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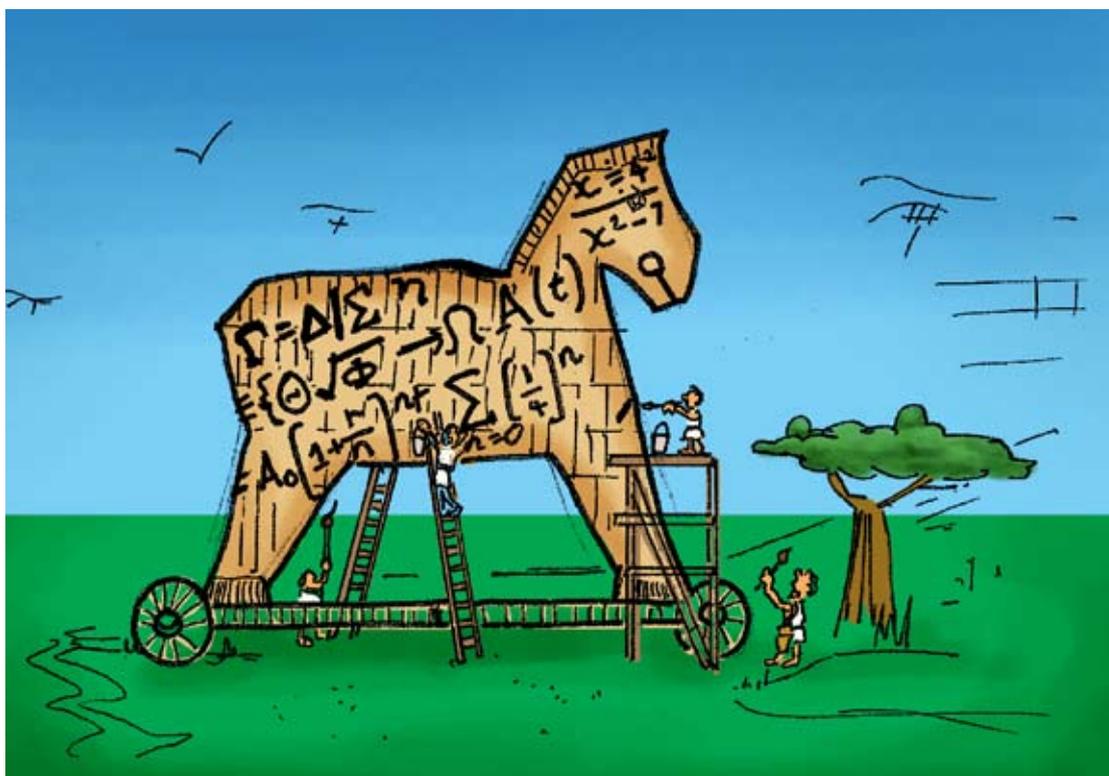
Do. Models. Behave. Badly?

Reflections on Emanuel Derman's return to the bookshelves...

If you Google “models behaving badly,” in addition to many hits for Emanuel Derman's new book of that title (but with periods after each word), you'll get accounts of club parties and fashion shoot fights, along with crimes and misdemeanors of professional fashion models. Digging a bit deeper, you'll find lots of references to people: *Girls Behaving Badly*, *Scientists Behaving Badly*, *Lawyers Behaving Badly*, etc.

But models, in Derman's sense, are not people and therefore the verb “behave” and adverb “badly” have different meanings as well. A model in the sense of a simplified picture of the world is useful if its behavior corresponds to what happens in the world. If we model the Earth and sun as incompressible perfect spheres of constant density alone in the universe, the model's predictions of the Earth's future position relative to the sun will be tolerably accurate. If they are not accurate enough for our purposes, we still wouldn't say that the model behaved badly. It did what it was supposed to do. It answered the question it was asked. At worst, its behavior was unrefined. Bad behavior requires predictions that are qualitatively absurd, perhaps showing the Earth in a square orbit or reversing direction periodically. To be dangerous, the model has to perform well in testing and save its absurdity for actual operation.

People can behave badly through relying on models that do not behave badly in themselves. In the example given above, an engineer could misdirect a spacecraft or a physicist could deny the reality of tides. It's also possible to design a model that seems to work well over validation



datasets but gives violently misleading results when something changes in the future, or even through the model's internal logic. We may or may not blame the model designer for the error but, either way, it's fair to say that the model behaved badly (i.e., in a manner that was not a simplification or approximation of the world). The model was wrong, not merely less accurate than required.

