta_{0t} + \beta_1\, male_{it} + \beta_2\, year_{it} + \beta_3 \text{autumn}_{it} + \beta_4 winter_{it} + \beta_5 summer_{it} \\ & + \beta_6 annapurnaI_{it} + \beta_7 choOyu_{it} + \beta_8 dhaulagiriI_{it} \\ & + \beta_9 kanchenjunga_{it} + \beta_{10} lhotse_{it} + \beta_{11} makalu_{it} + \beta_{12} manaslu_{it} \\ & + \beta_{13} other_{it} + \beta_{14} france_{it} + \beta_{15} russia_{it} + \beta_{16} southKorea_{it} \\ & + \beta_{17} switzerland_{it} + \beta_{18} spain_{it} + \beta_{19} italy_{it} + \beta_{20} japan_{it} \\ & + \beta_{21} germany_{it} + \beta_{22} australia_{it} + \beta_{23} uk_{it} + \beta_{24} india_{it} \\ & + \beta_{25} canada_{it} + \beta_{26} nepal_{it} + \beta_{27} china_{it} + \varepsilon_{it} \end{aligned}$$

Table 1: Variable Explanations

Category	Benchmark/excluded variables	Variables
Sex	Female	Male
Season	Spring	Winter, Summer, and Autumn
Peak	Everest	Annapurna, Kanchenjunga, Lhotse, Makalu, Cho-Oyu, Dhaulagiri, and Manaslu
Citizenship	US	France, South Korea, Germany, Spain, Japan, Russia, India, Nepal, China, Switzerland, Italy, Australia, UK, Canada, and Other
Year	N/A	Continuous variable 1995 = 0 1996 = 1 … 2019 = 24

V. Results

Table 2 outlines the primary regression run on all 27 climbing variables at a 95% confidence level.

Table 2: Logistic Regression

Binary logistic regression run with all 27 climbing data variables at a 95% confidence interval.

Term	Coefficient (β)	Standard Error	t-value	p-value	95% CI
Intercept ***	-0.38	0.09	-4.45	< .001	[-0.55, -0.22]
Male**	-0.16	0.06	-2.77	.006	[-0.27, -0.05]
Autumn ***	-0.54	0.06	-8.80	< .001	[-0.67, -0.42]
Winter ***	-1.94	0.32	-6.00	< .001	[-2.63, -1.35]
Summer	12.88	139.11	0.09	.926	[-8.96, NA]
Annapurna I ***	-1.04	0.11	-9.58	< .001	[-1.25, -0.83]
Cho-Oyu	-0.24	0.48	-0.49	.623	[-1.27, 0.65]
Dhaulagiri I ***	-1.13	0.08	-13.56	< .001	[-1.29, -0.97]
Kanchenjunga ***	-0.61	0.10	-6.14	< .001	[-0.80, -0.41]
Lhotse ***	-0.62	0.07	-9.34	< .001	[-0.75, -0.49]
Makalu ***	-0.87	0.08	-11.18	< .001	[-1.03, -0.72]
Manaslu *	-0.16	0.07	-2.35	.019	[-0.30, -0.03]
Other	0.09	0.06	1.35	.177	[-0.04, 0.21]
France ***	-0.46	0.13	-3.50	< .001	[-0.72, -0.20]
Russia ***	0.43	0.13	3.32	.001	[0.17, 0.68]
S Korea **	-0.29	0.10	-2.85	.004	[-0.48, -0.09]
Switzerland	-0.15	0.14	-1.09	.275	[-0.42, 0.12]
Spain *	-0.22	0.10	-2.24	.025	[-0.42, -0.03]
Italy	-0.11	0.11	-1.00	.317	[-0.34, 0.11]
Japan **	0.29	0.10	3.01	.003	[0.10, 0.48]
Germany *	-0.28	0.12	-2.27	.023	[-0.52, -0.04]
Australia	0.05	0.13	0.37	.709	[-0.21, 0.30]
UK	0.08	0.09	0.87	.384	[-0.10, 0.25]
India ***	0.53	0.09	5.94	< .001	[0.35, 0.70]
Canada	0.11	0.13	0.87	.386	[-0.14, 0.36]
Nepal ***	0.72	0.12	6.00	< .001	[0.49, 0.96]
China ***	1.07	0.10	10.30	< .001	[0.87, 1.28]
Year ***	0.04	0.00	13.41	< .001	[0.03, 0.05]

