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Black Swans, Fat Tails, and Extreme Values Visit Energy Risk

R. Kenneth Skinner

Most of us who have been in the energy industry for a while have a story or two of how unexpected events can cause serious problems. Stories like the California energy crisis, the collapse of Enron, or the failure of the First Energy transmission system and the resulting northeast blackout have captured international attention, and there are less-well-known personal stories of how seemingly good positions quickly turn bad.

Recently, as the banking crisis unfolded and the $700 billion bailout bill was rushed into law, many in the energy industry found themselves once again confronted by events that no one would have thought possible a few months earlier. Naturally many have questioned the effectiveness of energy risk management methods—some of the same methods supposedly in place to protect the banks.

Many in the energy industry have stopped to consider what lessons can be learned from the banking crisis. As you listen to the many risk professionals opine about what we can learn, it is hard not to be struck by the divergent opinions and tenacity with which many promote their opinions. Some have suggested that the current methods are fine but that the managers failed to interpret the information that the models provided,

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Columns

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whereas others assert that the methods themselves are at fault, either by luring managers into complacency or because the methods are just wrong. Nassim Nicholas Taleb, the best-selling author of *The Black Swan*,[1] has argued for years that value at risk (VaR) models can cause more problems than they purport to solve.

Some have suggested that the current methods are fine but that the managers failed to interpret the information, whereas others assert that the methods themselves . . . are just wrong.

In this article we briefly take a look at the traditional VaR model and consider the arguments of Taleb and others. We discuss the benefits of changing our risk reporting methods and consider the obstacles standing in the way of significant change. We conclude by considering the virtues of extreme value theory as an add-on to current VaR methods and take a look at a simple application of extreme value risk using interest rates and examine how we may better manage interest-rate risk using an extreme value perspective.

THE IMPORTANCE OF VaR

The popular notion of VaR and other similar methods used in the energy industry today have their roots in the work of J.P. Morgan in the early 1990s. The story goes that Dennis Weatherstone, the new chairman of J.P. Morgan, asked his quants to develop a reporting method that would characterize the risk of the firm. After several years, the basic ideas underlying VaR took hold and were popularized through the spinoff company RiskMetrics.

The great appeal of VaR is that it can express corporate risk as a single number. In its most common form, it measures the boundaries of risk in a portfolio over short durations. For example, if you have $25 million of daily VaR, that means that over the next 24 hours, there is a 95 percent chance that your portfolio will not lose more than $25 million. That portfolio could consist of many different physical obligations, assets, traded commodities, and financial hedges, and express these together in one measure of risk.

VaR can be used to report corporate risk, departmental risk, or the risk of a single transaction. VaR by itself is not very useful. But together with predetermined risk limits, a risk policy that, among other things, describes actions when risk thresholds are breached and a history of VaR to measure changes or trends, the method is considered the standard by which all other risk methods are judged.

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ARGUMENTS AGAINST VaR

But there are limitations to the approach that became clear during the banking crisis. Taleb's primary concern is not with what VaR tells us but what it does not tell us. VaR can estimate maximum dollar loss that a portfolio, or a group of portfolios, can statistically expect to incur over a defined period of time, at a predetermined confidence interval. But it does not tell us what can happen outside of the predetermined confidence interval, at the extreme edge of the curve.

VaR assumes that the underlying distribution characterizing the risk is Gaussian—normally distributed. But what if the extreme tails are not Gaussian? What if instead of losing $1 million at the extreme as predicted by VaR, we lose $1 billion? What will cause you to lose billions instead of millions? Something rare, something you have never considered a possibility. These are the "fat tails" or "black swans" that Taleb and others write about in extreme value theory. Taleb is convinced that they take place far more frequently than most human beings are willing to contemplate.

The statistical methods underlying VaR require historic information to calibrate the model. But historic data is no indication of what can happen in the future.

But how do you plan for something that you have never considered a possibility? Regardless of the technique that is used, the statistical

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methods underlying VaR require historic information to calibrate the model. But historic data is no indication of what can happen in the future.

And the range of historic data is often intentionally chosen to focus on short-term changes in the market variables. For example, a risk manager of a natural gas portfolio may choose to measure the trailing 30 volatility so as to better identify short-term changes in market conditions. Thus, the risk manager intentionally chooses to focus on the 95 percent business as usual rather than the 5 percent extreme outliers.

The range of historic data is often intentionally chosen to focus on short-term changes in the market variables.