Derman's book begins with some autobiography. As you would expect from his earlier *My Life as a Quant*, this material could stand on its own as literature with impressive honesty, a novelist's ear for telling detail, masterful dry wit, and a fluid style worthy of a professional writer. There are also sentences that bring the reader up short, sounding almost like practice translation

sentences from a foreign language text; for example, “*An enormously fat man on our plane had a heart attack after eating some pickled meat somewhere over the Sudan.*” We never hear of the man again and none of the details about weight, diet, or geography seem to have anything to do with the narrative. “[Our plumber] *spoke Yiddish, and once, when he arrived at our front door while I was in bed with a bad cold, I fearfully mistook his voice and intonations for that of our doctor.*” Plumber, cold, and doctor do not reappear, and no explanation is given for his fear of doctors.

My first thought was that Emanuel had caught the professor's disease of working as much information as possible into each lecture, even if much of it is not directly on point. After all, it never hurts students to learn, and if you

know as much as Emanuel, you have a lot of useful information to convey. But as I continued to read, I realized that there was nothing pathologic about it. He weaves a tale with subtle layers of meaning in which the same points apply to life, philosophy, politics, and finance. The reader slowly comes to understand that every word, even those describing apparently trivial and unrelated events, is working toward a clear goal.

My family history has some common elements with Derman's. Although I am only about 15 years younger, I am from a different generation. My family fled Russia about 30 years before his fled Poland. Thus, it was my grandfather who built a small business (a clothing store in a small town in Indiana), as did Derman's father. My father and uncle got Ph.D.s in physics and math and became professors, as did Derman. While his childhood was comfortable middle-class, his life outlook was shaped by living in a totalitarian state, experiencing apartheid, and attraction to Zionist socialism. (A classic sentence, and there are many in this book, "*Habonim was Lord Baden-Powell's colonial boy scouts with the Mowgli mythology replaced by an evangelical pioneering leftist political Zionism, overlaid with the back-to-nature romanticism of the German Wandervogel movement of the early twentieth century.*") I had a similarly comfortable middle-class upbringing in a freer society, but in a world that seemed headed for disaster led by evil tyrants, lunatics, and incompetents; with scientists who should have been the hope for the future enthusiastic fellow travelers. Derman saw leaders he respected fail to live up to their principles, principles he had rejected but nevertheless took more seriously than the apostates. I was similarly affected by what I perceived as the shallowness and greed of the supposedly idealistic generation that came of age in the 1960s.

In Seattle in the 1970s, it seemed to me that people respected any guy who supported his family and kept his grass cut. Alcoholism, infidelity, sexual abuse, drug addiction, and other problems were no less common than in other places and times, but were never mentioned. People could be mean, or stupid, or desperately unhappy, but it was considered polite to pretend otherwise. If someone lost a job and couldn't find a new one, the family disappeared from the

neighborhood and was never spoken of again. Not having money was the only shame. This leads to considerable insecurity, particularly since the economy seemed to be falling apart.

Derman found his solace in physics. I wasn't sure the world would be around long enough for any pure research to matter. I wanted to anchor my security in something that didn't depend on government or institutions or credentials. I had faith instead in the local credit webs and cooperations that help people survive without appearing on government radar screens. At 14 I discovered that I could walk into a tavern poker game and walk out with more money than I came in with; which meant that I could survive on my own

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terms. The skills involved went beyond card play; you had to get admitted to the game, collect your winnings, and avoid cheaters, harassment, robbery, and arrest. I learned that there were subcultures that supported anyone who played by their rules, without asking for identification.

These disparate experiences lead to divergent views of finance. Derman's fundamental unit of analysis is the security. Mine is the game. To me, gambling is a form of exchange. Even purely random games are useful for concentrating wealth enough to form capital, and freeing losers to exercise real options. If there is some skill involved, the game can also allocate the newly formed capital into good hands.

Poker was a tremendous breakthrough. Earlier games were played for cash or items of value. Around the same time as poker developed, the first commercial gambling arose, in which case the house or professional might offer credit. But poker generated self-organized credit. People played for "checks," personally identifiable tokens. At the end of the game there was a clear

ing operation that left each player with either net checks from other players, or having some of his checks in the hands of others. For the most part, players honored their poker debts, working them off as necessary. But it was the winner's responsibility to collect the bilateral debt from the loser, which might require giving him a job.

Some decades later, these innovations were ported to futures markets. This added an important element; the bets had relevance for real economic activity. The winners were the people with the best local knowledge of agriculture and infrastructure, thus the best place to invest their winnings wisely. The futures prices gave useful signals, and it was possible for some people to use

the contracts for real transactions. These were seldom hedging transactions; hedging is best done through commercial contracts for the precise goods you have or want, at the place and time you have or want them – not standardized contracts. The main commercial use of futures was to borrow and lend commodities and services, bypassing the intermediation of money.

Anyway, this is how things looked to someone who had been immersed in subcultures run without official laws or regulations. The game was the important thing, the securities incidental tokens. It was the energy of the trading pit and the people it attracted that nurtured innovation, more than the marginally useful price discovery and commercial hedging.