Significance codes: 0 '***' 0.001 '**' 0.01 '*'

Source: Himalayan Database and Author Calculations

Table 3 lists the intercept coefficient interpretation derived from the equation below. This equation derives the benchmark case probability (UCLA, Statistical Consulting Group). The results indicate that a woman from the US climbing Everest in the Spring of 1995 had a 41% chance of a successful summit.

Interpreting the baseline probability:
an American woman climbing Everest in the spring of 1995

$$logit(p) = log(\frac{p}{1-p}) = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k \quad (1)$$

$$\frac{1-p}{p} = \frac{1}{exp(\beta_0)} \quad (2)$$

$$\frac{1}{p} = 1 + \frac{1}{exp(\beta_0)} \quad (3)$$

$$\frac{1}{p} = \frac{exp(\beta_0) + 1}{exp(\beta_0)} \quad (4)$$

$$p = \frac{exp(\beta_0)}{1 + exp(\beta_0)} \quad (5)$$

$$p = \frac{0.68}{1 + 0.68} = 0.41 \quad (6)$$

Table 3: Logistic Regression Intercept Interpretation

Interpretation of the intercept's coefficient outlining the benchmark case success probability.

Variable	Regression Coefficient	Odds Ratio	Probability	P-value
Intercept	-0.38	0.68	0.41	<0.001

Table 4 outlines each term's regression coefficient, odds ratio, and significance. Given the nature of the regression - binary independent variables with multiple categories - evaluating odds ratios is the most effective way to illustrate the marginal effect of changes within each category.

Table 4: Converting regression coefficients to odds ratios

Each variable's regression coefficient, odds ratio, and p-value. Each variable's odds ratio is compared to its benchmark variable's ratio of 1.

Variable	Regression Coefficient	Odds Ratio	P-value
Seasons			
Spring		1	
Winter	-1.94***	0.14	< 0.001
Autumn	-0.54***	0.58	< 0.001
Summer	12.88	391,939.40	0.926
Peaks			
Everest		1	
Dhaulagiri I	-1.13***	0.32	< 0.001
Annapurna I	-1.04***	0.35	< 0.001
Makalu	-0.87***	0.42	< 0.001
Lhotse	-0.62***	0.54	< 0.001
Kanchenjunga	-0.61***	0.54	< 0.001
Manaslu	-0.16*	0.85	0.019
Cho-Oyu	-0.24	0.79	0.623
Gender			
Female		1	
Male	-0.16**	0.85	0.006
Year			
Year	0.04***	1.04	< 0.001

Table 4: Converting regression coefficients to odds ratios Each variable's regression coefficient, odds ratio, and p-value. Each variable's odds ratio is compared to its benchmark variable's ratio of 1.			
Variable	Regression Coefficient	Odds Ratio	P-value
Citizenships			
US		1	
France	-0.46***	0.63	< 0.001
South Korea	-0.29**	0.75	0.004
Germany	-0.28*	0.76	0.023
Spain	-0.22*	0.80	0.025
Japan	0.29**	1.34	0.003
Russia	0.43***	1.53	0.001
India	0.53***	1.69	< 0.001
Nepal	0.72**	2.06	< 0.001
China	1.07**	2.92	< 0.001
Switzerland	-0.15	0.86	0.275
Italy	-0.11	0.89	0.317
Australia	0.05	1.05	0.709
UK	0.08	1.08	0.384
Other	0.09	1.09	0.177
Canada	0.11	1.12	0.386
Significance codes: 0 '***' 0.001 '**' 0.01 '*' Source: Himalayan Database and Author Calculations			

