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TARGETS FOR CHARACTERIZING RISKY BEHAVIORS: ANALYSIS AND A CASE STUDY ON HOME AFFORDABILITY

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Abstract
Risk is often measured in terms of variability in outcomes. Hence, a highly variable outcome is often described as risky. In this paper, we use thresholds, also called targets, to characterize risks. Targets have been widely studied in the literature on risk, especially in the context of the two popular metrics: downside risk and semi-variance. Downside risk is generally measured as the probability of revenues falling below a target or costs rising above a target. Semi-variance captures the component of variance below the target revenue (or above the target cost). Going *too close* to the target can be alluring, and yet even *approaching* the target can be dangerous, because accompanying it is the danger of falling off a cliff. This paper will focus on analyzing behaviors associated with hovering around the target. Such behaviors can be seen in numerous consumer and industrial activities, e.g., selling a house, changing raw materials of a product, introducing a new drug into the medicine market, offering financial schemes to consumers etc. Oftentimes, such behaviors are known to be fraught with danger, and yet vested interests prevent their risks from becoming well-known. The risks associated to these behaviors usually become apparent after disaster has struck, but at times their root causes can remain unknown even in the aftermath of a disaster.

Keywords
Risk, threshold, target, home-affordability calculators

Introduction
Risk is often quantified in terms of randomness in the outcomes of events. Therefore, if a highly variable event occurs, it is considered to be *risky*. In general, but not always, risk is treated as an undesirable trait. An exception to this is entrepreneurial risk, which is considered to be positive, although it also assumes the probability of failure. Undesirable outcomes are those that are related to loss of money and/or life. This paper seeks to analyze risk from the perspective of targets. In the jargon used in the world of financial risk, a target is a pre-set value for net revenues or net costs. In terms of revenues, the common understanding is that if revenues fall below the target, one enters a *risky territory*. Similarly, in the context of costs, if costs rise above a target, one enters risky territory. These targets have to be chosen carefully. The target is sometimes obvious, but at times it is not. There are many well-known instances of situations where targets were blatantly violated to enter risky territory, but the consequences became apparent later. The motivation for entering risk territory is usually short-term profits, but the long-run impact is generally negative. The goal of this paper is to show that although targets are known to producers or service-providers, consumers (e.g., users of products and other stakeholders) are often misled into believing that either those targets do not exist, or that operating on the target, which is dangerous, is perfectly acceptable and in fact in the customer's best interest. The paper will provide multiple illustrative examples from industry for such scenarios and one case study from real-estate finance where customers are encouraged to be at the target.

Targets are useful in risk analysis because for settings where outcomes are highly variable they provide much-needed thresholds that should not be crossed. Consider the returns from a stock. The target for a stock can be usually set depending on the risk appetite of the buyer. The target will typically be a price for the stock below which the buyer will not be interested in keeping the stock. Now consider an event such as an individual buying a home loan, approval of a new drug by FDA, a space shuttle taking off, or changing the raw materials in a product. Oftentimes, the variability here is not known. It is in such conditions that identifying targets is really crucial. The different analyses in this paper will threaded by the role played by targets – in making risk *visible* in the analysis, even if it not always measurable.

Threshold or target risk is often measured in terms of two metrics: (i) downside risk, i.e., probability of revenues falling below a pre-set target and (ii) semi-variance, which is the component of the variance that falls below the target revenue. When targets are known and so are the distributions underlying the returns, one can compute these risks. At times, it is clear what the target is, but the underlying distribution is unknown. A related term is called tail risk or Black-Swan risk (Taleb, 2007); the existence of tail risk implies that the associated decision's outcomes have a non-normal, unknown distribution of returns with a fat tail, i.e., with potentially high danger. Such situations where the target is known and there is the possibility of high tail risk, the professional code of conduct calls for enlightening the user about the target. For instance, a drug company selling a drug with possible side-effects is required to advertise the side-effects even if the probability of those side effects is low.

The rest of this article is organized as follows. The following section discusses metrics in which the target is numeric. The section following that provides a discussion on targets in risk assessment. The section that follows discusses home-affordability calculators. The last section provides concluding remarks.

