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The value of life: Real risks and safety-related productivity in the Himalaya

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ABSTRACT

This paper estimates the value of a statistical life from commercial Himalayan expeditions. Because deaths occur with a fair amount of regularity, fatality rates are calculated for each mountain trail and are, hence, disaggregated measures of risk. Also, since the marginal product of labor in the industry is (in part) the marginal product of safety, our revenue measures may account for unobserved safety-related productivity of guides. Guide safety is explicitly observed by market participants, and is reflected in higher wages for safer guides. Our VSL estimates are about \$5 M.

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"Anything on Everest is dangerous. It's not safe. This is crazy. I mean, you're going into the death zone." – Russell Brice, professional guide, *Everest: Beyond the Limit*, Discovery Channel.

1. Introduction

Society may face choices that involve a tradeoff between physical risk and pecuniary returns, and our decisions reveal our willingness to trade money for the risk of physical harm (Ashenfelter, 2006). Economists have recognized the existence of this tradeoff since the time of Adam Smith (1776), and this tradeoff is often called the value of a "statistical life" or VSL. Econometric estimates of the VSL are used for understanding and informing public policies where risk/reward tradeoffs are important (Kniesner et al., 2006). There is an extremely rich literature on estimating the VSL, and we will not do it justice here. Early modern treatments are Thaler and Rosen (1976) and Viscusi (1978). In-depth surveys are Viscusi (1993) and Viscusi and Aldy (2003). Recent papers are Ashenfelter (2006), Ashenfelter and

Greenstone (2004), Kniesner et al. (2006), Kniesner et al. (2010), Schnier et al. (2009), and Viscusi (2009), to name a few.

This research estimates the VSL from detailed risk/reward data collected from recent expeditions into the Himalayan Mountains of Nepal and India. For the majority of the 20th century, climbing in the Himalaya was for scientific purposes, so there is a lasting tradition of detailed record keeping: expedition size, daily accents, injuries, deaths, equipment, Sherpas, peak, trail, etc. Therefore, current data on commercial (for-pay) expeditions are ideally suited for producing a VSL estimate, while avoiding many of the conceptual and econometric problems that have plagued (and perhaps biased) estimates in the past. Using a standard two-stage, hedonic regression of expedition revenues on expedition fatality risk, we find VSLs between \$4.05 M and \$5.39 M. Our estimates are calculated for paid guides (not paying climbers) from developed countries with the U.S. (35%), U.K. (22%), New Zealand (14%) and Germany (14%) representing the majority of our observations.¹

Ashenfelter (2006) and Kniesner et al. (2006) discuss several econometric problems related to VSL estimation: endogeneity of risks, omitted safety-related productivity bias, heterogeneity of preferences, and errors in the fatality risk measure. All of these issues are addressed in this research to a greater or lesser extent. For example, the final data set spans 10 years, so lags of fatality risk are valid instruments for today's fatality risk. Also, one of a mountain guide's primary outputs is the

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¹ Clearly, mountain guide risk preferences may be different from the general population.

production of safety.² Insofar as observed revenues capture the marginal product of safety, there is no unobserved safety-related productivity.³ That is, in risky occupations a worker's wage may reflect a compensating differential, but workers are rarely paid for their safety-related behaviors (be they observed or unobserved by the employer). Therefore, a worker's ability to mitigate risk is neither observed explicitly by the econometrician nor implicitly through a wage adjustment for safe behavior. Once we observe revenues in the mountain guide industry we may implicitly observe safety-related behavior, because the wage is adjusted for this behavior through the market mechanism.⁴ Hence, omitted safety-related productivity is not an issue (or at least is less of an issue) for these data.

Measurement error refers to the fact that measured fatality risk may not correspond to the actual risks faced by workers, and this may manifest itself as an aggregation problem. That is, at fairly disaggregate levels there may be few deaths, so fatality rates may be imprecise. Therefore to improve precision fatality rates are often calculated at more aggregate levels to estimate the VSL. Our data allow us to calculate fatality risk at fairly disaggregate levels and still incur a fair number of deaths. Hence, we can calculate fatality rates in different ways: for the entire Himalayan region, particular peaks, particular trails on peaks, and even for particular guides. Even at extremely disaggregate levels, fatalities can be non-zero in this industry.⁵ We demonstrate empirically the effect of aggregation on the estimated VSL for these data. (e.g., \$5.39 M for trail deaths vs. \$4.05 M for peak deaths).