VI. Discussion

Peaks

All peak variables but Cho-Oyu were significant at the 1% confidence level and have lower odds ratios of success compared to Everest. Cho-Oyu's insignificance is likely a result of its relatively small sample size in this study's dataset after excluding routes originating in Tibet. As explained in the exclusion criteria, records originating from China and Tibet were excluded in this analysis because some archives do not differentiate between hired personnel and members. While there are several routes on Cho-Oyu, the most popular is undoubtedly the western face in Tibet. Other than Cho-Oyu, all of the peaks have lower odds ratios than Everest and are statistically significant. There are two possible interpretations for these results. Firstly, some of the 8,000-meter peaks are accepted within the mountaineering community to be more difficult than Everest. Annapurna, for example, has a fatality rate of nearly 27% compared to Everest's 3.29% (Whitman, 2023). This discrepancy in fatality rates is consistent with this study's results which found a member climbing Annapurna I has 0.35 times the odds of succeeding compared to climbing Everest. Similarly, Kanchenjunga is the only peak analyzed in this study that has maintained an increasing death rate year-over-year and is regarded "as the home of a rakshasa (or man-eating demon)" and "out of respect for the mountain's immense religious significance among the region's Buddhists, climbers have always stopped short of the summit" (St. George, 2020). In this study, a member climbing Kanchenjunga is shown to have 0.54 times the odds of succeeding compared to climbing Everest. Said differently, a climber has a (0.54 - 1 = -0.46) 46% reduction in their odds of success climbing Kanchenjunga than Everest.

That said, these results should not be interpreted as evidence suggesting that summiting Dhaulagiri I, Annapurna I, Makalu, Lhotse, Kanchenjunga, or Manaslu is more difficult than

Everest. Theoretically, a climber's failure to summit one of the aforementioned 8,000-meter peaks might dissuade them to attempt Everest. For instance, a popular mountaineering blog - Nepal Guide - explains Manaslu as being the easiest 8,000m peak to climb in Nepal (Peak Climbing Nepal, 2022). On the contrary, this study shows a climber has a 15% reduction in their odds of success climbing Manaslu compared to Everest. Rather than assuming that Everest is more difficult than Manaslu, it could be proposed that climbers who fail on Manaslu do not attempt Everest - meaningfully changing each mountain's sample of climbers. The proposed, but not implemented, permit rules mentioned previously require anyone attempting to climb Everest to have climbed another high-altitude, technical Himalayan peak. These results could be interpreted as exemplifying the successful nature of this initiative: poorly skilled climbers who attempted and failed to summit other mountains did not pursue Everest. Thus, the population of Everest's climbers might be more equipped to succeed.

Seasons

As for the season variables, the results signal that success is most likely in the spring. These results align with current mountaineering practices: weather patterns make spring and autumn the most practically viable seasons to climb. This is largely due to the Asian monsoon that provides temperatures adequate for human survival and decreased winds at high altitudes (Goodier, 2012). Notably, a climber has an 86% reduction in their likelihood of success climbing in the winter compared to the spring. Although winter is not a popular season, extreme mountaineers do set out on expeditions inviting the added challenge. These results show that even with a self-selected incredibly skilled sample group the season is unforgiving in its difficulty.

Another interesting takeaway is the difference in success probabilities between autumn and spring. As overall demand to climb the Himalayan mountains - especially Everest - increases with time, a larger number of expeditions crowd popular routes during busy seasons. In this context, the demand to climb outside of popular expedition windows increases. It is widely accepted that climbing during the summer and winter is dangerous. For example, "throughout the winter, hurricane-force winds pummel the summit for three days out of four" (Goodier, 2012). With winter and summer largely excluded as a possibility, the viability of the autumn season is increasingly important as expedition planners look to avoid overcrowded routes. While the intense winds decrease during September as they do in May, "snow falls during the September calm, so fresh snow drifts offset the break from the wind" deteriorating conditions (Goodier, 2012). That said, this analysis illustrates a relatively substantial difference in the odds of success - 42% reduction - in autumn compared to spring, encouraging expedition planners to think critically about the tradeoffs between success probabilities and overcrowding.