That's my model, anyway. I understand it is a simplification of the world that can be misleading in some cases. I also understand there are other useful models, including securities-based ones like Derman's. One great virtue of *Models. Behaving. Badly* is that it explores philosophic, scientific, financial, and other models in enough



theoretic generality to be useful, regardless of your preferred starting point.

I don't know which came first, physics or scientific philosophers, but Derman is fond of the rationalist Spinoza, the clear Schopenhauer, and the pseudo-scientific Freud. He quotes liberally from great scientists as well. I lean instead toward the cynic Diogenes, the brilliantly mystical Pascal, and the skeptic David Hume, and find great enlightenment from 20th century statisticians including De Finetti, Wald, Savage, and Tukey. *Models.Behaving.Badly* contains a profound discussion of the idea of metaphor, but Derman gives pride of place to theories, something he denies finance can achieve. I don't so much disagree with that as fail to see the sharp dividing line between metaphor and truth.

It's probably logically inconsistent to analyze this question with metaphors, but here goes. Most thinking is clearly metaphoric – it's how we make sense of the world. Yet, there must be something more than metaphor, or thinking would be entirely self-referential – and we wouldn't know what a metaphor was. I'm willing to call the something more “truth,” although I see no logical reason to assume it is true. My guess is that it is the basic physical reality burned into primate brains, whose reasoning facility got co-opted for more abstract purposes. Our evolutionary ancestors for hundreds of millions of years must have had practical instincts about gravity, so our thinking is filled with mappings that allow the logic of gravity to supply correct solutions to other problems, like the computer programs that translate questions into arrangements of binary digits.

I think that last metaphor fails, however. In a computer, binary digits are fundamental but contentless. All the meaning in computer output comes from mapping bits to useful information, then letting the deterministic mathematical relations of bits produce a pattern that can be mapped to the answer we want. I see no reason to assume that the human brain has similarly fundamental or contentless truth that is the foundation for all metaphors, just as Euclidian geometry is a series of tautologies that can be used to give approximate answers to practical questions if we map things correctly. I suspect that the brain has lots of layers of mostly metaphoric

thinking, with a bit of truth mixed up in each. In other words, truth is not unitary or deeper than metaphor; it's scattered in with the metaphors like steel rods in a concrete building.

Derman does not exploit the heuristic element of the models-as-metaphor metaphor. The *Washington Post* ran a bad metaphor contest in 2008 and the winning entries displayed the main flaws that make models behave badly. Several entries, such as Jack Bross', “*He was as tall as a six-foot-three-inch tree,*” and Russell Beland's, “*John and Mary had never met. They were like two hummingbirds who had also never met,*” are just wasted words that add nothing. We've all seen models that add mathematical superstructure to a simple rule, muddying the waters so that they might appear deep. It makes modelers feel and seem more important. It may be that if you said, “*Let's average the two numbers,*” people would think you irresponsible, but if you said, “*I ran an optimal multivariate discretization of a naive Bayesian classifier under a maximum entropy criterion,*” that just happens to give $(X + Y) / 2$, everyone would go along. However, there is a cost to using mathematics to add ballast. It erodes your credibility and everyone's trust in mathematics, and can lead to confusion and error.

Joseph Romm supplied, “*He spoke with the wisdom that can only come from experience, like a guy who went blind because he looked at a solar eclipse without one of those boxes with a pinhole in it and now goes around the country speaking at high schools about the dangers of looking at a solar eclipse without one of those boxes with a pinhole in it.*” Jennifer Hart had the similar, “*Long separated by cruel fate, the star-crossed lovers raced across the grassy field toward each other like two freight trains, one having left Cleveland at 6:36 p.m. traveling at 55 mph, the other from Topeka at 4:19 p.m. at a speed of 35 mph.*” Here, the problem is that the metaphor is far more specific than what it is supposed to illuminate. Modelers do this by taking a general concept – say, uncertainty – and translating it to a highly specific example – say, standard deviation under a Normal distribution; or perhaps by considering a special case, like an at-the-money option or a nondividend paying stock, and asserting that the results apply generally. This makes it easier to get precise and rigorous results, but those results may apply

only to the model, not to the general issue.

Another entry from Russell Beland was, “*The little boat gently drifted across the pond exactly the way a bowling ball wouldn't.*” It's common in mathematics to solve an inverse problem; for example, if you want to know the chance of an event happening that could occur in many ways, it can be easier to solve for the probability that the event does not occur. However, that technique often fails in practical application because knowing how a bowling ball doesn't float doesn't tell you much about how a boat does. More generally, modeling allows you to redefine a question into one you have the data to answer, but you have to be careful with that. A good general rule is to study what you want to know about, or as close as you can to it. If you want to predict defaults, studying changes in credit spreads may not be the best approach. As a modeler, you like the continuous measurement and large data set that credit spreads give you, compared with the discrete and relatively rare defaults, but it could be that defaults are qualitatively different from anything you can derive from a credit spread.