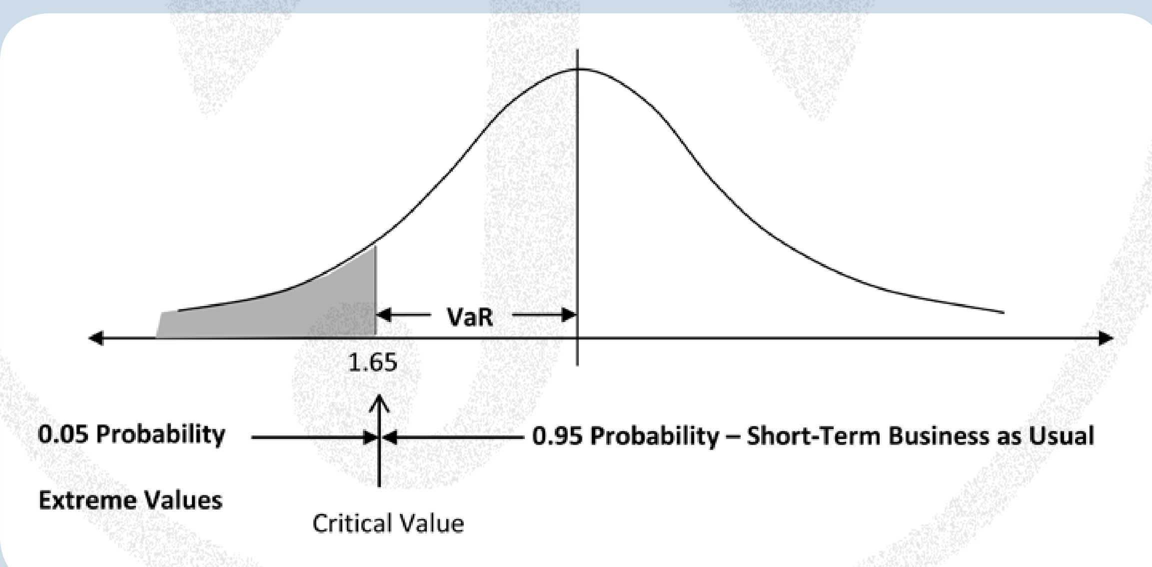
Critics of the VaR approach point to this short-term bias as the reason why managers can be lulled into overlooking the longer-term extreme events that, although rare, can be devastating to the portfolio. Perhaps this is the lesson that we can learn from the banking crisis. While focusing on business as usual is necessary in order to track short-term market variation, we should not be lulled into forgetting about the black swans lurking in the tails.

Perhaps the problem is best described by two separate analyses: (1) business as usual and (2) what happens in the tails. This approach is where extreme value theory can help us. Extreme value theory provides a theoretical foundation for describing the potential risks lurking in the tails of the distribution.

Perhaps the problem is best described by two separate analyses: (1) business as usual and (2) what happens in the tails.

However, a note of caution is in order here. Even extreme value theory cannot replace the objective human component of the risk manager. This too is a lesson that we learned from the banking crisis. At the end of the day, the risk tools only provide information to help management decide on a course of action. It is within the decision-making process that nonquantifiable risks—those risks without historic precedence—are considered.

Exhibit 1. Traditional VaR Focuses on the 95 Percent Probable Occurrences



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Extreme Value Theory

In a recent article focusing on risk lessons from the banking crisis, Philippe Jorion classifies risks into three categories: "known knowns," "known unknowns," and "unknown unknowns," each corresponding to different levels of uncertainty.[2] The known knowns are those risks that we measure with our traditional methods—the risks within the 95 percent confidence interval. These are the risks that we need to understand in the short term to manage portfolios on a daily basis.