Also, because we observe individual guides on different expeditions (a pseudo-panel), any heterogeneity of risk preferences can be controlled with panel data techniques (e.g., fixed effects).⁶ Additionally, we observe single agents paid heterogeneous wages in heterogeneous risk environments within the same data, providing another source of variability that helps us confidently pin down our VSL estimates.⁷ Lalive (2003) discusses heterogeneity of risk across occupations, and argues that aggregate measures of risk do not uncover (or exploit) this variability, and my lead to biased VSL estimates. Therefore, our ability to observe the same guide in heterogeneous risk environments (e.g., different trails and peaks) also speaks to the aggregation and measurement errors problem. Again, we are able to pin down the real risks at low levels of aggregation and, hence, with high levels of risk heterogeneity.

One drawback of this research is that the electronic data purchased from the Himalaya Database does not contain revenue data. Therefore, we collect "per climber" revenue data from commercial climbing company websites and merge it with the climb data. Internet prices vary by guide and by peak. To capture price variability over time, we used the Internet *Wayback Machine* to record historical prices at each website. Therefore, our left-hand side variable may be measured with error, but we believe the errors are random, as we shall describe.

² Guides are also paid for their ability to get climbers to the summit of the peak. However, 'getting to the top' implies 'getting to the top *in one piece*,' so climber safety has to be an important output for the guide. In fact, guides are paid full wages regardless of getting to the top of the peak. Informal conversations with guides reveal that there are reputational incentives at work in this specialized field. Getting to the top can improve a reputation, but losing climbers on the way to the top can damage a reputation.

³ In fact, any safety measures that we included in our hedonic wage model (e.g., oxygen and rope) were insignificant.

⁴ Taken this way, one could envision the wage as life or injury insurance. However, monitoring on the part of the insurer is perfect, since the guides observe client behavior. There are no reliable measures of injuries in the data.

⁵ Even though we cannot produce feasible results with a fatality measure at the guide level, it is interesting to note that there can be deaths associated with a particular guide (a client death), yet he continues to be observed in the data. Death is a production "bad". There can be death without the paid risk-taker leaving the data set.

⁶ We actually find that guide-specific fixed-effects are small and do not affect the estimated VSL, so in our analyses fixed-effects (i.e., heterogeneity of risk preferences) are ignored.

⁷ Any panel dataset where workers change jobs may possess these features, but our 'workers' change 'jobs' frequently.

Additionally, our results change very little when we limit the data to only current internet prices (\$3.8 M to \$5.1 M), so we feel that the historical imputation is fairly innocuous.

Another drawback of this study is conceptual: mountain guides may not be central to the distribution of societal risk preferences, so the applicability of the results to policies involving the general public may be questioned. Even if this is a problem, it is not unreasonable to envision public policy geared towards risk-loving individuals. The proliferation of extreme sports and their effect on the environment may be of importance to policy-makers. Also, there are costs and benefits associated with outdoor recreational sports (e.g., white water rafting, skiing, hunting, etc.). Perhaps policy analysis of these endeavors requires a VSL from a subpopulation with proclivities for risk-taking behavior. Finally, it could be argued that combat soldiers are relatively risk-loving, so the VSL of mountain guides may be more useful for calculating the human costs of war than the mean VSL. That being said, our final estimates are not different from typical estimates in the literature. For example, Schnier et al. (2009) estimate a \$4–5 M VSL for crab fishermen, a fairly risky occupation. Kniesner et al. (2006) estimate \$5.5–7.5 M from census labor data, and Ashenfelter and Greenstone (2004) estimate \$1.6 M from policy decisions on highway speed limits. The US DOT uses \$5.8 M per life for traffic fatalities (Viscusi, 2009).

This research confronts and overcomes several other conceptual issues with the VSL. For example, in many studies it is not clear that the decision-makers are even aware of what the true risks may be (Ashenfelter, 2006). Since mountain guides regularly face real life-and-death decisions, they are specifically trained to understand the inherent risks of their occupation, so our data avoid this problem. Also, Ashenfelter (2006) points out that there may be agency issues in the decision process that may distort the VSL. The idea is that the agents at risk may not be in complete control of the decision to engage in the risky behavior. This is particularly relevant when managers (agents) control behavior or when governments control laws that affect the safety of others. Schnier et al. (2009) confront this issue in a meaningful way by examining the decisions of captains on crabbing vessels, but even in their study, the risks to captains in stormy seas are distinctly different from the risk to deck hands. In our empirical framework the risk environment of the decision-maker (the guide) and the people in his/her charge (assistant guides and Sherpas) are identical, and this intimate "physical" link between the guide and his/her charges mitigates agency problems. (Indeed, climbers may literally be linked with ropes on the more dangerous portions of the climb.) Ultimately our analysis measures the marginal rate of substitution between "paid climber" revenues (guides, assistant guides and Sherpas) and expected paid climber deaths, so we are teasing out a compensating differential for paid climbers.⁸ Since we are ignoring the lives of the "paying climbers" (unpaid expedition members), agency issues are unimportant to our analysis.