Metrics

The world of finance has devised a large number of metrics to measure risk. The most popular measures of risk are variance and its square root, standard deviation, which were popularized by Markowitz (1952). Unfortunately, many of these metrics are often computed in absolute terms or in terms of percentages. Here the word "absolute" is used to mean that there is no target under consideration. Both standard deviation (σ) and variance (σ^2) are absolute in this sense. Also, since stock returns are usually measured in terms of percentages, metrics like Value at risk (VaR) are computed in terms of percentages. Conditional VaR (CVar) is another metric that has become increasingly popular in finance. See Bacon (2002) for a comprehensive review of numerous such risk metrics. Unfortunately, a majority of these metrics do not directly apply in non-financial settings such as those encountered by engineering managers, where metrics typically have to be defined in terms of profits or losses. Nonetheless, these metrics have versions that are directly applicable to our community and two such metrics are described below in detail.

Downside risk, also called **shortfall risk**, is a metric that appeals to engineering managers. Let *X(i)* denote the returns (revenues) from the *i*th sample. Then, the variance, which is the most popular risk metric, is given as:

$$\sigma^2 = \frac{\sum_{i=1}^{n}[X(i) - \bar{X}]^2}{n-1}, \tag{1}$$

where $\bar{X}$ is the sample mean of the returns. Now, the downsider risk (*DR*), which is the probability of the revenue falling below *T*, is computed as follows:

$$DR = \frac{\sum_{i=1}^{n} I(X(i) < T)}{n}, \tag{2}$$

where *I(condition)* equals 1 if the *condition* is true and equals 0 otherwise; *n* denotes the number of samples; and *T* denotes the target revenue. Thus, to compute this probability, only those instances are counted where the revenues fall below the target. To illustrate this idea, consider a small sample as follows: *X(1)* = 12, *X(2)* = 15, *X(3)* = 16, *X(4)* = 17, *X(5)* = 11, and *X(6)* =17. If the target, *T*, equals 14, then the downside risk can be computed as follows: *DR* = (1+0+0+0+1+0)/6= 1/3. In practice, arriving at an accurate value for *DR* will need a large value of *n*, the sample size. The other metric, **semi-variance** with respect to the target *T*, is computed as follows:

$$\sigma^2(T) = \frac{\sum_{i=1}^{n}[T - X(i)]^2 \, I(X(i) < T)}{n-1}, \tag{3}$$

Clearly, semi-variance measures the variance but only that below the target. For the example above, the semi-variance would equal $(2^2 + 3^2)/5$ = 2.6.

It will now be useful to consider how these targets are useful in characterizing risk. Consider two options, named A and B, which have different distributions for the returns. The mean returns from both options are approximately the same. For A: *DR* = 0.3, $\sigma^2(T)$ = 25.24, σ^2 = 100.34, while for B: *DR* = 0.1, $\sigma^2(T)$ = 12.21, and σ^2 = 134.9. Clearly, option B would be preferred here, since it has a lower downside risk and semi-variance; note that variance (σ^2) as a risk metric does not have significant discriminatory power, since it does not account for targets. In fact, variance can be misleading, since the variation above the target revenue is also accounted for in variance, but this part of the variation is actually healthy and higher the better. In other words, variance cannot distinguish between good and bad variation, and is hence not the best possible metric for risk.

Although the notion of targets is obviously useful in a numerical setting, it also applies to **qualitative** assessment of risk. This paper will seek to analyze multiple scenarios where the notion of targets can be employed gainfully to better understand and estimate risk.

Targets in Risk Assessment

A popular case study for risk analysis is that of the Challenger disaster, where a space shuttle carrying seven crew members exploded very soon after takeoff. One major lesson that can be drawn from the Challenger disaster is that the risk arises when one enters conditions *not tested before*. Now, all entrepreneurship is about entering uncharted territory and so is sending a shuttle into space, but, when human life is involved with a vehicle, every attempt has to be made to ensure that the vehicle does not encounter conditions for which it is not designed or has not been tested previously. The range of temperatures to which Challenger was subjected in earth, as it was rising, was not one that its rubber seals (called o-rings) were tested or designed for (Starbuck and Milliken, 1988). Clearly, this invited risk into the system; engineers had warned the previous day that the temperatures forecast for the time of launch in Florida on the next day were very low and that the behavior of the rubber seals in those temperatures was unknown (Bell and Esch, 1987). The target in this scenario is the boundary of conditions under which the object has been tested and is known to perform well. There was pressure from the managers to send the vehicle, despite warnings from the engineers that the boundary of known conditions was being violated.