Sex

The sex variable's significant odds ratio of 0.85 suggests that men have similar - but lower - odds of success compared to women. This is consistent with the existing research published in 2021 citing that "men had significantly higher ascent rates than women during the 1950-1989 period (21.7% to 15.1%), but this advantage subsequently reversed during the 1990-2019 period (39.0% to 41.8%) with women doing significantly better on the 8000ers" (Salisbury, Hawley, and Bierling 2021).

Year

These results suggest that starting in 1995, the odds of success increased by 4% every year. This supports the trend of increased ascent success over time undisputed within the high-altitude mountaineering community. On Everest, for example, the success rates for "2006-2019 are essentially double those from 1990-2005" (Huey et al., 2020).

Citizenship

Of the fifteen most numerous citizenships, eight were statistically significant at a 95% confidence interval. Citizens from the countries of France, South Korea, Germany, Spain, Russia, India, Japan, Nepal, and China were all significant with p-values of less than or equal to 2%. There appear to be three groups in the data: those that underperform Americans, outperform Americans, and the clear outlier of China.

Chinese citizens' success rates are a clear outlier in this study. A Chinese climber has 2.92 times the odds of succeeding compared to an American. Said differently, a Chinese climber has (2.92 - 1 = 1.92) 192% more odds of success than an American. There are many possible interpretations of this result. Interestingly, a Chinese expedition was the only group to summit Everest during the coronavirus pandemic (Khadka, 2020). The Chinese government allowed a team composed of Chinese surveyors to climb to re-measure the height of Everest (Khadka, 2020). Sending climbers to the summit while the entire world was on pause could be interpreted as a statement illustrating the Chinese government's large investment in its climbing community. One could extrapolate that this study's results conform with the seemingly high intensity that Chinese leadership places on its citizen's high-altitude mountaineering activity. Also, it is important to note that some researchers working with the Himalayan Database exclude expeditions originating in

China to avoid possible discrepancies in the differentiation between hired personnel and members of each expedition. It is possible that the data used in this study was not properly cleaned to exclude all instances of Chinese expeditions with inconsistent differentiations; therefore, inflating the success rate of Chinese members. Beyond China's results, there seem to be two clear groupings - citizenships that outperform and underperform the US - as seen in the figures below.

Figure 3: Underperforming countries compared to the US (France, South Korea, Germany, and Spain)

Figure 4: Overperforming countries compared to the US (Japan, Russia, India, Nepal, and China)

There appears to be a clear geographical grouping between the countries that underperform and overperform compared to the US. With the exception of South Korea, the underperforming countries are centered around Europe. French climbers, for example, have a 37% reduction in their odds of success compared to an American. The overperforming countries are mainly in Asia. Citizens from these countries all have greater than 33% more odds of success than Americans.

There are many avenues to be explored to interpret these results. Interestingly, these results conform with each region's relative average elevation ranking. There has been extensive scientific research examining the incredible performance of Sherpas: a Nepalese ethnic group famous for their expert climbing skills. In 2017, the National Academy of Science published a paper presenting interesting differences in the muscle cells of Sherpas compared to lowlanders (Sohn, 2017). The results showed that within Sherpa's muscles "the cells' mitochondria (the energy-producing parts) converted more oxygen into energy" (Sohn, 2017). Although each group's metabolisms functioned similarly at low altitudes, "when you push the system by exposing them to low oxygen, you start to see differences between populations" (Sohn, 2017). The geographical grouping trends found in this study conform to each region's relative average elevation. More than half of Europe's land is composed of lowlands, "standing mostly below 180 meters but infrequently rising to 300 meters" (Berentsen, et al. 2023). The US' average elevation is 763m and Asia's is 1010m (O'Neil, Aaron, 2022; Mappr, 2018). The ranking of average elevations – Europe, the US, and Asia – follows this study's trend of generalized regional performance. Further, Asia is the most mountainous continent in the world and is home to the Himalayas (Boudreau et al., 2022). While all citizens analyzed in this study from the general Asian region surely do not have high-altitude biological advantages comparable to Sherpas, average elevation may play a role in preparing climbers for mountaineering's extreme environments. That said, a climber's citizenship does not necessarily correspond to where they've spent the most time living and therefore adapting biologically. In a further study, it would be interesting to analyze each climber's country of residence, the country's elevation, and their performance.