This paper is organized as follows. The next section discusses the industry and our data. Section 3 presents the hedonic revenue model and our two-stage least squares (2SLS) estimates of the VSL. We highlight the sensitivity of our VSL results to levels of fatality risk aggregation. The last section summarizes and concludes.

2. Industry and data

2.1. Industry

The mountain climbing industry consists of small companies, owned and operated by lead guides who are seasoned climbers. A well-established lead guide has anywhere from 10 to 20 assistant guides and manages six to eight trips a year in places such as Ecuador, Tanzania, Argentina, Russia, France, Italy, New Zealand, and, of course, Nepal and

⁸ In our analyses we cannot distinguish between the wages of the guides and Sherpas, so we cannot estimate a separate VSL for guide and Sherpas.

Pakistan. He has anywhere from 50 to 100 climbing clients per year. A Himalayan lead guide must be certified by the local governments of Nepal, Tibet and China and be familiar with the Katmandu and Himalayan valleys. The lead guide hires assistant guides and Sherpas. Assistant guides are typically company employees with good climbing experience, but without the reputation (or certification) that the lead guide has developed over time. The Sherpas are contract laborers that are Nepal natives and extremely experienced climbers in their own right. The lead guide typically has his favorite Sherpas in Nepal which he hires every time he visits the country.

Most trips into the Himalaya take about a month (28.8 days on average) and gross revenues are about \$150,000 on average. Many of the approach hikes are a week long and the climbs may take as long as two months as climbers acclimate (become accustomed to the higher altitude), build camps high on the mountain, and wait out dangerous weather conditions. Clients are typically interviewed by the lead guide prior to signing a contract to ensure that they have adequate climbing experience and to ensure that they are physically fit. Once the climb begins, clients are tested for endurance and speed as they complete acclimation hikes. Eventually the lead guide will break the expedition team into groups of two or three clients. When summit day arrives, the guide takes the fastest group and assigns Sherpas or assistant guides to each of the other groups. Throughout the climb he has the final decision to continue or turn back. (Reasons for turning back are always safety-related.) However, his assistants and Sherpas also have authority to turn back at any point they feel uncomfortable or feel that the safety of their groups are compromised. If an assistant or Sherpa decides to turn back, typically other groups continue forward. However if the leader turns back, everyone goes back. The leader takes ultimate responsibility for the safety of all clients and, therefore, always has the final word on safety.

Deaths can occur for a variety of reasons with avalanches and falls being a common cause. Climbers have been known to trip and slide down the mountain. Those who live may sustain sprains or broken bones and are typically carried back down the mountain. Some slide off the path, are deemed inaccessible to rescue crews, and are left for dead. There are also deaths related to the high altitudes: heart attack, stroke, cerebral edema or pulmonary edema. While weather conditions are carefully monitored, they can change abruptly, resulting in hypothermia, blindness or starvation from being snowed in for too long.⁹ Most who die are left in place. The culture is that it is not worth risking more lives to carry a corpse down difficult mountain paths.

2.2. Fatality data

Our data are taken from [Salisbury and Hawley \(2007\)](#), including updates downloaded from <http://www.HimalayanDatabase.com>. The database includes detailed descriptions and notes for 5965 expeditions that took place from 1950 to 2008. The primary unit of observation is the expedition (effectively “the guide”). For each expedition, we know the starting date, the number of clients, guides, Sherpas, the number of climbers who reached the summit, the duration of the expedition, the termination date and reason, the number of camps, the highpoint reached, the amount of extra safety rope used, whether or not the team used supplemental oxygen, the peak climbed and the route taken (called the trail), the height of the peak, the name of the team leader, and the nationality of the guide company. An expedition team consists of a single team leader, who is the primary guide and decision maker, assistant guides, Sherpas, and clients. A guide experience variable is created by identifying all of the climbs the team leader has led in the Himalaya. This variable is specific to the leader and is not created for assistant guides since they cannot easily be tracked by name in the data.

⁹ Weather would be a valid instrument for fatalities, but it is only available at the regional level. Since our goal is to measure disaggregate levels of fatality risk, weather was not a practical instrument in our case.