Numerous other examples exist of situations where recklessness leads to loss of lives. In such incidents, one typically finds safety norms not being followed, or perhaps a design flaw. A prominent example is the incident that occurred in the Twin Towers of the WTC in New York City on September 11, 2001, when people in the South Tower were advised that the building was safe after a plane had hit the North Tower. Had everyone evacuated immediately, more lives would have been saved. In fact, those who left urgently saved their lives (Moore and Cachon, 2002); the two towers were adjacent to each other, and fire in one could have easily spread to the other, even without that second plane. Risk can also be introduced by faulty design. For instance, the gap between footboards of a train (where the customer places the first step while entering) and the train platform can lead to a person slipping in between the gap; further, the height of the platform may be insufficient, causing people to fall while descending from (or ascending) the train (Website 1, 2014). In what follows are presented three examples of scenarios where a target can be tracked to risk.

Catastrophic Failures of Tires

Around the year 2000, more than 100 deaths were reported from Ford Explorers, which had Firestone tires, rolling over. Initially, it was suspected that the height of the SUV (Ford Explorer) had a role to play in the process (Greenwald, 2001), but it was later discovered that the rollover was occurring due to catastrophic failure of the tires manufactured by Firestone. In 2000, many such failures occurred resulting in tragic deaths on the highways when the vehicle was operating at a high speed. A several-month-long investigation at Firestone (Bradsher, 2000) revealed that using *rubber pellets instead of rubber sheets* in certain manufacturing processes in their plant in Decatur, IL was one of the critical factors responsible for the explosion of the tires. Obviously, this was a design and manufacturing *change* that was not studied in the laboratories prior to sending the product to the customers. Eventually, the Decatur plant was shut down. Tests performed during the investigation revealed that the lubricant used in the manufacturing process stuck more to the pellets than to the rubber sheets, essentially making the resulting tire weaker. Of course, this investigation occurred after more than a hundred lives were lost and numerous lawsuits ensued. Investigations showed that customers were making complaints related to such failures for several years before 2000. The lesson here is that changes in design or the manufacturing process for a product as critical as a tire essentially amount to crossing the threshold of risk, and should not be made without prior, extensive testing in laboratories. This applies to every change to each manufacturing process or design of any auto component whose failure can cause an accident.

Approving a Medical Drug

Approving a medical drug is a critical, but high-risk, activity performed by the United States FDA (Food and Drug Administration). This is something that may take several years, and is a multi-step process. Typically, even on approved drugs, the FDA gets several complaints regularly. It has a difficult job of tracking all complaints and act when it sees a red flag. FDA for the most part has approved drugs that are effective, where the side effects have been advertised appropriately. Nonetheless, there have been many exceptions to this: diet pill Redux, anti-biotic Rexar, blood pressure medication Posicor, painkiller Duract, diabetes drug Rezulin, and heartburn drug Propulsid (Willman, 2000). The last caused death of children, and the FDA had never warned physicians and pharmacists, although it was aware of the risk for children. Two types of errors are known to occur with FDA's actions: Type I when a drug that should be approved is not, which is a less serious error, and Type II when a drug that should not be approved is in fact approved (Website 2, 2016). Commercial considerations (Willman, 2000) should never be taken into account, but are they always ignored? It is hard to tell, since the world of risk is full of case studies where commercial motives got precedence over risk considerations of which the Challenger disaster is a prime example. When the illness is serious, the FDA is under pressure, and was in the past required to reduce the time it took to approve a drug by one year (Willman, 2000).

So what is the target here? The literature suggests that the target is to determine the frequency of side-effects on patients before the drug is released. If that frequency (or probability) is less than a commonly accepted threshold, the drug is approved. It must be noted that the sample size in these tests has to be huge and the threshold is not zero. Even the best drug or vaccine often has some side effects. But for defining a target here, not succumbing to commercial pressures or pressures from the illness' seriousness is a prerequisite. Many cancer patients are often given experimental drugs, but with the permission of the patients and only after the patients are made aware of the risks.

Multi-Level Marketing

Multi-Level Marketing (MLM) schemes are those in which salespersons are compensated (rewarded in monetary form) for their own sales. MLM schemes often involve direct selling in which people sell products directly to consumers through referrals and word-of-mouth contacts, i.e., no retailer is involved. Many home-based business franchising schemes fall under the umbrella of MLM. While many MLM schemes are legal in the U.S. and in other parts of the world, several schemes of this nature "lure people into believing that they have the formula to instant riches" (Dalal & Sapkale, 2012a). An example of a promise made by a Singapore-based MLM firm called QNet was that all an investor had to do was to invest x dollars and then the system would ensure that the investor would keep getting x dollars every week. It was also advertised that the investor who would acquire the so-called Goldstar status would earn what a billionaire was earning weekly (Dalal & Sapkale, 2012b). Schemes such as Amway have not necessarily been illegal in the U.S., but the U.S. Federal Trade Commission (FTC) strongly recommends people to stay away from schemes that pay commissions for recruiting new distributors, especially if these commissions exceed what is being paid for selling the product; it further warns that such schemes are usually pyramid schemes that are illegal and typically collapse when new distributors are not available (Website 3, 2016)