In addition to the geographical factors of highest elevation and mountainous terrain, economic factors - such as gross domestic product - might also play an important role in explaining these results. High-altitude mountaineering is not an inexpensive hobby: in 2023 a guided Everest climb can cost anywhere from $30,000 to $160,000, with an average price tag of around $50,000

(Richard and Kilpatrick, 2023). With the foundation of these interesting citizenship success results, this study's next regression analyzes to what extent a country's average per capita income affects its success probabilities. In the following regression, the log of per capita gross domestic product of each country is added at an individual member level. From there, the changes in significance and magnitude of the citizenship variables are evaluated.

VII. GDP Regression

For this regression, the log of per capita GDP associated with every individual's citizenship country is added to their existing data. The GDP information is extracted directly from datasets hosted by the World Bank and returned natively in R using an API connection. Notably, climbers from Venezuela, Yugoslavia, and Taiwan were excluded (52 of 12,644) due to insufficient GDP data. The selected GDP per capita is from 2019; the final year of the analyzed data in this study. The regression equation is as follows:

$$Y_i = \beta_{0t} + \beta_1\, male_{it} + \beta_2\, year_{it} + \beta_3 \text{autumn}_{it} + \beta_4 winter_{it} + \beta_5 summer_{it} + \beta_6 annapurnaI_{it} + \beta_7 choOyu_{it} + \beta_8 dhaulagiriI_{it} + \beta_9 kanchenjunga_{it} + \beta_{10} lhotse_{it} + \beta_{11} makalu_{it} + \beta_{12} manaslu_{it} + \beta_{13} other_{it} + \beta_{14} france_{it} + \beta_{15} russia_{it} + \beta_{16} southKorea_{it} + \beta_{17} switzerland_{it} + \beta_{18} spain_{it} + \beta_{19} italy_{it} + \beta_{20} japan_{it} + \beta_{21} germany_{it} + \beta_{22} australia_{it} + \beta_{23} uk_{it} + \beta_{24} india_{it} + \beta_{25} canada_{it} + \beta_{26} nepal_{it} + \beta_{27} china_{it} + \beta_{28} \log(gdpPerCapita)_i + \varepsilon_{it}$$

Results

Table 5 outlines the logistic regression run including GDP data associated with climber's respective citizenships at a 95% confidence interval.

Table 5: Logistic Regression with GDP

Binary logistic regression run with 27 climbing data variables and each individual's per capita GDP associated with their citizenship at a 95% confidence interval.