We focus on expeditions from 1987 to 2007, a period during which modern techniques and equipment were in standard use. Prior to 1987, climbers used equipment which was less advanced and, in many cases, less safe. This limits our number of expeditions to 4372. It is important to note that over this period there were many deaths. For example, on average there were 3.3 deaths and 729 lives at risks over the relevant three-year periods on the trails associated with our final dataset, resulting in a death rate of about 0.45%. Of these, Everest was the worst. The 32 Everest expeditions in our data faced three-year average frequencies of 6.56 deaths in about 751 lives at risk for a death rate of 0.87%. The point is that deaths are fairly common, so our fatality rates, based on three-year moving averages, are potentially fairly precise.

Our empirical approach regresses expedition revenue on expected deaths (the aggregate fatality rate times the number of at-risk paid climbers on an expedition) and other variables related to revenue. Since we have a pseudo-panel, we use lagged expected deaths as an instrument for expected deaths in a 2SLS framework. Expected deaths are generated for each observation at three different levels of aggregation. The most disaggregate level of the expected deaths variable is a three-year moving average on each specific trail in the range. Calculations proceed as follows. First a fatality rate is calculated for the three years of interest on the trail of interest. This is accomplished by dividing deaths for all climbers by the number of at-risk climbers on the trail over the three-year period. (This fatality rate is based on three-years of fatality data culled from our sample of 4372 expeditions between 1987 and 2007.) The expected deaths of the expedition on the trail is this fatality rate times the number of paid professional climbers at risk. (Note that we are using the fatality rate for all climbers in calculating the expected deaths of paid climbers. This is because we cannot differentiate between deaths of clients and paid personnel in the data. It is not clear that there should be a difference between these death rates.) Similarly, three-year moving averages are calculated for each peak (an aggregation of trails on each peak) and for the entire region (all peaks in the mountain range).¹⁰ The implication of our expected deaths measure is that we are aggregating the lives of the guides, assistant guides and Sherpas into one representative agent, which is necessary given the fact that our wage measure is gross revenue for the entire expedition, a large percentage of which is paid out to assistant guides and Sherpas.¹¹

One problem that arises when calculating expected deaths is accounting for observations in which the fatality rate is zero in any three-year period. After discussions with several guides it seemed that “zero-deaths” was an unrealistic expectation for an industry whose main purpose is to produce safety for clients. (See the Russell Brice quote before the [Introduction](#).) Zero deaths occur more frequently at more disaggregate levels of observation.¹² To circumvent this problem we also consider a calculation in which the expected deaths at the trail-level is used first, if that number is zero then the expected deaths at the peak-level is used for the trail, and if both are zero then the expected deaths at the regional level is used for the trail (deaths, trail/peak/region). We suspect that this last calculation most likely represents the true expectations of guides, since it potentially incorporates information on deaths as higher levels of aggregation when deaths at lower levels of aggregation are unobserved. We also view this innovation as an important contribution to the VSL literature, and believe that this fatality measure produces our most credible VSL estimate of \$4.69 M, as we shall see.

Summary statistics for the four expected death measures are contained in [Table 1](#). After all data cleaning, accounting for the three-

¹⁰ Our choice of a three-year moving average was effectively data-driven as we explain later.

¹¹ We do not have complete cost data to calculate net profit for the lead guide, so lumping professional climbers in this way is our only option.

¹² This precluded us from doing an analysis at the guide-level, which would have been interesting.

Table 1
Summary statistics for 155 recent expeditions.

| Variable | Average | Std. dev. | Coeff. var. | Min. | Max | Observations |
|-------------------------------------|-----------|-----------|-------------|---------|-------------|--------------|
| Expected deaths (trail) | 0.0450 | 0.0821 | 1.83 | 0 | 0.4423 | 155 |
| Expected deaths (peak) | 0.0423 | 0.0667 | 1.57 | 0 | 0.3884 | 155 |
| Expected deaths (region) | 0.0647 | 0.0802 | 1.24 | 0.0062 | 0.5297 | 155 |
| Expected deaths (trail/peak/region) | 0.0517 | 0.0795 | 1.54 | 0.0014 | 0.4422 | 155 |
| Revenues | \$147,978 | \$210,903 | 1.43 | \$5,534 | \$1,616,340 | 155 |
| Days | 28.32 | 14.38 | 0.50 | 6 | 80 | 155 |
| Experience | 4.40 | 5.26 | 1.20 | 1 | 24 | 155 |