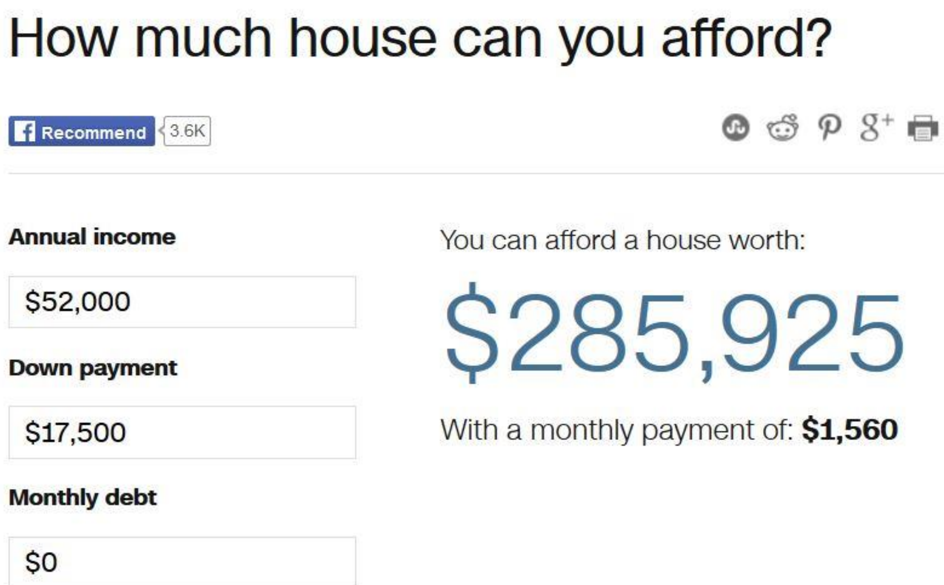
So how does one recognize the target here? One approach is to determine whether the scheme offers money in return for recruiting new salespersons. If any money is offered in exchange for that, the scheme is likely to be of a Ponzi nature that will ultimately unravel. Schemes that offer money just for selling products and not for recruiting new salespersons are likely to carry less risk. Nonetheless, any scheme that asks the user to first buy the product and then sell it from home directly always carries some risk in that the products purchased may not sell. Unemployed people seeking jobs are often lured into buying such products through television ads.

Home-Affordability Calculators: A Case Study

One of the greatest incidents of failure of risk management in recent times is the Great Recession starting in 2007-2008, a notable feature of which was Lehman Brothers declaring bankruptcy in 2008. Home foreclosures from sub-prime loans were an important feature of the recession. Foreclosures produced a contagion effect depending on other factors (Gangel, Seiler & Collins, 2013). One of the underlying reasons why so many homes were foreclosed during the Great Recession is that when disaster struck (loss of a job), many with home loans could not afford to pay the minimum payment due on the mortgage, i.e., the loans were unaffordable (Harnik, 2009). Affordability of loans is not easy to define but one possible reason for it is *high* monthly payments (Foote, Gerardi, Goette & Willen, 2010). The last reference also develops an elaborate model for affordability, i.e., what makes a borrower determine whether a loan is unaffordable (which can lead to default). In this study, the focus is on understanding, from the perspective of the buyer, whether the loans that would be considered affordable would actually turn out to be sustainable, i.e., one that would likely be paid off in its entirety. Do note that since the financial crisis of 2007-2008, banks have tightened their rules for providing loans. Nonetheless, a lot of people who do qualify are not always in positions to afford the loan. Many consumers use online home affordability calculators to determine the price of the home they can afford. Exhibit 1 below shows a typical home-affordability calculator available freely on the web (Website 4, 2016). An annual income of $52,000 was entered, along with a down payment of $17,500. As is clear from the exhibit, the calculator advises that the user can buy a home worth $285,925. Below the actual calculations, it shows the methodology used, which is shown in Exhibit 2. The methodology explains that this is a 30-year loan, and it assumes that the user can spend 36% of the gross income on payments to the loan. 36% of the gross income of $52,000 equals $18720, which leads to a monthly payment of $1560. This, the methodology does state, does not include mortgage insurance.