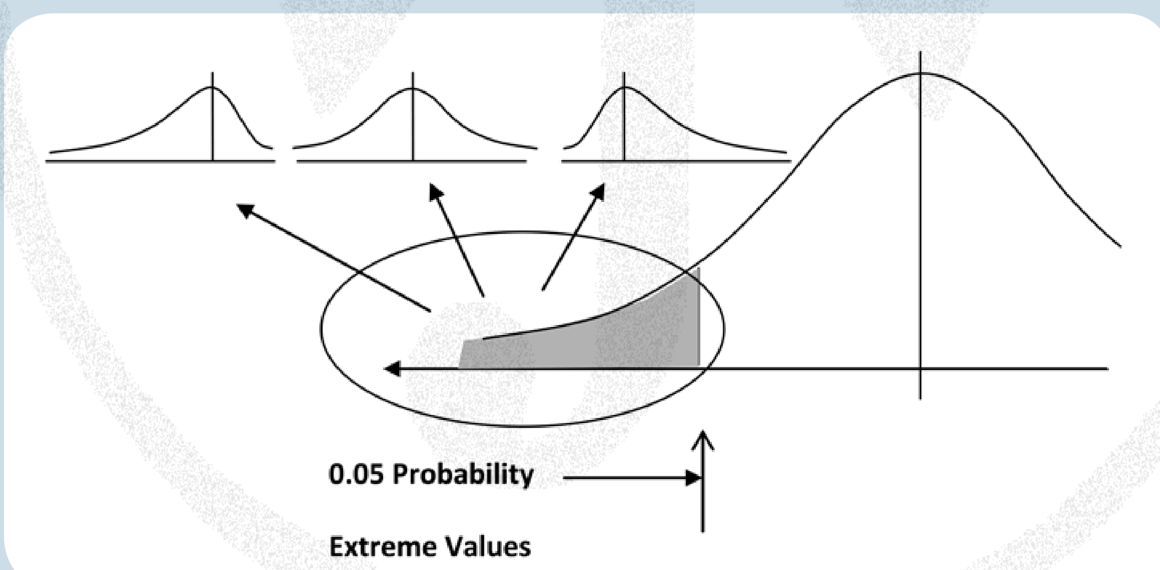
Known unknowns refer to those risks that we are less likely to pay attention to. They can refer to errors in the model or uncertainty in the parameter calculations. But for our purposes, these are the uncertainties in the tails of the distribution that extreme value theory can help us identify and manage. Extreme value theory provides a theoretical framework to measure black swans or fat tails in our decision-making process.

Jorion further describes what he calls unknown unknowns. These are those risks that we know nothing about and have no historic precedence to use in our risk models. These risks cannot be measured or reported and can only be included in the risk management process through the objective consideration of the risk manager.

Thus, extreme value theory still requires information about what potentially could happen at the extremes. In it most common form, extreme value theory uses much of the same statistical methods used in the calculation of VaR. We still examine historic data and measure distributions and confidence intervals. However, our attention is on the extreme events rather than the short-term business as usual. In **Exhibit 1**, the traditional VaR measure focuses on the movement within the 95 percent confidence interval. It is within this range that we set up our daily risk measures and manage the portfolio in the short term. In **Exhibit 2**, the focus is on the tails of the distribution.

There is no need to assume that the tails are Gaussian. The analysis of the tails may reveal a large negative skew indicating an extreme danger lurking in the tail, or it may reveal that no unusual risks are present. This additional information can provide the basis for designing actions to counteract extreme negative events

Exhibit 2. Extreme Value Theory Focuses on the 5 Percent Tails and Possible "Black Swan" Extreme Outcomes



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if they occur. It does not mean you will ever need to take those actions, but having information describing the consequences of black swan events can help managers avoid being caught by surprise in the event of these low-probability and high-consequence events.

There are several approaches to incorporating extreme value theory into an analysis. We have to be careful at this point to not become too dogmatic regarding one method over another. In the *Black Swan*'s glossary, Taleb defines Locke's madman as someone who makes impeccable and rigorous reasoning from faulty premises, thus producing phony models of uncertainty that make us vulnerable to black swans. We cannot forget that regardless of the techniques we use to measure risk, we are using that information to forecast the future in spite of its uncertainty. A good econometrician knows not to overfit models, because what may work well over historic data may have little explanatory power for future performance.

What may work well over historic data may have little explanatory power for future performance.

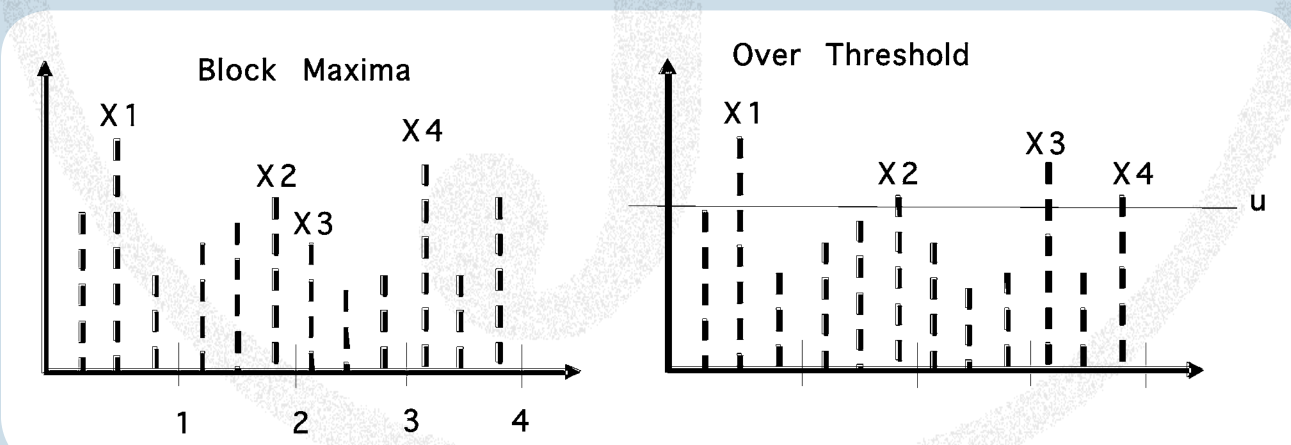
The basic idea is to examine the extreme values of a data set and incorporate those into the analysis. Two methods often used to analyze extreme values are shown in **Exhibit 3**. In this exhibit, block-maxima are shown in the left panel and excesses over a threshold *u* are shown in the right panel. The block-maxima method splits the data into segments.