year lag needed for instrumental variables, and limiting the data to only the most recent trips for purposes of merging with revenue data, the total sample used for the analysis is 155 recent commercial expeditions. (Historical revenue data only go back to 1996.)¹³ For deaths at the trail-level the average expectation across the 155 expeditions is 0.0450 lives lost.¹⁴ This average includes zero-death observations (i.e., the minimum expected death is zero) The standard deviation is 0.0821, so there is a fair amount of variability in deaths for this measure (coefficient of variation of 1.83). As we aggregate up from trail to peak deaths, the average expected death number is essentially constant (from 0.0450 to 0.0423), and the standard deviation shrinks (coefficient of variation goes from 1.83 to 1.57). The aggregation decreases the variance of the distribution while keeping the mean constant, because we are removing variation across trails on each peak. (This is precisely the issue that *Lalive* (2003) discusses: aggregation masks the true heterogeneity or variance of risks.) We still have zero observations at the peak-level death rate, but there are fewer of them.

When we aggregate up to the regional level (third row of *Table 1*), all the zeros and all the variation across peaks are removed, so we are left with only variation over time. This is reflected in the relatively low coefficient of variation of 1.24. One problem with this measure is that the average expected deaths increases to 0.0647. (This is being driven by three peaks of eleven that account for most of the expeditions: *Ama Dablam*, *Cho Oyu* and *Everest*.) It doesn't seem reasonable that expected deaths would be this large for expeditions on all trails. While we ultimately will not put much faith in this particular VSL estimate, we still report and discuss it to highlight the effects of aggregation on the VSL for these data. Aggregate measures of fatality risk most certainly distort VSL estimates, and this is a problem with typical labor market studies from census data. Industry-wide or occupation-wide fatality measures can be likened to our regional level fatality measure. They remove an important source of disaggregate variability (heterogeneity), and they may simply bias risk/reward estimates.

Notice that all the expected death measures in *Table 1* have very large maximal values (0.4423, 0.3884, 0.5797, and 0.4422). This is being driven by a few very large expeditions facing "normal" fatality rates. For example, there was one expedition that faced a three-year moving average fatality rate of 0.0143, but there were 37 paid climbers at risk. We do not treat these observations as outliers, since they are "highly visible events" in the industry, and the expectations of guides can certainly be shaped by the occurrence (or lack of occurrence) of a catastrophic event on these expeditions.

Lagged variables are also created for each of the expected deaths variables for use as instruments in the IV model. The lagged expected deaths are lagged by exactly one three-year period. Additional intervals were tried, both in the calculation of the expected deaths variable (e.g., one year periods, two year periods) and in the calculation of the lag (e.g., two period lag). Shorter time intervals resulted in the "too many zeroes" problem and were dismissed. When longer time intervals were used it severely reduced the number of observations. Therefore, our choice of a three-year using average was effectively data-driven.

2.3. Revenue data

Since our dependent variable is expedition revenue and since the Himalayan Database does not contain these data, we had to exploit other sources to obtain them. The guides in each expedition are all employees of the same professional company. In most cases, though not all, the leader of a given expedition is the owner or CEO of the company. Almost all of these companies list their prices publicly on their websites. The company for each expedition is identified in the Himalayan Database and the per-client prices were collected from each of the company websites. We assume the price paid is the advertised price, (i.e., no discounts, add-ons, or negotiated prices). Initially we used only current posted pricing (collected in December 2008) for our revenue measure and estimated VSLs between \$3.8 M and \$5.1 M, but we could only use about 50–80 observations for these estimates. Therefore, we sought to find historical pricing to expand the data in the (pseudo) time dimension.

To get historical prices, we used the internet *Wayback Machine* which archives "snap shots" of websites over time (several times per year). We discuss its functionality below. Using the *Wayback Machine* we collected offer prices for expeditions that took place after 1996. The data were collected from the *Wayback Machine* in October of 2009. Inflation adjustments are made using a calculator from the website *Inflationdata.com*. The inflation rate for a given expedition is calculated as the rate from January of the year of the expedition to January 2008. In this way all results are in 2008 dollars. International conversions are calculating using the conversion rate published on www.x-rates.com. The rate used is that from the first month of the season of the expedition. That is, spring expeditions use the March conversion rate, summer expeditions use June, fall expeditions use September, and winter expeditions use December. The rates are first converted to US dollars in the year of the expedition, then the inflation rate is applied to convert to 2008 USD. The price is multiplied by the total number of expedition clients to generate total revenues. Clearly, our revenue variable is subject to many forms of measurement error, but they are the best available data on Himalayan climbs.