A critical aspect of the numbers calculated above is that living on the 36% threshold invites risk. It is clear that an individual with a monthly gross income of $52,000/12=$4333.33 will earn less than $4333 monthly in net income, but will spend $1560 on just the monthly mortgage payment, not counting the insurance. This does not appear ideal. Unfortunately, most individuals are given similar advice when buying homes.

Exhibit 1. A Freely-Available Home Affordability Calculator.



Below the calculator in smaller print, it explains that the total debt payments should not exceed 36% of the gross income. Typically, it is also assumed that the user has a god credit history. Exhibit 2 explains the methodology.

Exhibit 2. The Methodology Used in the Online Calculator, Including the Threshold (36%).

Methodology

To arrive at an "affordable" home price, we followed the guidelines of most lenders. In general, that means your total debt payments should be no more than 36% of your gross income.

Once you enter your monthly debt (including credit cards, student loan and car payments), we come up with a maximum monthly home payment you could handle while staying under that threshold.

Why do lenders use this guideline? It's been shown to be a level of debt that most borrowers can comfortably repay.

That home payment assumes a 30-year mortgage at current rates, and includes 1% property tax and 0.4% for homeowners insurance.

It does not factor in private mortgage insurance, which you'll owe if your down payment is less than 20% of the purchase price.

You should reduce the maximum target if you have other savings needs (such as retirement and college) or additional expenses (such as child care, private school tuition, health care, or alimony payments).

The 36% value has roots in the age-old 28/36 rule used by mortgage lenders (Investopedia, 2016). According to this rule, one can use 36% of one's gross income towards debt payments and 28% towards mortgage payments. Thus, the 36% value for mortgage payments assumes that the user has no debt other than the home loan. Unfortunately, there are strong incentives for real-estate builders, agents and financial institutions to sell people bigger homes, as their own profits are proportional to the selling prices of the homes.

The 28/36 rule really states that 36% of the gross income is the *maximum* (threshold) one should spend on paying debts. Also, note that the last sentence in Exhibit 2 calls the payment the "maximum target." The minimum one can borrow is 0%. In engineering, when the distribution is not known, the following rule is used for computing the average: average = (minimum + maximum)/2; see e.g., warehouse calculations in Askin and Standridge (1993). The assumption is that the underlying distribution must be a symmetrical distribution. This would lead to (36 + 0)/2 = 18%. The home foreclosure crisis strongly suggests that the 36% threshold used in these calculations needs to be reduced substantially. Therefore, this paper proposes 18% as the suggested proportion of gross income for mortgage payments, or perhaps a range between 15% – 20%, depending on the taxation rates. Using 15%, an individual making $52,000 annually would be able to afford a home whose monthly payment would be $650. Of course, it is possible that this may lead to a home that is too small or perhaps not in the location sought (which could depend on the school district and length of the commute to work), but the risks of buying an unaffordable home far outweigh those of renting in the desired location.

Further, living on the threshold is like walking on a cliff. Individuals with lower income levels are more susceptible to other shocks, such as hospitalization in case of insufficient medical insurance. Other factors, e.g., marital discord, are also known to lead to foreclosures. Clearly, given that many of these other factors cannot be ruled out, it appears that financial advice based on the 36% threshold needs to be revised. Before concluding the paper, it will be helpful to summarize the targets associated with the different scenarios analyzed in the paper via Exhibit 3.

Exhibit 3. Targets/Thresholds for Risk in Examples Studied.

Example	*Target*
Challenger Case Study	The boundary of conditions for which the product is not tested previously
Tire Failure	Changing raw material without extensive testing
Approving a Medical Drug	Frequency of side-effects
Multi-Level Marketing	Money offered for recruiting salespersons in a home-based business franchise
Computing Affordability of Home with Online Calculators	The percentage (or proportion) of gross monthly income used to determine the monthly mortgage payment: 36% used in many free, online calculators, but 18% proposed here

Conclusions

The central goal of this work was to show how targets are useful in characterizing risk in many industrial and consumer activities in a variety of systems. While targets can often be numerical, it was shown above that they are often not. Recognizing the target can go a long way in avoiding risk, or even in approaching risky situations. Risk is often difficult to characterize, and negative outcomes from poor decisions become obvious only after disaster has struck. As a result, targets can play a critical role in determining when a system starts approaching a risky state. A number of examples were described in this paper, along with how to determine the target for the example considered. The paper ended with a case-study from real-estate finance, where online calculators are frequently employed by users to determine affordability of homes. The case study sought to highlight the fact that online calculators use a threshold that appears to lure people into risky purchases and should be revised downwards.

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