“*Upon completing kindergarten, Lance felt the same sense of accomplishment the Unabomber feels every time he successfully blows up another college professor,*” came from an understandably anonymous writer. Susan Reese added, “*She had a deep, throaty, genuine laugh, like that sound a dog makes just before it throws up,*” and Paul Kocak was responsible for, “*The revelation that his marriage of 30 years had disintegrated because of his wife's infidelity came as a rude shock, like a surcharge at a formerly surcharge-free ATM.*” The metaphors are meaningful in a direct sense, but the connotations are discordant. Modelers make this error when they construct a mathematically useful model that has inputs or outputs presented in ways that invite error. Using the term “credit correlation” for a pure calibration input to a structured CDS model suggests that there is some underlying economic meaning to the input. This will cause problems when people try to set the parameter using intuition, or export it to other models. Fischer Black famously disliked graphical model output because it caused the brain to make assumptions not justified by the numerical model results.

It can take years of experience to recognize

errors that cause models to behave badly, but most of us have an instinctive ear for a bad metaphor. Ask yourself whether your model represents the important aspects of reality accurately, and whether it simplifies things enough to allow deductions you cannot make directly. Check that the model captures the full range of situations to which it will be applied. And pay attention to the connotations, both names of inputs and form of output, because those may end up being more influential than the number.

This is getting a bit abstract; let's move on to Derman's favorite financial model, the Black-Scholes-Merton (BSM) option pricing model. It is discussed at length but, oddly, never defined. There is the BSM formula, which is merely a mathematical identity relating an option price to an implied volatility. Since there was no such thing as an implied volatility before the model was invented, the formula has no content on its own.

The formula has the same logical status as the yield to maturity (YTM) of a bond. For any given set of future cash flows, we can convert a price to a yield or vice versa. But yield has no meaning other than in the YTM formula. The conversion is useful because a graph of bond price versus time is a random scatter of points, but bond yield through time suggests smooth curves (different curves for different currencies and credit qualities). This is an empirical point, not a logical one. We can imagine a world in which bond prices form a smoother curve than bond yields. We don't even have to imagine – this happens when issuers approach bankruptcy and coupon rates become irrelevant (your recovery is based on principal and interest due before filing only) and maturity only matters to the extent that you might get paid off before the filing. The first and second derivatives of price with respect to yield are useful quantities for fixed-income portfolio managements, as are more complicated analytics.

Similarly, graphing option price versus time and moneyness gives a random scatter of points, while graphing implied volatility suggests a smooth surface. Derivatives of option prices with respect to implied volatility and other parameters of the BSM model are useful quantities for managing option positions. But for all

the usefulness, the YTM and BSM formulae are neither models nor theories. They are mathematical identities. They cannot behave badly.

One model in BSM is that the points we observe reflecting trades or bids on specific options are all on a volatility surface that evolves through time. Option prices and some option bids are real. A volatility surface is an abstraction. We can estimate volatility surfaces and try to predict their evolution, or at least parameterize them to make conditional predictions, but all of this is in the unreal model space.

If the volatility surface is used to interpolate option prices in between observed transactions and bids, it's hard to see how it could behave badly. BSM is rational enough that results cannot

and Zou). This shows how to construct an implied variance swap from a portfolio of options that relies implicitly on the concept of a volatility surface. This is the methodology that underlies the CBOE's VIX and has proven robust. The biggest challenge for a model is shared by Pygmalion, the Velveteen Rabbit, and Pinocchio's Guiseppe: what happens when it becomes real? In this case, that occurred with an active market in VIX futures and options. The model passed this test.

But there are other models built on the BSM formula. Some of them assert or assume relations between implied volatility and actual volatility. These have far more capacity to behave badly, and have in fact contributed to actual disasters. That doesn't mean that it's foolish to

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be too far off from robust interpolation schemes. The model might not behave well – that is, we might completely misguess what the volatility surface does, and thinking of it as a surface might turn out to be a misleading metaphor. But to behave really badly, we'd have to use the surface for pricing exotic options or constructing highly offset portfolios.

On the other hand, not all reliance on the model beyond smooth interpolation risks disaster. A great example is Emanuel Derman's own 1999 note, "More Than You Ever Wanted To Know About Volatility Swaps" (with Demeterfi, Kamal,

study this relation but safety requires you to keep in the front of your mind the difference between fact and fiction.

Models.Behaving.Badly will be an instant classic of quantitative finance and will be read for pleasure by people uninterested in money. However, its most important contribution may be in the philosophy of quantitative modeling, spanning fields from physics to metaphysics, from the great questions of life to everyday decisions, from the world of a shy and serious child to the most powerful movers and shakers in the world. It is a book that literally everyone should read.