The *Wayback Machine* is a web crawler archiving service. Crawlers, also called spiders, are sent out to survey the World Wide Web. These crawlers collect all of the details of a given website and send the information back to the *Wayback Machine* server. The server then puts the website back together, catalogs it, and archives it for retrieval by the public. Little has been written about the reliability of the archives (e.g., *Hashim et al., 2007*), but the archives are currently being used for litigation purposes (*Howell, 2006*), so we suspect that understanding

¹³ Restricting the sample to guide companies with published web pricing could introduce a selection bias if those guide companies have systematically different risk behaviors than the rest of the guide company population. A quick correlation analysis suggests that this is not the case. The correlation between having a website and number of recorded deaths in the data was 0.08 and the correlation between having a website and the number of (at risk) members per expedition was -0.04 .

¹⁴ The reader is reminded that expected deaths is based on fatality rates which are culled from all relevant expeditions on the particular trail and not just the 155 expeditions in the final sample.

the efficacy of crawler technology for data collection and validity will be a high-priority in the scholarly literature in the near future.

It is believed that the crawlers visit and archive each publically available website (approximately 16 million of them) every two months (Hashim et al., 2007), but this is obviously not a static number. However, with archives updated five or six times a year in an industry where companies only generate Himalayan revenues once or twice per year, we suspect that any publically available internet price changes are being captured by the crawlers within three to four months of their occurrence. Unfortunately, the crawlers only record the date that the website is captured and not the date that the website changed, therefore we cannot record the exact date of the price change and, hence, our prices are measured with error. However, there is no reason to believe that price changes and the activities of the crawlers are correlated (we explore this in limited detail below), so any measurement error in our pricing data is likely to be random.¹⁵

Although the crawlers are using a priority code to select websites for archiving, the collection process appears random for the archived websites we visited. That is, the frequency of crawler visits was approximately the same across websites. There are several ways in which crawlers can be prioritized. Often the priority methods are centered around the popularity of the site. That is, sites that are visited more often get a higher archival priority. (We suspect that mountain guide sites are not highly-visited relative to all other 16 million websites on the internet.) Additionally, owners of websites can opt out of the archival process. However none of these issues seem to be influencing the websites where we collected data. (All sites appeared to be archived at fairly regular intervals.) In the archives, expedition prices were typically updated every one or two years, and since the crawlers visit the websites several times a year we were able to verify price stability across any one or two year period (we did this only sporadically). In the end we did not collect all the pricing data for a given company. We simply search archived prices three months before and after the expedition and recorded the price two months before the start data of the expedition.¹⁶

As a preliminary exercise we relate the “per client” price to fatality rates for each of our 155 expeditions in Table 2 for the deciles of “per client” price. Each decile in the table represents a single expedition's price across the distribution of prices. As we can see, as price increases down the second column in the table, the expected fatality rate in the third column is generally increasing (based on the three-year moving average fatalities, using our trail/peak/region definition of the fatality rate). That is, for our sample, guides tend to charge more per client when risks appear higher on a particular trail/peak/region. The only real aberration in Table 2 is the twentieth decile, where the fatality rate is relatively high (0.027). This expedition's average fatality rate is high because of a single death in only 37 at risk climbers on Annapurna IV (very few attempted climbs, relatively speaking).¹⁷

3. Model and results

To estimate the tradeoff between revenue and death we estimate the following hedonic regression:

$$\ln R_i = \alpha + \beta \ln \text{deaths}_i + \gamma \ln \text{days}_i + \delta \ln \text{experience}_i + \varepsilon_i, i = 1, \dots, n,$$

¹⁵ In our personal communications with a few climbing companies, we determined that price changes typically occur every one or two years and never more than annually. This was also our experience with the Wayback Machine. Since these are small business with owners engaged in production, more effort is placed on climbing than on financial manipulations of the business.

¹⁶ Informal communications revealed that the down-payment is typically due two months before the expedition and final payment one month before the expedition.

¹⁷ As a robustness check we also performed the analysis with this observation removed. Our results changed only slightly. In column IV of Table 3 the *deaths* coefficient change from 0.912 to 0.930 and the VSL changed from \$4.69 M to \$4.81 M.