Term	Coefficient (β)	Standard Error	t-value	p-value	95% CI
Intercept	1.31**	0.43	3.06	.002	[0.47, 2.15]
Male	-0.16**	0.06	-2.77	.006	[-0.27, -0.05]
Autumn	-0.55***	0.06	-8.84	< .001	[-0.67, -0.43]
Winter	-1.96***	0.32	-6.05	< .001	[-2.65, -1.37]
Summer	12.87	139.11	0.09	.926	[-8.97, NA]
Annapurna I	-1.05***	0.11	-9.73	< .001	[-1.27, -0.84]
Cho-Oyu	-0.24	0.48	-0.50	.620	[-1.27, 0.65]
Dhaulagiri I	-1.13***	0.08	-13.53	< .001	[-1.29, -0.97]
Kanchenjunga	-0.61***	0.10	-6.11	< .001	[-0.80, -0.41]
Lhotse	-0.63***	0.07	-9.51	< .001	[-0.76, -0.50]
Makalu	-0.89***	0.08	-11.33	< .001	[-1.04, -0.73]
Manaslu	-0.16*	0.07	-2.31	.021	[-0.30, -0.02]
Other	-0.10	0.08	-1.23	.218	[-0.26, 0.06]
log_gdp	-0.15***	0.04	-4.03	< .001	[-0.23, -0.08]
France	-0.53***	0.13	-4.00	< .001	[-0.79, -0.27]
Russia	0.17	0.14	1.16	.246	[-0.12, 0.45]
South Korea	-0.39***	0.10	-3.78	< .001	[-0.60, -0.19]
Switzerland	-0.11	0.14	-0.81	.420	[-0.38, 0.16]
Spain	-0.34***	0.10	-3.30	.001	[-0.55, -0.14]
Italy	-0.21	0.12	-1.83	.068	[-0.44, 0.01]
Japan	0.22*	0.10	2.23	.026	[0.03, 0.41]
Germany	-0.33**	0.12	-2.66	.008	[-0.57, -0.09]
Australia	0.02	0.13	0.19	.852	[-0.23, 0.28]
UK	0.01	0.09	0.14	.890	[-0.16, 0.19]
India	0.00	0.16	0.03	.979	[-0.31, 0.31]
Canada	0.06	0.13	0.46	.646	[-0.19, 0.31]
Nepal	0.11	0.19	0.59	.554	[-0.26, 0.49]
China	0.79***	0.13	6.31	< .001	[0.55, 1.04]
Year	0.04***	0.00	13.16	< .001	[0.03, 0.05]

Significance codes: 0 '***' 0.001 '**' 0.01 '*'

Source: Himalayan Database and Author Calculations

Table 6 outlines the derivation of the benchmark case probability. To intercept the probability, the intercept coefficient must be added to the product of the log per capita US GDP and the log_gdp coefficient.

$$\ln(65120.4) \times -0.15 = -1.66 + 1.31 = -0.35$$

The results indicate that a woman from the US climbing Everest in the Spring of 1995 had a 41% chance of a successful summit.

Table 6: Logistic Regression with GDP (Table Five) Intercept Interpretation

Interpretation of the intercept's coefficient outlining the benchmark case success probability.

Variable	Regression Coefficient + GDP term	Odds Ratio	Probability	P-value
Intercept	-0.35	1.42	0.41	0.002

Table 7 outlines each term's regression coefficient, odds ratio, and significance resulting from the regression above.

Table 7: Converting regression coefficients to odds ratios

Each variable's regression coefficient, odds ratio, and P value. Each variable's odds ratio is compared to its benchmark variable's ratio of 1.

Variable	Regression Coefficient	Odds Ratio	P value
Seasons			
Spring		1	
Winter	-1.96***	0.14	< 0.001
Autumn	-0.55***	0.58	< 0.001
Summer	12.87	389,861.36	0.926

Table 7: Converting regression coefficients to odds ratios

Each variable's regression coefficient, odds ratio, and P value. Each variable's odds ratio is compared to its benchmark variable's ratio of 1.

Variable	Regression Coefficient	Odds Ratio	P value
Peaks			
Everest		1	
Dhaulagiri I	-1.13***	0.32	< 0.001
Annapurna I	-1.05***	0.35	< 0.001
Makalu	-0.89***	0.41	< 0.001
Lhotse	-0.63***	0.53	< 0.001
Kanchenjunga	-0.61***	0.55	< 0.001
Manaslu	-0.16*	0.85	0.019
Cho-Oyu	-0.24	0.79	0.623
Citizenships			
US		1	
France	-0.53***	0.59	< 0.001
South Korea	-0.39***	0.68	< 0.001
Spain	-0.34***	0.71	0.001
Germany	-0.33**	0.72	0.008
Japan	0.22*	1.24	0.026
China	0.79***	2.21	< 0.001
Italy	-0.21	0.81	0.068
Switzerland	-0.11	0.90	0.420
Other	-0.10	0.90	0.218
India	0.00	1.00	0.979
UK	0.01	1.01	0.890
Australia	0.002	1.02	0.852

Table 7: Converting regression coefficients to odds ratios

Each variable's regression coefficient, odds ratio, and P value. Each variable's odds ratio is compared to its benchmark variable's ratio of 1.