In the example shown in Exhibit 3, the segments consist of successive groups of three observations. The maximum of each group is selected to represent the extreme value of the group. The resulting set of extreme values can then be analyzed as a group using traditional probabilistic methods to characterize extreme value risk. The excesses over threshold *u* method, shown in the right panel of Exhibit 3, is simply an alternative to collecting the extreme value set. In either case, the resulting data provides the risk manager information about extreme conditions and potential loss beyond that reported with the VaR measure.

INTEREST-RATE RISK FROM AN EXTREME VALUE PERSPECTIVE

Although the lessons learned from the banking crisis and the extreme value theory described in this article have applications in all aspects of energy risk, what might that look like if applied to a specific example? What if we applied these lessons to interest rates, for example? Today interest rates are at all-time

Exhibit 3. Block Maxima vs. Over-Threshold Extreme Value Measures



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lows. How should our models reflect the risk of rising interest rates?

If we consider the lessons learned described in this article, we would identify the three categories of risk: "known knowns," "known unknowns," and "unknown unknowns." We could focus on the short-term business as usual to track variation in the market variables but recognize the longer-term risk of rising interest rates. We would be careful to remember that risk decisions are not made by computers or methods, but by people who use the information provided by the risk models to make informed decisions. We would back-test our models and watch for inconsistencies in the statistical methods. We would have actions in place to protect against the eventual rising rates. At the end of the day, we would believe that there remain risks that we cannot envision or calculate using statistical methods.

Having predetermined tactics to protect the portfolio in the case of black swan events will prevent management from being caught unprepared.

However, taken as a whole, the information can provide the risk manager with a basis for making decisions and enacting risk-mitigation strategies. Actions may never be needed for extreme events, but having predetermined tactics to protect the portfolio in the case of black swan events will prevent management from being caught unprepared. Although a risk measure cannot tell you how to respond, the information can indicate that action is warranted. In the case of interest rates, perhaps it is easy to be lulled into watching the short-term variations, but with the knowledge that we are at all-time lows, we are prepared to act when rates eventually break through the short-term VaR and behave as extreme values.

THE FINAL LESSONS

What lessons can risk managers learn from the banking crisis? Jorion suggests that experienced risk managers should be aware of the limitations of the VaR methods: "This is why risk management should be driven by people, not machines."

Jorion further suggests, "Risk managers should also stress test their models, changing the assumptions for the distributions and parameters such as volatilities and correlations. Risk managers should also be prepared to react if they see developing signs of weaknesses in their models." Focus on known knowns, include known unknowns in your analysis where possible, and watch out for unknown unknowns.

Or as Taleb says, watch out for black swans and do not be lulled into believing that our statistical methods can predict all possible outcomes. Taleb warns us to not be fooled by the uncertainty of the deluded, whom he defines as "[p]eople who tunnel on sources of uncertainty by producing precise sources like the great uncertainty principle or similar, less consequential, matters to real life, worrying about subatomic particles while forgetting that we cannot predict tomorrow's crises."

Do not be lulled into believing that our statistical methods can predict all possible outcomes

Perhaps energy risk professionals are farther along in understanding the limitations and benefits of current risk management tools and methods. After all, it seems that energy prices are consistently inconsistent. But maybe it is time to reexamine the extreme value methods and include these in the corporate risk reporting.

We are not suggesting to change the "business as usual" VaR calculations but to include extreme value analysis as a second analysis. The "business as usual" 95 percent confidence interval may contain Gaussian risks, and the extreme tails may contain highly skewed risks reflecting low-probability, high-consequence events. Having both analyses at hand will enable the risk management team to better manage portfolio risks.

NOTES

1. Taleb, N. (2007). *The black swan: The impact of the highly improbable.* New York: Random House.
2. Jorion, P. (2009, April). *Risk management lessons from the credit crisis.* Keynote address to the 2009 European Financial Management Association Meeting, Nantes, France.

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