Table 2
Per client prices and fatality rates.

| Decile | Per client price | 3-year moving average fatalities Trail/Peak/Region |
|--------|------------------|-------------------------------------------------------|
| 10 | \$5,627 | 0.001 |
| 20 | \$7,813 | 0.027 |
| 30 | \$9,118 | 0.001 |
| 40 | \$10,208 | 0.004 |
| 50 | \$12,350 | 0.006 |
| 60 | \$13,940 | 0.006 |
| 70 | \$16,764 | 0.002 |
| 80 | \$20,130 | 0.007 |
| 90 | \$42,193 | 0.009 |

where i indexes expedition. We have repeated observations over guides, over peaks and over trails on peaks, which we do not make explicit in the notation. There is also a time dimension to the data which we do not make explicit, but that we do use for purposes of identification (i.e., we use lagged *deaths* as an instrument for current *deaths*). Here R_i is total expedition revenue. The variable deaths_i is the three-year moving average of expected deaths of paid climbers measured at different levels of aggregation (e.g., trail-level or peak-level), days_i is the expedition length, and experience_i is the total number of climbs in the entire Himalayan database for the lead guide at the start date of the expedition. The 2SLS estimate $\hat{\beta}$, using lagged *deaths* _{i} as an instrument, is the marginal rate of substitution between paid-climber revenue and paid-climber deaths, and our VSL estimate is the usual $\hat{VSL} = n^{-1} \hat{\beta} \sum_i R_i / \text{deaths}_i$. As such our VSL estimate reflects professional climbers' valuations of their own lives and not their valuations of their client's lives.

Our model does not include guide, trail, peak, or time fixed effects, as these variables were largely insignificant, and even if they were included in the specification, they did not have a large effect on the magnitude of our estimated VSL. We also had information on the height of the climb and the difficulty of the climb, but these were highly correlated with days_i and were excluded.¹⁸ The few safety-related measures (e.g., rope and oxygen) that we had, were insignificant. Again, we view the marginal product of labor as the marginal product for safety, so once revenues are measured, all safety-related productivity (observed or unobserved) is accounted for in the hedonic regression. Even so, our *experience* variable is certainly a proxy for a guides ability and, hence, his ability to “produce” safety.

Our final data set consists of 155 expeditions over 10 years (however our fatality rates are based on 3-year moving averages from 4372 expeditions over 21 years). The expeditions were led by 89 guides, representing eleven countries. The majority of the guides were from the U.S. (29), the UK (25) and Germany (12). Other countries include Australia, Austria, Canada, France, Japan, Netherlands, New Zealand, Poland and Switzerland. We do not have enough observations to confidently calculate VSLs for each country, so our VSL estimate is an international figure for developed countries, however the figure is dominated by U.S. and UK guides.¹⁹

Results are contained in Table 3, and our general finding is that higher levels of aggregation in the expected deaths variable reduce the average VSL measure. When expected deaths is average deaths on the same trail (column I), 2SLS yields a significant risk/reward coefficient of 0.924, and a robust standard error of 0.182. This regression only includes 78 observations, because observations with no deaths on the trail within a three-year period or no deaths in the lagged period (for the instrument)

¹⁸ Plausible results were achieved using the height of the climb, and VSL results were slightly higher for all four measures of expected death.

¹⁹ Sherpas are from Nepal, so they may be lowering our VSL estimates, but if the non-wage costs of the expedition are folded into Sherpa wages, then perhaps, their portion of the VSL is more in line with that of a developed nation.

Table 3
2SLS and VSL estimates for various expected death measures.

| Variable | 2SLS | 2SLS | 2SLS | 2SLS |
|-------------------------------|-------------------|------------------|------------------|------------------|
| | I | II | III | IV |
| Deaths (trail) | 0.924 (0.182) | – | – | – |
| Deaths (peak) | – | 0.728 (0.124) | – | – |
| Deaths (region) | – | – | 0.781 (0.081) | – |
| Deaths (trail/peak/region) | – | – | – | 0.912 (0.262) |
| Days | 0.608 (0.205) | 0.641 (0.211) | 0.723 (0.124) | 0.424 (0.349) |
| Experience | –0.043 (0.084) | 0.005 (0.054) | 0.041 (0.051) | 0.028 (0.081) |
| Observations | 78 | 114 | 155 | 155 |
| 1st stage F-test | 14.95 | 38.29 | 140.5 | 21.48 |
| VSL average revenues | \$171,685 | \$165,295 | \$147,978 | \$147,978 |
| VSL average deaths | 0.0570 | 0.0494 | 0.0647 | 0.0517 |
| VSL observations | 120 | 133 | 155 | 155 |
| VSL | \$5.39 M | \$4.05 M | \$1.98 M* | \$4.69 M |

First-stage regressions include *experience* and *days* as regressors.