Variable	Regression Coefficient	Odds Ratio	P value
Canada	0.06	1.06	0.646
Nepal	0.11	1.12	0.554
Russia	0.17	1.18	0.246
Others			
Log(GDP per capita)	-0.15***	0.86	<0.001
Male	-0.16**	0.85	0.006
Year	0.04***	1.04	< 0.001

Significance codes: 0 '***' 0.001 '**' 0.01 '*'

Source: Himalayan Database and Author Calculations

Discussion

After adding the gross domestic product data, many variables changed in their significance and magnitude. Russia, India, and Nepal's variables lost significance at a 95% confidence interval. South Korea, Spain, and Germany increased in their significance. As for magnitude, all of the citizenship variable coefficients decreased except for Japan, which increased by 0.07. Notably, China's coefficient dropped by 0.28, Russia's by 0.16, and Spain's by 0.12. To check for robustness, three additional regressions were run excluding each country that lost significance. In these regressions, the per capita GDP coefficient did not change significantly with the exclusions, implying that a singular citizenship did not account for the magnitude of GDP's effect.

The variable representing per capita GDP was highly significant with a coefficient of -0.15. These results suggest that a 10% increase in per capita GDP translates to a 1.5% decrease in a climber’s likelihood of success. Regressing per capita income detects a trend: citizens from poorer countries in this dataset tend to be more successful. That said, it cannot be asserted that this trend is completely attributable to wealth. It is a sound assumption that citizens from the three countries that lost significance - Nepal, Russia, and India - very reasonably could perform well for other societal and economic factors. The farthest-reaching assertion these results suggest is that income may not be an important determinant of success.

Beyond the possible model misspecification discussed above, there are straightforward insights that can be taken into account. When regressing on income, some wealthy countries maintained their high significance and negative magnitude. This suggests that there are other factors - in both underperforming and overperforming countries - that meaningfully contribute to the success rates. Also notable, adding per capita GDP did not alter the benchmark probability; both regressions output a 41% probability of success for a woman climbing Everest in 1995 from the US.

Additionally, Chinese citizens maintained their strikingly high success rates. Holding per capita GDP constant, a climber from China has about 80% more likelihood of succeeding. China’s variable maintained its tremendous significance, despite the GDP variable's negative magnitude capturing significance previously attributed to countries with relatively low per capita GDP values. That said, calculating probabilities by inputting China’s low per capita GDP would result in a much higher likelihood – even more than 80% - of success than the US and those that underperformed the US. Further research is warranted to evaluate the outlying nature of Chinese citizenship and summit success. These findings could benefit high-altitude mountaineering's knowledge base and potentially help to raise average success rates.

VIII. Conclusion

This study presents evidence suggesting there are significant differences in the odds of success associated with climbers of different citizenships. After controlling for each individual's per capita GDP of their associated citizenship, further trends are illuminated that detect the country's exceptional or lacking odds in their likelihood of climbing success. This study provides a solid basis for further research to explore other aspects of these countries that contribute to their performance.

Knowing that citizenship is a significant determinant of success, many potential analyses could further this research. An intuitive next step would include each country's percentage of mountainous area. Also, it would be interesting to analyze differences in participation and performance rates based on gender within a citizenship group. Another avenue could explore how a citizenship group's GDP relates to their hired vs. member ratios on expeditions. After hearing of this research, John Westhoff, a published researcher in this area, also suggested the possibility of comparing Hofstede cultural dimensions to climbing performance to evaluate how different cultural customs might manifest themselves in mountaineering.

Every high-altitude mountaineer assumes risks of an extreme magnitude. The choice to surpass 26,000' endangers one's physical and psychological well-being. By wrangling and analyzing Himalayan climbing data, trends can be uncovered that - if left unknown - could cost someone their life. As demand increases year to year, so does the value of analysis to inform climbers of their prospective success, injury, and death rates. Additionally, these investigations can help inform governments of the economic, social, and safety impacts of proposed climbing policies and restrictions.

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