Dependent variable in second-stage regression is the logarithm of Revenues.

All regressors are in logarithms.

Standard errors are in parenthesis.

* The VSL estimate of \$1.98 M is not reliable due to mis-measurement of *deaths*.

are dropped from the regression.²⁰ This results in an average VSL measure of \$5.39 M, based on 120 observations.²¹ In column I we also see that the average of the 120 expected trail deaths was 0.0570 lives and the average revenues on these 120 expeditions was \$171,685. Both of these values are higher than the sample averages of 0.0450 expected deaths and \$147,978, based on 155 observations (Table 1).²² However, the ratio of the values (\$/death) is approximately equal, implying that the lost zero-death observations may not be effecting our average VSL results. The VSL estimate of \$5.39 M is reasonable except for the fact that it is based on few observations. To increase our effective sample size we considered estimates using higher levels of aggregated expected deaths. When all of the deaths at the peak-level are used for the expected death rate on the trail (column II) the risk/reward coefficient is 0.728 (0.124). The average VSL estimate is \$4.05 M, based on 133 observation with averages of 0.423 deaths and \$165,295 in revenues. These are fairly stable results despite the fact that zero-death trails are either dropped or set to the higher peak death level across the analyses.

Then we aggregated one more time to include all deaths in the Himalayan region (column III). In this case all of the variability in the fatality rate is in the time dimension (i.e., no variation across trails and peaks). The risk/reward coefficient is 0.781 (0.081) and the average VSL estimate is \$1.96 M. We do not put much faith in this estimate, because the fatality rate aggregation distorts the true expect deaths. In this case we can see that the average expected deaths is a rather large 0.0647 lives. We report these results for completeness only.

Ultimately the most satisfying method we employ is to use higher levels of aggregation only when lower levels are unavailable (deaths, trail/peak/region). The idea is that if the agent knows the lower level of fatality rates, this will be most important in determining risk. However, if there have been no fatalities on a given trail in the most recent three year period, then the guide considers the fatality rate on the peak. If there have been no fatalities on trail or peak in the given period then the guide

²⁰ Obviously with 78 observations, standard inference requires a normality assumption on the regression errors.

²¹ Forty-two additional observations with non-zero expected deaths and zero lagged expected deaths can be included in the VSL calculation that were not in the 78 regression observations.

²² The reader is reminded that that the average expected death measures in Table 1 includes some zero-valued observations (in 155 observations) while the average death measures in Table 3 do not. Hence the difference in Table 3 Columns I and II relative to the first two rows of Table 1.

considers the fatality rate in the region. Using this method we obtain a risk/reward coefficient of .912 (.262) in column IV of Table 1. The mean VSL is \$4.69 M based on average values of deaths and revenues for all 155 observations of 0.0517 and \$147,978. The VSL of \$4.69 M lies between our other two reliable measures of \$4.05 M and \$5.39 M.

It is not difficult to speculate on the direction of VSL biases that might result from changing the levels of aggregation, dropping zero-observations, or imputing higher levels of aggregation within a particular aggregation of expected death. However, the relative stability of our VSL estimates over our three preferred methods of measuring expected deaths is undeniable.

4. Conclusions

This paper estimates a VSL of \$4.05 M–\$5.39 M using data on Himalayan expeditions over the past decade. In 2008 the U.S. Dept. of Transportation established \$5.8 M as the agency's benchmark VSL (Viscusi, 2009). Our VSL estimate at the most disaggregate level is \$5.39 M, which is quite close to the US DOT value. Perhaps, the policy is the correct one. Our results are similar to the those of Schnier, Horrace and Felthoven (2009) who had a much larger sample, but used more aggregate measures of expected death.

Unfortunately, we did have a problem finding historical revenue data and had to resort to using the internet *Wayback Machine* to record pricing. However, we believe that any error we may have induced in the process is random, so our regression estimates should not be biased. (Besides it is widely held that measurement error in a dependent variable is fairly innocuous in a regression context.) We believe that ours is the first study to use archived internet data for the purposes of regression analysis, and it is interesting to speculate how the *Wayback machine* might be used in subsequent research.

For future research, we would like to survey climbing companies and collect data on historical revenues to verify the accuracy of the present VSL results. It is also interesting to think of the mountain guide industry as a form of life insurance without moral hazard (i.e., where the behaviors of the insured, paying climbers, are directly observed by the insurers, the paid guides). Perhaps something could be done to exploit this unique feature of the industry and data.

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